Addressing mobile neonatal image quality through an educational programme

by

Beatrix Kotzé

A dissertation submitted in fulfillment of the requirements

for the degree

Magister Technologiae in Radiography (Diagnostic)

Department of Clinical Sciences

Faculty of Health and Environmental Sciences

Central University of Technology, Free State

BLOEMFONTEIN

August 2015

Supervisor: Prof HS Friedrich-Nel

Co-supervisor: Dr B van der Merwe

As promised Granddad

(Marthinus Schalk Du Plessis Prinsloo)

DECLARATION

I declare that *Addressing mobile neonatal image quality through an educational programme* is my own work, that it has not been submitted before for any degree or examination at any other university, and that all the sources I have used or quoted have been indicated and acknowledged as references.

This dissertation was verified for originality by submitting the electronic version using the 'SafeAssign' course tool on the Blackboard server of the Central University of Technology. The percentage similarity found (6%) by this course tool is indicated below as inserted from Blackboard. It was however verified by the researcher and the supervisors' that the indicated similarities can be assigned to the repetition of words or phrases used in headings and in the text that follows a heading and also by necessary similarities in chapter two, three and four.

safeassign by Blackboard

ROOT – BEATRIX KOTZE

Beatrix Kotze
on Mon, Jun 01 2015, 11:06 AM
6% match
Submission ID: 73481708

Attachments (1)

Combined chapters.doc 6%
Word Count: 45,209 Attachment ID: 93861910

B Kotzé

June 2015

ACKNOWLEDGEMENTS

Blessing, and glory, and wisdom, and thanksgiving, and honor, and power, and might, be unto our God for ever and ever. Amen. Revelations 7:12

Without the following people, this research and its findings would not have been possible:

- Professor Hesta Friedrich–Nel, my supervisor and research mentor, who challenged and sustained me throughout the research.
- Dr Belinda van der Merwe, my co-study leader and friend, who inspires me through her unrelenting dedication and commitment to radiography.
- My colleagues in the Department of Clinical Sciences, for their care and fortitude.
- The Central University of Technology for financial and academic support.
- Mrs Maryn Viljoen, who provided the statistical consulting services for the research.
- Mrs Hettie Human who edited the language of the final product.
- Doctor Johan Venter, Radiologist, who supported me by assisting with the pilot study and problem statement for the research. Doctor provided me with the vision that formed the basis of the research.
- The radiographers from the participating institutions for your tolerance and enthusiasm to have been involved in this research.
- NICU nursing staff of the participating institutions for your patience when myself and the radiographers invaded your work environment. Your warmth and dedication to neonatal patients is remarkable.
- My family, for your love, confidence, support and understanding.

TABLE OF CONTENTS

Page number

Central University of Technology, Free State

CHAPTER 3

DESIGN AND PRESENTATION OF THE EDUCATIONAL PROGRAMME

CHAPTER 4

RE-EVALUATION OF MOBILE NEONATAL CHEST IMAGE QUALITY

CHAPTER 5

CONCLUSIONS, RECOMMENDATIONS AND LIMITATIONS

LIST OF FIGURES

Page number

CHAPTER 4

LIST OF TABLES

Page number

GLOSSARY OF TERMS

Adequate image quality means that the image may not be within all the acceptable limits but can still be used for a diagnosis (Carlton and Adler, 2014:460).

Artefacts are seen as foreign objects superimposed on the normal chest anatomy and can impair the visibility of anatomy (Hardy and Boynes, 2003:1180).

Babygram is a combination of chest and abdomen on a single image (Jones, Palarm and Negus, 2001:924).

Computed Radiography (CR) system is a system that is film free. Images are stored on re-usable image plates. These systems are considered to be digital systems (Carlton and Adler, 2014:227).

Educational programme is described by the Criteria and Guidelines for Short Courses and Skills Programmes documented by SAQA (2004:14) as non-credit bearing short courses, aimed at addressing a specific skill set or field of knowledge.

Evaluation criteria are the aspects of an image that a radiographer will evaluate when analysing the quality of an image to determine the adequacy of the image for providing a diagnosis (McQuillen Martensen, 2011:3-4; Bontrager and Lampignano, 2014:30).

Exposure creep, as defined by Gibson and Davidson (2012:458), is the systematical increase in exposure parameters selected by radiographers which results in increased radiation dose.

Exposure index in the digital radiography environment refer to a value that provides feedback to the radiographer on the estimated amount of exposure that reached the imaging plate (Seibert and Morin, 2011:573-574).

Image quality is the features of an image which depend on the positioning of the anatomical part, sufficient contrast selection with expected detail in the absence of artefacts (Carlton and Adler, 2014:460).

Inadequate image quality is an image of poor quality from which a reliable diagnosis or disease process evaluation cannot be made by treating physicians. An additional repeat image will have to be produced, which increases the radiation dose to the patient, in order to ensure a reliable diagnosis of a disease process is possible (McQuillen Martensen, 2011:2-3).

Mobile radiography as defined by Bontrager and Lampignano (2014:565) is the production of images outside the radiology department due to a patient's condition which prohibit the transport of the patient to the radiology department.

Neonate is a medical term used to describe a human infant from the time of birth through to the 28th day of life (WHO, 2014:online).

Optimal image quality of an image can be defined as an image that is within acceptance limits. This means that there are no technical errors, procedural problems or equipment malfunctions (for example grid lines due to grid malfunction) visible on the image. This image can be submitted by the radiographer to assist with the diagnosis of a patient by the radiologist and/or referring physician (Bushberg, Seibert, Leidholdt and Boone, 2012:60).

Parenchymal markings are lung markings representing the bronchial tree throughout the lung fields (European Commission, 1996:27).

Positioning technique is the physical work done by a radiographer to place a patient in the optimal position for the production of an image (McQuillen Martensen, 2011:2-3).

Standardised image quality is the production of image quality of an acceptable standard, consistently, from one examination to the next (Carlton and Adler, 2014:460).

Vascular patterns include the hila and lung markings found in the central half of the lungfields (European Commission, 1996:27).

LIST OF ACRONYMS AND ABBREVIATIONS

AAPM	American Association of Physicists in Medicine
ALARA	As Low As Reasonably Achievable
AP	Anterior Posterior
ARPANSA	Australian Radiation Protection and Nuclear Safety Agency
ARSPI	Alliance for Radiation Safety in Pediatric Imaging
CEU	Continuing Educational Unit
CHE	Council on Higher Education
CPD	Continuing Professional Development
CR	Computed Radiography
CRCPD	Conference of Radiation Control Program Directors
DoH	Department of Health
Dr	Doctor
DRC	Directorate: Radiation Control
Dx	Diagnosis
EC	European Commission
ECG	Electrocardiogram
EI	Exposure Index
ESD	Entrance Skin Dose
ETT	Endo Tracheal Tube
HEI	Higher Education Institution
HIS	Hospital Information System
HPCSA	Health Professions Council of South Africa
IAEA	International Atomic Energy Agency
ICRP	International Commission of Radiological Protection
IR	Image Receptor
ISRRT	International Society of Radiographers and Radiological Technologists
IVD	Intervertebral Disc Space
kVp	kilo-Voltage peak

Lat	Lateral
LGM	Log Median Exposure
mAs	milli-Amperé per second
MSP	Midsagittal Plane
NAP	New Academic Policy
NB	Nota Bene
NCRP	National Council on Radiation Protection and Measurements
NGT	Nasogastric Tube
NICU	Neonatal Intensive Care Unit
PA	Posterior Anterior
PACORI	Pan African Congress of Radiology and Imaging
Pt	Patient
RIS	Radiology Information System
SA	South Africa
SAQA	South African Qualifications Authority
SP	Symphysis Pubis
SPR	Society of Pediatric Radiology
UAC	Umbilical Arterial Catheter
USA	United States of America
UVC	Umbilical Venous Catheter
WFPI	World Federation of Pediatric Imaging
WHO	World Health Organisation
WMA	World Medical Association

LIST OF APPENDICES

SUMMARY

The World Health Organization has given special attention within its recommendations to the restriction of radiological diagnostic procedures on children. Should a neonatal examination be done, the use of special lead shielding devices and correct radiographic techniques is essential. The Alliance for Radiation Safety in Pediatric Imaging (ARSPI) and the Conference of Radiation Control Program Directors (CRCPD), founding bodies of the “Image Gently” campaign promote additional training to ensure that patients receive a timely and optimal imaging examination with the lowest amount of radiation. The primary goal of diagnostic radiographers working in the neonatal intensive care unit (NICU) is to produce an image of optimal quality using an optimal exposure technique without repeating exposures, so as to keep the neonatal radiation dose to a minimum. Thus the main concern in this study was whether radiographers were producing optimal quality chest images and if not, whether additional training could assist radiographers to reach this goal in the Free State province of South Africa.

This question was addressed by a study comprising three phases. First, the neonatal chest image quality was determined in the NICU by means of a checklist based on and compiled from guidelines in the literature on image quality. This checklist was tested with a pilot study and adjusted as necessary. The researcher evaluated 450 images, selected through simple random sampling. The results of this phase showed that image quality areas required improvement because radiation shielding was absent on 98.7% of images, and collimation absent in 74.9% of images. These results indicated that, for 74.9% of images, four sided collimation was not visible on the image, and there was a probability of 98.7% that such an image had been taken without radiation protection. In addition, lead markers were not utilised in the production of 66.4% of images.

The second phase of the study entailed the design and presentation of an educational programme. The educational sessions were based on the evaluation criteria of the checklist as well as image quality areas identified in Phase 1 as needing enhancement. The educational sessions also referred to positioning techniques that should be applied to ensure optimal image quality as specified by the evaluation criteria in the checklist. After the presentation of the educational programme, participating radiographers commented on the programme by completing an evaluation form. Radiographers rated the educational programme as excellent by 96.4%. A small number of participating radiographers (15 of 56 participants) suggested adjustments to the educational programme. The additional information requested by the participating radiographers related to pathology appearances and exposure index recorded on the image.

The final phase entailed the assessment of 450 neonatal chest images produced after the educational programme in the NICU, using the same checklist. These images were selected through purposive sampling. Only neonatal chest images produced by participating radiographers that completed the educational programme were included in this phase. The purpose of this evaluation was to establish whether the image quality had improved after delivery of the educational programme. In general, the results from this phase showed strong similarities to the results obtained from the first phase. However, in some areas there was significant improvement of image quality, among which a reduction in electrocardiogram (ECG) lines superimposed on chest anatomy (61.9% in Phase 1 to 41.8% in Phase 3), a tendency to centre closer to thoracic vertebra four, and visible four-sided collimation on images (ρ-value 0.002, Chi-Square test). Image quality areas with no significant enhancement were the absence of lead markers (absent on 63.1% images in Phase 3) as well as the absence of radiation shielding (absent on 98.9% of images in Phase 3).

The study, through its educational programme, had a positive effect on the following aspects of neonatal chest image quality: collimation, centring points, and visibility of artifacts (ECG lines). Neonatal chest image quality aspects that require further improvement include lead markers and lead shielding. The study has shown that an educational programme has the potential to improve neonatal chest image quality, which aligns well with the main concerns of the Image Gently campaign.

The checklist that was designed can assist radiographers in future evaluations of neonatal radiographic image quality. A neonatal quality control audit programme can be implemented to encourage participation of nursing staff, referring physicians and radiographers with the purpose to address neonatal mobile chest image quality while optimising the radiation dose.

KEYWORDS: Newborn, neonatal radiation dose, neonatal intensive care unit, chest radiographs, optimal image quality, mobile radiography, radiation protection.

CHAPTER 1

OVERVIEW OF THE STUDY

1.1 INTRODUCTION

The role of a diagnostic radiographer in the health care system is to produce images of the highest diagnostic quality. These images must be produced with the lowest possible radiation dose to the patient – this is a fundamental principle (Willis, 2009:266) and is known to radiographers as the "as low as reasonably achievable" (ALARA) principle. The principle is reproduced in Reports 116 and 127 of the National Council on Radiation Protection and Measurements (NCRP) of the United States of America (USA) (NCRP, 2013:online) and in the Public Health Amendment Act, 1971 of the Department of Health (DoH) in South Africa (RSA DoH, 1973:8). To ensure consistent, optimal image quality with acceptable radiation protection, Willis (2009:266) advises radiographers to continuously enhance their skills and utilise constant quality control programmes.

"Neonate", in relation to this study, is a medical term used to describe a human infant from the time of birth through to the 28th day of life (WHO, 2014:online). Diagnostic radiography can significantly contribute to the timely treatment and management of neonatal patients (Lowe, Finch, Boniface, Chaudhuri and Shekhdar, 1999:55). An example of the important role played by diagnostic radiography in the initial diagnosis and evaluation of conditions is illustrated by the diagnosis and treatment of hyaline membrane disease, a common respiratory and/or cardiovascular system neonatal condition evaluated through chest images. During the neonate's stay in the neonatal intensive care unit (NICU), radiography also assists in the assessment and verification of line positions, such as the percutaneous intravenous lines. Depending on the neonate's symptoms, a substantial number of chest images can be taken before the neonate is discharged (Dougeni, Delis, Karatza, Kalogeropoulou, Skiadopoulos, Mantagos and Panayiotakis, 2007:807).

The radiographic examination most commonly requested for neonates is chest images (Lowe *et al*., 1999:55), therefore this is the diagnostic examination this study focuses on.

The aim of this chapter is to provide a literature orientation to underpin the research problem identified. It provides the background to the study on neonatal chest image quality. The literature orientation is followed by a brief overview of the research design and methodology used to address the research question and objectives. This chapter concludes with a layout of succeeding chapters.

1.2 LITERATURE ORIENTATION AND BACKGROUND TO THE RESEARCH PROBLEM

As stated in the introduction, it is imperative for optimal diagnosis that diagnostic radiographers deliver images of the highest possible quality, at the same time keeping the radiation dose to all patients, including neonatal patients as low as possible, in accordance with the ALARA principle (Sherbini, 2000:online). The International Atomic Energy Agency (IAEA) in close collaboration with the World Health Organisation's (WHO) gives special attention in its recommendations to the restriction of radiological diagnostic procedures on children (IAEA, 2002:online). Pedrosa de Azevedo, Osibote and Boechat (2006:1638) emphasise that, if a neonatal examination must be done, the use of special lead shielding devices and correct techniques are compulsory.

In a radiology practice located in a Free State private hospital in South Africa (SA), the practicing radiologists questioned whether the radiographers working in the NICU were producing images of the highest quality, and providing optimal radiation protection for the neonates during mobile radiography. Venter (2009) reported that, during a weekly management meeting, the radiologists discussed unsatisfactory image quality areas, which included the visibility of minimum collimation on images; suboptimal patient positioning; recording of exposure index (EI) outside of manufacturers prescribed ranges and the absence of lead shielding on the chest images of neonates.

A similar problem was recorded by a USA-based study, in New York. In this study the problem statement was determined after management staff of the imaging department noticed an increase in "babygram" images that showed minimum collimation without radiation shielding in place. The authors of this study, Hellwig and Wilson (2013:1), investigated methods to address these areas of concern by means of a radiation safety quality improvement process.

The previously mentioned Free State radiology practice utilises a Computed Radiography (CR) system for imaging of neonatal patients. In CR systems display and acquisition of images are separate and isolated processes, which have advantages, for one, reusable image plates associated with lower monthly costs (Bansal, 2006:425). However, the disconnection between acquisition and display allows for mechanical rescaling of images, which may have negative consequences.

The disconnection causes radiographers to unconsciously allow for "exposure creep", because the feedback mechanism of density with which they are familiar in analog radiography systems is arbitrary and meaningless in CR systems. As a consequence of this mechanical rescaling, any image of incorrect density and/or collimation can be rescaled into the desired density range and/or collimation field, irrespective of the initial exposure settings and/or collimated field (Willis and Slovis, 2004:373).

Challenges arising from the use of CR systems have led to the promotion of additional radiography training programmes by The Alliance for Radiation Safety in Pediatric Imaging (ARSPI) also known as the Image Gently campaign (Image Gently, 2014:online). This alliance promotes additional training to ensure that patients receive timely and optimal imaging examinations with the lowest amount of radiation in an era of new imaging technologies, such as CR systems (Goske, Charkot, Herrman, John, Mills, Morrison and Smith, 2010:618; Willis, 2009:266).

1.3 RESEARCH QUESTION AND PROBLEM STATEMENT

The primary goal of radiographers working in NICUs is to produce an image of optimal diagnostic quality, without repeating the exposure unnecessarily, while utilising an optimal exposure technique to limit the neonatal radiation dose to the minimum. The main concern in this study was thus whether radiographers were achieving this goal and, if not, whether additional training, as suggested by the Image Gently campaign, could assist radiographers to reach this goal.

Hence, this study asked the following question: Can chest image quality produced by radiographers during mobile radiography in a NICU be addressed by means of an educational programme?

In the context of the current study, the term educational programme is described by the Criteria and Guidelines for Short Courses and Skills Programmes, documented by the South African Qualifications Authority (SAQA), as non-credit-bearing short courses aimed at addressing a specific skill set or field of knowledge (SAQA, 2004:14).

1.4 AIM AND OBJECTIVES

The overall aim of the study was to address the image quality of mobile neonatal chest examinations executed in NICUs by the application of an educational programme and, thereby, to deliver optimal radiation protection measures to neonates. The following objectives were set for achieving the aim of the study:

- To determine the quality of chest images produced in the NICU prior to the delivery of an educational programme. The quality of these images was assessed by means of a checklist based on and compiled from guidelines in literature on image quality.
- To design and present an educational programme. The design of the educational sessions was based on the evaluation criteria of the checklist used for the initial assessment of the images as outlined in the first objective. The educational sessions were informed by areas of image

quality in need of improvement as identified by the initial checklist as well as optimal radiographic positioning techniques found in literature.

- To re-evaluate the quality of the images produced in the NICU to establish whether image quality improved after delivery of the educational programme. The same checklist used for the initial assessment of the images was utilised.

1.5 DESIGN AND SCOPE OF RESEARCH

Fouché (2011:452) defines evaluation research as a social science methodology. Evaluation research is designed to utilise assessment during the implementation and application of an intervention process. The current study comprised an evaluation study design with quantitative and qualitative elements: First, the image quality for neonatal chest images was determined, after which an intervention in the form of the educational programme was implemented. The success of the designed and implemented educational programme was then measured by the assessment of the quality of neonatal chest images taken after completion of the educational programme.

Evaluation research allows a researcher to determine whether the intervention process did indeed lead to the change required. For this type of research, data has to be captured in a systematic, standardised way. The information gathered can be linked to the performance of participants and may therefore be used to judge the effectiveness of a professional in performing his/her work. Evaluation research can include quantitative and qualitative elements (Fouché, 2011:452).

The study's quantitative and qualitative elements consisted of a checklist (Appendix E), based on and compiled from the literature sources discussed in Chapter 2 (Section 2.2.5), research notes made during discussion sessions of the educational programme, as well as an evaluation form (Appendix H) utilised by participants to evaluate the educational programme.

Quantitative research refers to data that can be displayed as numbers or measurements (Delport and Roestenburg, 2011:171). Methods used for quantitative data collection include questionnaires and checklists (ECS McREL, 2004:online). The quantitative aspect of this study was the structured options in the checklist (Appendix E) and the structured questions in the evaluation form (Appendix H).

Qualitative research refers to finding an understanding of the underlying motives, thoughts and drives of participants to provide insight into the research problem (Fouché and Schurink, 2011:312). It ensures that data will be captured in relation to contradictory behaviours which provide the researcher insight into the human element of a study (Mack, Woodsong, MacQueen, Guest and Namey, 2005:online). In this study qualitative data was captured by means of comments made by the researcher on the checklists (Appendix E), research notes taken during discussion sessions to record specific challenges experienced by participating radiographers (Section 3.5.1), as well as open-ended questions in the evaluation form (Appendix H).

The scope of the research involved the NICU environment, where mobile chest images of neonates were produced using a mobile x-ray unit. These neonatal chest images were evaluated to determine chest image quality. The time frame in which the empirical study was conducted was 2011 to 2012.

1.6 METHOD OF INVESTIGATION

The research was executed in three hospitals, two government institutions and one private institution in the Free State province of SA. All three participating hospitals have NICUs and radiological imaging departments that utilised the CR system for the imaging of neonatal patients. The phases of the investigation are presented in Figure 1.1.

The first phase of the study commenced in February 2012 and was completed in June 2012. In this phase, the researcher established neonatal chest image quality before any interventional steps were taken. This phase involved evaluation of 450 neonatal chest images produced with a mobile radiography unit, which were assessed for image quality with the aid of a checklist (Appendix E). In total, 150 images were assessed for image quality per participating institution by simple random sampling. The researcher retrieved images from the temporary archive of the CR systems at each participating institution.

In phase two, which started in April 2012, the areas of image quality for improvement at the three participating institutions were identified from the checklists and summarised; this informed the design and development of an educational programme. Areas were identified over a period of three months, which overlapped with the data collection of phase one. In addition, the design of the educational programme content consisted of literature sources on evaluation criteria in relation to positioning techniques. The literature sources were consulted during April, May and June of 2012.

The educational programme was presented at each participating institution, and comprised three theoretical and two practical sessions. The educational programme was presented after the design process had been completed. Presentations commenced in the last week of June 2012 and continued until July 2012. The programme was presented to the radiographers involved in the imaging of neonates. The number of participants varied for the different institutions, but five radiographers per institution were indicated as the minimum number of participants statistically acceptable. There was no limitation on the maximum number of radiographers required to participate in the study -- the final numbers are reported on in Chapter 3.

The third phase of the study began once the presentation of the educational programme had been presented in all three participating institutions; it started during August 2012 and was completed December 2012. In this final phase of the study the influence of the educational programme on neonatal image quality was assessed. The assessment was done by using the same checklist (Appendix E) of phase one. The researcher visited each institution to assess 450 recently produced neonatal chest images (150 chest images per institution) for image quality. The 450 images of this phase where purposively sampled. Figure

1.1 illustrates the phases of the study as well as the allocated chapters that describe each phase of the study.

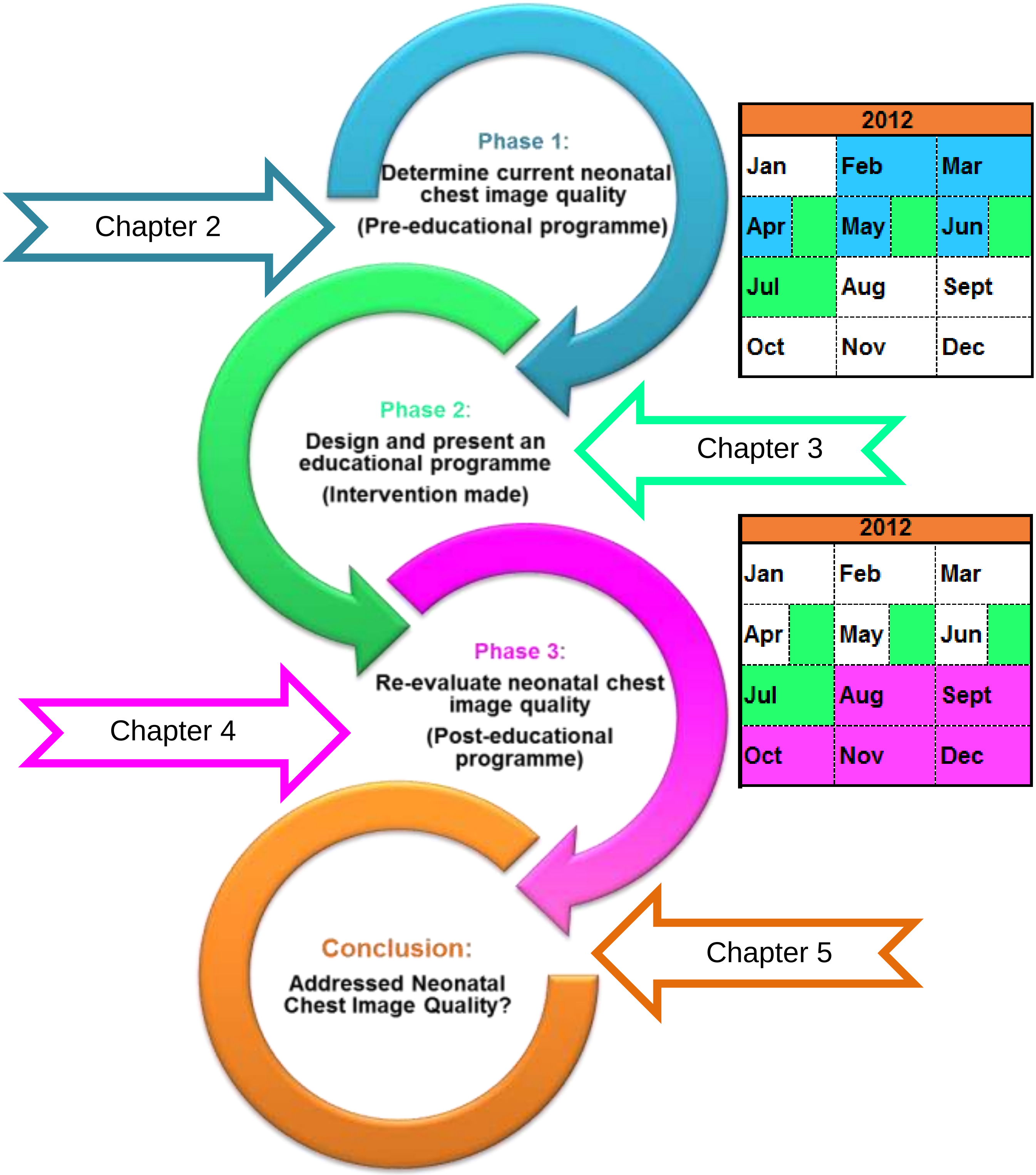


Figure 1.1: Phases of the study

1.7 STATISTICAL ANALYSIS

Descriptive statistics, namely frequencies and percentages, were calculated for categorical or qualitative data. Means and standard deviations or medians and percentiles were calculated for numerical or quantitative data. The descriptive statistics were calculated separately for phase one (pre-educational programme) and phase three (post-educational programme) for each of the institutions. Mean or median values from phases one and three were then compared using either the Chi-Square test for difference between frequencies or the Kruskal-Wallis test for differences between median values. The data was displayed in tables and summarised in graphs, as can be seen in Chapters 2, 3 and 4.

1.8 ETHICAL CONSIDERATIONS

The philosophy of "good clinical practice" was applied throughout the data accumulation phase, which meant that the rights, safety and wellbeing of the participating radiographers were protected as described by the Declaration of Helsinki (WMA, 2008:1). During assessment of the neonatal chest images, no physical information of patients (name, physical address, etc.) was recorded by the researcher. The identity of each participating radiographer was protected and participation was voluntary. Although the researcher kept a record of the participants in the educational sessions, the identity of each participant is only known to the researcher and is confidential. Participants could withdraw at any time during the study. Thus, the data used in the final report is anonymous – no confidential information was disclosed about the institutions, participants or neonatal chest images.

Permission to conduct the study was obtained from the head of department/directors of the three participating institutions (Appendix A), as well as the Ethics Committee of the Faculty of Health Sciences at the University of the Free State (Appendix B, ECUFS No. 163/2011).

Informed consent to participate in the educational programme was requested from the radiographers and the informative permission document was made available in three languages (Afrikaans, English and Sesotho) common to the central region of SA (Appendix C). Participating radiographers, who consented to participate in the study, did so for phase two and three.

1.9 QUALITY ASSURANCE OF THE RESULTS

In order to obtain the desired results the study design had to incorporate qualitative and quantitative elements. According to Delport and Fouché (2011:436), a combination of qualitative and quantitative data collection elements lead to an integrated observation, which ensures that a more holistic conclusion will be drawn from the results at the end of the research process.

1.9.1 Reliability and validity

The quality of quantitative results is ensured through the reliability and validity of the research methods. Validity, or transferability, is assured when results are obtained by means of a comprehensive sampling method, which should ensure representation of the study population (McMillan and Schumacher, 2006:261). According to Goddard and Melville (2001:41) and Leedy and Ormrod (2002:31) validity of a study is determined by the extent to which a research instrument measures what it is supposed to measure. In addition, Bowling (2002:150) indicates that a research instrument can only be considered valid if it was piloted in a population for which the research instrument was designed.

The quality of the results was considered to be transferable because the sampling method was simple and ensured representation of the study population (Section 2.3.1). The checklist (Appendix E) is valid and dependable because its design was based on literature and it was benchmarked to research studies that utilised a similar research instrument (Sections 2.2.5 and 2.3.2.1). The checklist therefore measures what it was supposed to measure. In addition, the checklist was piloted (Section 2.3.2.2) by the researcher in a similar population group as that involved in the study. The construction of the checklist is of such a nature that it will deliver uniform results time after time, because it consists mainly of structured image quality areas.

Reliability or dependability of results (Delport & Roestenburg, 2011:177), as described by Goodwin (1995:56) and Hinds (2000:42), refers to the extent to which a research instrument will produce consistent, uniform results every time, after repeated application of the instrument under similar conditions. In addition, Delport and Roestenburg (2011:177) state that dependability is enhanced when a research instrument is based on literature.

The educational programme (Appendices I, J and K) is considered to be valid and reliable because its design was based on literature relating to neonatal chest image quality, and on positioning techniques that can ensure optimal neonatal chest image quality, as recommended by literature sources. Data from the first phase of the study, therefore, confirmed the inclusion of certain literature areas (Section 3.3.2.1) in the educational programme. The same educational programme was presented at three participating institutions. Due to the specific format (PowerPoint slide show with footnotes), the same programme was repeatedly presented.

1.9.2 Trustworthiness

The worth of qualitative results is ensured through the trustworthiness of the research methods. Schurink, Fouché and De Vos (2011:419-421) list the following aspects as important for trustworthiness: credibility, transferability, dependability and conformability.

Anney (2014:276) defines credibility as the assurance that can be placed in the results of a study. Credibility of qualitative results as stated by Shank (2009:92) is assured when there is good communication between the researcher and participants during the collection of data. Section 3.3 describes the design and presentation of the educational programme, which aimed to ensure confidence in the results obtained by the study. The discussion sessions utilised as part of the educational programme (Section 3.3.3) ensured good communication between the participants and the researcher.

Schurink *et al.* (2011:420) describes transferability as whether results obtained from a study can be transferred to another case or study. Designing a study with more than one research instrument strengthens the study's transferability to other similar studies. In this study, two main research instruments where utilised; a checklist (Appendix E) and an educational programme (Appendices I, J and K). The instruments were complemented by research notes for discussion sessions to document challenges experienced by radiographers (Section 3.5.1), and an evaluation form for the educational programme (Appendix H). Both these instruments were based on literature of other research studies, which were consulted to confirm that the results are transferable.

Dependability of qualitative results is ensured by documenting and auditing these results (Schurink *et al.*, 2011:420-421). Anney (2014:278) explains auditing of results as a process accomplished by study participants, who evaluate the documented results of a study. The dependability of the educational programme can be deduced from the evaluation of the content and applicability of the programme (Appendix H), which was conducted by the participants (Section 3.5.2).

Results conformability can be achieved when a researcher acts in good faith in reporting results, in the process avoiding personal bias (Mays & Pope, 1995:110). Conformability of results, according to Schurink *et al.* (2011:421) and Anney (2014:279), is assured by the corroboration of the results found by other, similar study results that indicate no personal bias. The main results expected from the educational programme are to improve neonatal chest image quality. Section 4.2.2 provides findings of other research studies that enabled the researcher to ensure conformability of this study.

1.10 ORGANISATION OF THE DISSERTATION

The chapters are set out as follows:

Chapter 1 presents the reader with an overview of the study, namely, addressing chest mobile neonatal image quality through the delivery of an educational programme.

Chapter 2 explains how the first objective, which was to establish quality of chest images produced in the NICU prior to the presentation of an educational programme, was achieved. The chapter explains the compilation of a checklist from literature sources in relation to evaluation criteria, and the implementation of the checklist to determine neonatal chest image quality.

In **Chapter 3** the design, development and presentation of an educational programme, as mentioned in the second objective of this study, are described. The chapter explains how the findings relating to the first objective were incorporated with relevant literature sources in relation to patient positioning to achieve the second objective.

Chapter 4 reveals how the third and final objective was achieved, which entailed the assessment of chest image quality produced in the NICU after participants had undergone the educational programme. Literature referred to in this chapter points to the approach of regulatory bodies to radiation protection and image quality for neonates. The chapter compares the data obtained for the different assessments of image quality, namely, those done before and after the presentation of the educational programme. This comparison ultimately demonstrates whether mobile neonatal chest image quality was affected by the delivery of the educational programme.

Chapter 5 concludes the study and makes recommendations for improving neonatal chest image quality in the future. This final chapter reflects on limitations found in this study, which can be addressed by future studies.

1.11 CONCLUSION

Chapter 1 provided background regarding the title, problem statement, aim and objectives of this study. This chapter explained the need for specialised radiation protection and optimised radiographic techniques to ensure optimal diagnostic image quality when imaging neonates, as specified by governing bodies such as the DoH in SA. The chapter also referred to the need for additional interventions when utilising CR systems, as introduced by the Image Gently campaign.

The chapter also briefly elaborated on the methods used for data collection for this study, ethical considerations, statistical analysis and quality assurance implemented by the study. In the next chapter, Chapter 2, entitled, Evaluated neonatal chest image quality, the literature sources and research methods utilised to assess the image quality of neonatal chest images, are discussed.

CHAPTER 2

DETERMINING CURRENT MOBILE NEONATAL CHEST IMAGE QUALITY

2.1 INTRODUCTION

Standardised image quality enables health care providers to interpret images accurately in order to formulate appropriate interventions. It is important that a radiographer ensures that the first diagnostic image he/she produces is of optimal quality, so that repeat imaging due to suboptimal image quality is reduced to an absolute minimum, and thereby the radiation exposure is kept within acceptable ranges (Vyborny, 1997:479 - 480).

The first objective of this study was to determine the quality of the initial neonatal chest image, before presenting an education programme. To determine the neonatal chest image quality, a research instrument, namely a checklist, had to be designed. In this chapter special attention will be paid to the research instrument that was designed. This chapter will also describe the first phase of the study, which includes the application of the research instrument to evaluate the quality of neonatal chest images produced by radiographers in NICUs with mobile units.

The instrument that was designed is based on radiographic evaluation criteria, which, according to McQuillen Martensen (2011:2) and Bontrager and Lampignano (2014:36), strive to ensure an optimal image with the lowest possible radiation dose to the patient. The literature in this chapter is based on evaluation criteria as suggested by authors of radiographic books and research articles on radiographic image quality. The positioning technique applied by the radiographer to produce these images will be discussed in Chapter 3.

Image quality can only be evaluated with the evaluation criteria suggested and discussed by the literature cited in this chapter because the positioning technique applied is not visible on an image; all which is visible is the result of the applied positioning technique. For example, for chest radiography a radiographer can, hypothetically, centre midway between the sternal notch and xiphoid process of the sternum. This is a positioning technique applied by the radiographer during image production. However, on the image itself, the structure that will be seen in the centre of the image – if the positioning technique was applied correctly – will be the fourth thoracic vertebra. This is an example of the image quality evaluation criterion that can be utilised to determine if the centring (positioning technique) was applied correctly.

The data obtained from the initial evaluation of the image quality as produced by radiographers, enabled the researcher to establish which positioning techniques could have been addressed through an educational programme as an intervention. The data assisted the researcher to determine, on conclusion of the study, whether the education programme that was implemented did indeed address neonatal chest image quality, because the initial image quality was quantitatively and qualitatively known to the researcher.

2.2 LITERATURE ORIENTATION AND BACKGROUND OF NEONATAL CHEST IMAGE QUALITY

The literature in this chapter describes the link between the neonate, image quality and the evaluation of image quality. Factors that influence image quality and the link between image quality and radiation protection/dose will be described. The influence of correct positioning techniques on image quality will be discussed briefly – more detailed information will be provided in Chapter 3. This section concludes with listed evaluation criteria utilised to determine image quality of neonatal chest images, as implemented by researchers in various related studies and described by authors of books on this topic.

The radiography books consulted for this study are those by McQuillen Martensen (2011), Carlton and Adler (2014) and Bontrager and Lampignano (2014). These three sources have been reviewed and updated for more than 18 years. The book by McQuillen Martensen (2011) was first published in 1996, and updated regularly, with the latest edition published in 2011. Carlton and Adler (2014) published the first copy of their book in 1949 and the latest edition in 2014. Bontrager and

Lampignano (2014) first published in 1982 and the latest edition of their book was published in 2014.

These three sources were written by authors with clinical experience in the field of radiography, beyond the scope and experience of the researcher. McQuillen Martensen had more than 10 years of clinical experience in the field of radiography before embarking on a teaching career (McQuillen Martensen, 2011:vii). Carlton and Adler both have more than a decade of experience in teaching of radiological technology (Carlton and Adler, 2014:vi). Bontrager and Lampignano have both been involved in the education of radiographers for more 45 years, specifically radiographic positioning principles (Bontrager and Lampignano, 2014:v).

The books of McQuillen Martensen (2011) and Bontrager and Lampignano (2014) are updated sources regarding radiographic positioning techniques and image evaluation criteria, and the books contain direct reference to neonatal chest images. Other sources, for example, Swallow, Naylor, Roebuck and Whitley (1986), also refer to neonatal chest images but are outdated, with the latest editions older than 10 years. Carlton and Adler (2014) is referenced in relation to image quality and the factors that influence image quality. It is the preferred source because it was updated more recently than other sources, such as Ball and Price (1995), whose latest edition is also older than 10 years. Other updated sources, for example, Bushberg, Seibert, Leidholdt and Boone (2012) focus more on the radiation physics aspect of radiography than the application thereof on image production.

Literature searches were done with search engines such as Medline, Science Direct and Proquest, using keywords such as image quality, radiation dose, newborn, neonates, lead shielding, radiation protection, criteria, guidelines and international standards. References with some or all of these keywords were found. None of these references had information on a study in SA regarding an intervention for neonatal chest imaging that involves an educational programme focused specifically on improving image quality during the empirical study timeframe (2011 to 2012).

2.2.1 Neonatal classifications

Hardy and Boynes (2003:95) classify newborns according to two factors, the gestational age and birth weight. For example, a neonate can be premature (born before 36 weeks), or have a low weight at birth but born after a normal full-term pregnancy. The connection between age and weight in relation to possible complications for a neonate will be discussed.

Neonates born prematurely, at less than 28 weeks of gestation, experience the most severe complications. These neonates usually have low birth weight (less than 1 kg). They require treatment to develop their lungs by means of surfactant and oxygen administration, as well as mechanical breathing assistance (March of dimes, 2010:online). Furthermore, they cannot suck, swallow and breathe at the same time and have to be fed intravenously until these skills develop (Goldwire, 2013:online). Muscle tone is underdeveloped and therefore these neonates must be moved as little as possible. Pathological conditions most commonly identified in these neonates include respiratory distress syndrome, bronchopulmonary dysplasia and necrotizing enterocolitis (Arthur, 2011:313-323).

Neonates born between 28 and 31 weeks have features and complications similar to neonates born before 28 weeks. These complications are less severe and recovery rates are better because of the higher gestational age and birth weights of between 1 and 1.5 kg (March of dimes, 2010:online). Premature births at 32 to 33 weeks have birth weights of between 1.5 and 2 kg. These neonates may need supplemental oxygen to assist with breathing. Most of these infants can swallow, suck and breathe at the same time (Goldwire, 2013:online). According to Arthur (2011: 313–323), these neonates are less likely to develop complications of the severity as found in neonates born at earlier stages of gestation.

Late preterm neonates are born at 34 to 36 weeks gestation. They are usually healthier than babies born earlier and weigh between 2 and 2.5 kg (March of dimes, 2010:online; Goldwire, 2013:online). These neonates may also present with breathing and feeding problems, as well as difficulty regulating body temperature. However, these problems are usually mild in comparison to neonates born earlier (Arthur, 2011:313-323).

Almost 12% of all births in Western countries are premature, with about 2% of infants born at less than 32 weeks of gestation. The survival rate of preterm infants has risen to nearly 90% in Western countries (Bader, Datz, Bartal, Juster, Marks, Smolkin, Zangen, Kugelman, Hoffman, Shani, Ben-Shlomo, Margaliot and Sadetzki, 2007:579). In SA there is, however, uncertainty in relation to premature births and survival rates due to incomplete birth registrations and the fact that the most recent, reliable household survey with detailed birth history data dates to 1998. A report by Nannan, Dorrington, Laubser, Zinyakatira, Prinsloo, Darikwe, Matzopoulos and Bradshaw (2012:4), which summarises available South African data, states that, in 2007, 22% of neonates born did not survive their first month of life.

2.2.2 Image quality

Carlton and Adler (2014:460) define image quality as the features of an image. An image of optimal quality can be defined as one that is within acceptance limits. This means that there are no technical errors, procedural problems or equipment malfunctions (for example grid lines due to grid malfunction) visible on the image. This image can be submitted by the radiographer to assist with the diagnosis of a patient by the radiologist and/or referring physician (Bushberg *et al*., 2012:60).

Technical errors refer to either photographic problems relating to the visibility of detail, or geometric factor problems with detail. Photographic problems refer to the density and contrast seen on the image, which is mainly controlled by milli-ampere (mAs) and kilo-voltage settings (kVp) (exposure parameters) selected by the radiographer. Other influencing factors that are beyond the scope of this study are focal spot size and grid selection (McQuillen Martensen, 2011:34-38; Carlton and Adler, 2014:460). Geometric factors include recorded detail and distortion factors, which are controlled by the correct position of the image receptor (centring point), motion unsharpness (breathing technique) and image receptor tube alignment. Procedural problems refer to patient positioning and preparation errors that can be controlled by the radiographer (McQuillen Martensen, 2011:18-22; Carlton and Adler, 2014:460). Sections 3.2.5 will pay more attention to patient positioning and preparation errors.

Equipment malfunctions include image processing problems that are visible on an image as processing artifacts, for example, dust particles on the CR imaging plate will be scanned by the raster pattern laser of a CR system reader as light spots (Carlton and Adler, 2014:343, 356, 460). Equipment malfunctions fall outside the scope of this study.

Adequate image quality means that the image may not be within all the acceptable limits but can still be used for a diagnosis. Although not ideal, an image of adequate quality could be used for a diagnosis by a radiologist or referring physician. The radiographer should evaluate an image of adequate quality to determine which areas can be improved to ensure optimal image quality for future patients (Carlton and Adler, 2014:460). Without an image of at least adequate quality, a reliable diagnosis or disease process evaluation cannot be made by treating physicians. An additional repeat image will have to be produced, which increases the radiation dose to the patient, in order to ensure a reliable diagnosis of a disease process is possible (McQuillen Martensen, 2011:2-3).

2.2.3 Radiation dose and image quality for neonatal imaging

Taking special care to ensure radiation protection during examinations on neonates is justified by the fact that it is the neonate's irradiation that increases the population's genetic radiation risk. A neonatal patient has a potentially longer life expectancy and therefore a longer timespan for the manifestation of radiation-induced malignancies (Puch-Kapst, Juran, Stoever and Wauer, 2009:1557). An inconsistent and often unoptimised examination technique mat lead to large absorbed doses in neonates and will not always produce an optimal image (Pedrosa de Azevedo *et al.*, 2006:1637; Dougeni *et al*., 2007:807; Puch-Kapst *et al*., 2009:1557).

With the longer period for the potential expression of delayed effects of radiation in mind, it is prudent to consider that neonates are usually small in size, placing most organs within the useful radiation beam. This results in a higher effective dose per image. The organs within the radiation beam consist of intense proliferation and differentiation cells. These proliferating cells are, when irradiated, susceptible to the induction of cancer, because the sensitivity of tissue to radiation is directly proportional to its rate of proliferation (Dougeni *et al*., 2007:807; Olgar, Onal, Bor, Okumus, Atalay, Turkyilmaz, Ergenekon and Koc, 2008:416).

According to Dougeni *et al*. (2007:807) most neonates require multiple imaging examinations during their stay in the NICU, depending on underlying diseases present. This aspect is also mentioned by Lowe *et al*. (1999:55). Neonates frequently suffer from a wide spectrum of severe to life-threatening complications, usually resulting from disease processes in the respiratory and/or cardiovascular system (Section 2.2.1). Prompt diagnosis and therapy is of the utmost importance if such an infant is to survive. Diagnostic radiography offers a prompt and visible assessment of the neonatal respiratory and mediastinal anatomy (Lowe *et al.*, 1999:55; Dougeni *et al*., 2007:807).

Due to the prompt assessment of underlying disease processes provided by diagnostic radiography multiple imaging examinations will be executed during a neonate's stay in the NICU, leading to radiation dose. Should these multiple chest examinations be done without any form of radiation protection, the radiation dose will be more due to increased field of view and scatter/secondary radiation production which increases the potential risk (and possible with more severe effects). In addition, images of inadequate quality will require repeat imaging, which will increase the radiation dose further.

Radiation exposure during childhood results in a possible two- to threefold increase in lifetime risk for certain detrimental effects, compared with that in adults. These detrimental effects include solid cancers (Loovere, Boyle, Blatz, Bowslaugh, Kereliuk and Paes, 2008:198). This increased lifetime risk statement is also mentioned in the research done by Pedrosa de Azevedo *et al.*

(2006:1637-1638), which refer back to the research of the United Nations Scientific Committee on the Effects of Atomic Radiation.

2.2.4 Evaluation of image quality utilising radiographic evaluation criteria: a general perspective

An image of optimal quality can only be produced if the radiographer's skills include correct positioning techniques, selection of optimised radiographic exposure parameters and the ability to analyse both on an image (McQuillen Martensen, 2011:3-4). When analysing the quality of an image to determine the adequacy of the image for providing a diagnosis, a radiographer will evaluate specific areas on the image. These areas on the image are evaluated analytically and are termed radiographic evaluation criteria by McQuillen Martensen (2011:3-4) and Bontrager and Lampignano (2014:30).

According to McQuillen Martensen (2011:4-5) and Bontrager and Lampignano (2014:30) an image should be analysed to determine whether the image is optimal by evaluating the demonstration of the following criteria and/or areas:

- Demographical information, which includes the identification of the institution and patient. There are no rewards for producing an optimal image on the incorrect patient.
- Correct anatomical side identification, by placing a lead marker inside the field of view while avoiding superimposition of important anatomical areas. Only a lead marker can distinguish right sided anatomy from left sided anatomy on an image.
- Imaged anatomical structures aligned correctly to each other and the image receptor (patient positioning). This includes rotation of the patient anatomy, tilt of the patient anatomy in relation to the image receptor or main radiation beam as well as placing the patient's anatomy that should be imaged in the centre of the image receptor.
- Optimal geometric integrity, which includes correct focal spot size selection (incorrect focal spot selection results in a loss of edge detail, which is termed penumbra), minimised size distortion (short distance between neonate and image receptor with a larger distance between the source of

radiation and the neonate), functioning image receptor system, as well as limited motion unsharpness from the patient (breathing technique).

- Visible and appropriate radiation protection, which includes correctly applied gonadal shielding, optimised exposure parameters, immobilisation of the neonate (visible by the sharp representation of anatomical structures free of motion).
- Best possible density, contrast and an appropriate gray-scale with a minimum amount of noise visible on the image, achieved by utilising appropriate exposure parameters (noise will be seen as quantum mottle).
- No preventable artifacts included on the image.

2.2.5 Specific radiographic evaluation criteria for a neonatal chest image

The previous section discussed a broad spectrum of general radiographic evaluation criteria as stated by McQuillen Martensen (2011:4-5) and Bontrager and Lampignano (2014:30). These general criteria can be applied to neonatal chest images or any other radiographic image of the human body. However, above mentioned authors, and other research authors, included in the section below, created specific criteria for neonatal chest images. The authors also termed their criteria differently, in accordance to their needs and requirements. A short summary of these specific sets of neonatal chest evaluation criteria will now follow for each author or study.

McQuillen Martensen (2011:121) published a book based on the analysis of radiographic images. This book contains a section dedicated to neonatal chest image analysis. The book strives to provide the radiographer with a set of comprehensive criteria to evaluate an image and she terms these sets of criteria “analysis criteria”. The analysis criteria identified by this author for neonatal chest images are:

- Fourth thoracic vertebra should be in the centre of the image.
- Upper airways, lungs, mediastinal structures and costophrenic angles are included in the collimation.

- The distance between the clavicle sternal ends and borders of the vertebrae on both sides of the chest is equal. Posterior ribs are equal in length on both sides.
- Anterior ribs are projected inferiorly. Posterior ribs show a delicate superior bowed contour.
- Eight posterior ribs are demonstrated above the diaphragm.
- Lungs have a fluffy appearance with linear-appearing connecting tissue.
- The chin does not superimpose the upper airways or apical lungs.

Bontrager and Lampignano (2014:631) compiled a book on radiographic positioning and evaluation of images produced for each radiographic position. These authors included a section on chest radiography, which indicates that the listed chest criteria are essential for all chest images, which include neonatal chest images. Bontrager and Lampignano (2014:631) termed their criteria “radiographic criteria” and describe the optimal quality image of the chest as one that has the attributes listed below:

- **Structures that should be included (in the collimated field)**
  Entire lungs from the apices (level of cervical vertebra seven) to costophrenic angles.
- **Structures that should be clearly demonstrated**
  Air-filled trachea from the first thoracic vertebra inferiorly.
  Hilum regions should contain lung markings.
  Heart and bony thorax should be demonstrated.
- **To ensure correct positioning**
  The chin should not superimpose the lung apices.
  No rotation evident by equal distance of bilateral lung fields from the lateral rib margins to the spine in the centre.
  Full inspiration evident when the 8^{th} to 9^{th} posterior ribs seen superior to the diaphragm on the image.
- **Correct centring**
  Thoracic vertebra 4 should be in the centre of the collimated image.

- **Exposure is seen as optimal if**

  Fine lung markings are seen within the lungs.

  Faint outlines of the ribs and spine should be visible through the heart shadow and mediastinum.

- **No motion**

  No motion is indicated by sharp outlines of the rib margins, diaphragm, costophrenic angles and heart shadow.

Lowe *et al.* (1999:60) developed an image quality criterion and grading system based on the Commission of the European Community's (EC) image quality criteria. These researchers recommend their system as a valid means of assessing image quality. Seven criteria were used to assess image quality in five institutions in the northwest Thames region of the United Kingdom. All seven criteria were considered to influence patient dose because it entails the demonstration of specific chest anatomical structures that will not be visible if a inadequate exposure technique is employed. Should these structures appear on an image as overly light or dark, it can indicate over or under exposure of the imaging plate and hence that over or under exposure of the patient found between the plate and main radiation beam. Lowe *et al.* (1999:56) termed their system "criteria". These criteria are summarised as follows:

- Vascular pattern in the central half of the lungs are visible;
- Parenchymal markings throughout the entire lung fields are visible;
- Penetration of the trachea and proximal bronchi visible;
- Sharp reproduction of diaphragm and costophrenic angles;
- Visualise spine and paraspinal structures;
- Retrocardiac lung is visible; and
- Mediastinum is visible.

A quality improvement study done by Loovere *et al.* (2008:198) in a tertiary care NICU at McMaster University Medical Centre in Hamilton, Canada, was based on the evaluation of images according to established radiographic principles and techniques as recognised by these Canadian authors. These principles and techniques comprised correct positioning of the neonate, good collimation with complete inclusion of only the requested area on the image, a detailed, well-centered image with absence of rotation, least number of leads and artifacts that could superimpose the area of interest, and appropriate gonadal radiation shielding. Loovere *et al.* (2008:198) use the term "criteria" to refer to the following listed evaluations:

- Accurate position;
- Minimal to no artifacts visible on the image;
- Only anatomical area requested was imaged;
- No anatomy included that was not requested;
- Naught superimposing the area of interest;
- Detail on the image is acceptable;
- Rotation minimal or none;
- Centered correctly; and
- Radiation shield in the correct position.

A study by Slade, Harrison, Morris, Alfaham, Davis, Guildea and Tuthill, (2005:608-609) on the necessity of radiographers handling neonates during examinations was done in three NICUs located in the Cardiff region, United Kingdom. The study used a set of criteria to establish if there was a difference in the quality of the image according to the position of the imaging plate. Two options were available, the imaging plate in direct contact with the neonate or in the tray beneath the mattress (Slade *et al.*, 2005:608-609). The criteria utilised by these authors to score the images were:

- Over/under exposure;
- Blurring of anatomy present/absent;
- Rotation of anatomy present/absent;
- Collimation acceptable or cut-off found;
- Lead marker included/excluded in collimated area; and
- Subjective score of either awful or excellent.

Dougeni *et al.* (2007:807-810) conducted a study in the NICU of the University Hospital of Patras based in Rio, Greece. The study was based on dose and image optimisation in the NICU. The researchers investigated exposure techniques that lowered the entrance skin dose (ESD) for neonates without degrading the image quality. To investigate the differences in image quality for the variations in exposure technique, these researchers used criteria identified as important, as well as the criteria used by Lowe *et al.* (1999:56) described previously. These criteria were based on the guidelines of the EC, which defines an acceptable image (European Commission, 1996:27). The criteria utilised by Dougeni *et al.* (2007:807-810) refer specifically to the visibility of inserted lines and catheters associated with the management of a neonate:

- All criteria listed for the study done by Lowe *et al.* (1999:56);
- End of the endotracheal tube visible, if present;
- End of the umbilical catheter visible, if present;
- End of the long line visible, if present; and
- Bowel loops visible under the diaphragm.

The EC also listed additional criteria that were not included in the studies done by Dougeni *et al.* (2007:807-810) or Lowe *et al.* (1999:56). The reason for the exclusion was that only criteria applicable to exposure parameters were used in the Dougeni *et al.* (2007:807-810) and Lowe *et al.* (1999:56) studies. Both studies focused on radiation dose and measures to lower radiation dose without any negative effects on image quality. In a manual developed by the European Commission, (1996:27) called, *European guidelines on quality criteria for diagnostic radiographic images in pediatrics,* the following image criteria are listed as important:

- Produced on suspended inspiration, except when aspiration of a foreign body is suspected.
- Produced without any rotation or tilt of the thorax.
- From just superior the apices of the lungs to thoracic vertebra 12 should be included on the image.

- Reproduction of the vascular pattern in central half of the lungs, the trachea and proximal bronchi.
- Sharp visualisation of the diaphragm and costophrenic angles.
- Reproduction of the spine and paraspinal structures, retrocradiac lung and mediastinum.
- Protective shielding should include at least a lead-rubber cover of the abdomen/pelvic area in the immediate vicinity of the main radiation beams' edge.

Morris (2003:460-461), a consulting radiologist at the University Hospital of Wales in the Cardiff region, United Kingdom, provides practical points for the evaluation of a neonatal chest image as part of the quality evaluation of the image necessary before diagnostic interpretation can be done by a radiologist. These practical points form part of an article on the radiology of the neonatal chest with reference to specific pathological problems.

- As a starting point, evaluate an image in a methodical manner.
- Pertinent clinical history must be obtained before the examination.
- Technical factors, such as the correct identification on the image as well as correct lead marker placement (not over important anatomy) should be established.
- Rotation should be at a minimum as it can cause line position to appear as incorrectly placed.
- A sufficient inspiratory effort, so as to ensure that the lung fields do not appear misleadingly consolidated.
- No motion or medical equipment artifact should be present on the chest anatomy of interest.
- Tight collimation and lead shielding should be incorporated to lower scatter radiation production and radiation dose.
- The mandible must be lifted and immobilised to ensure that it does not superimpose the apices of the lungs.
- The image should be compared to previous images, if they are available.

As seen from the studies described above different researchers use different combinations of criteria for the evaluation of the neonatal chest image, for different reasons. The authors selected radiographic criteria based on the areas on the chest images they wished to focus the evaluation on in their studies. In the present study the focus was on all the aspects of chest image quality, hence, the researcher's approach was to include all chest evaluation criteria. It is important to note that the research studies consulted above did not include a South African study, because none could be found during the time interval when the research instrument was designed (prior to January 2012). Also noteworthy is that none of these studies utilised specific evaluation criteria for CR systems.

Evaluation criteria utilised on the digital CR system is similar to that utilised on an analog system (film and screen system) (Bontrager and Lampignano, 2014:85). The main difference lies in the evaluation of exposure parameters due to the disconnection between acquisition and display (Willis and Slovis, 2004:373), as already discussed in Chapter 1. To accommodate this disconnection in the research instrument designed for this study (Appendix E), the exposure indices were incorporated. More information in relation to exposure indices can be found in Section 2.2.6.

Table 2.1 offers a summary of radiographic evaluation criteria relating directly to this study. In the table, reference is made to the abovementioned authors who included similar chest criteria in their observations. The research instrument, the checklist (Appendix E) used in this study, was designed based on the information presented in Table 2.1.

Table 2.1: Radiographic evaluation criteria relevant to this study; cross-referenced to related literature sources

	McQuillen Martensen (2011:121-124)	Bontrager and Lampignano (2014:631)	Lowe *et al.* (1999:56)	Loovere *et al.* (2008:201)	Slade *et al.* (2005:609)	Dougeni *et al.* (2007:810)	European Commission (1996:27)	Morris (2003:460-461)
1. Included anatomical structures in collimation								
Entire lungs from the apices (level of cervical vertebra 7) to costophrenic angles (level of thoracic vertebra 12).	✕	✕		✕	✕		✕	✕
2. Demonstrated anatomical structures due to optimal radiation exposure quality								
Visible air-filled trachea from the first thoracic vertebra inferiorly and proximal bronchi.	✕	✕	✕	✕	✕	✕	✕	
Visualise parenchymal markings throughout the lungs.	✕	✕	✕	✕	✕	✕		
Visualise vascular pattern in the central half (two-thirds) of the lungs (hilum region with lung markings).	✕	✕	✕	✕	✕	✕	✕	
Visualise mediastinum.	✕	✕	✕	✕	✕	✕	✕	
Visualise the spine, paraspinal structures and retrocardiac lung.	✕	✕	✕	✕	✕	✕	✕	
Visibility of the endotracheal tube, umbilical catheter and/or long line - if present.						✕		
3. Anatomical positioning due to radiographer positioning technique								
The chin should not fall over the lung apices.	✕	✕		✕				✕
No rotation evident by equal distance of bilateral lung fields from the lateral rib margins to the spine in the centre.	✕	✕		✕	✕		✕	✕
Correct tilt (angulation) evident by anterior ribs projected inferiorly and posterior ribs showing superior bowed contour (trapezoid shape, no horizontal ribs).	✕			✕			✕	
4. Patient breathing technique								
Full inspiration seen by 8-9 posterior ribs visible above the diaphragm.	✕	✕					✕	✕
5. Anatomical centring point								
Correct centring within the collimated field should be the area level with thoracic vertebra 4.	✕	✕		✕				
6. Patient motion indicators								
No motion indicated by the sharp rib margins, the diaphragm, the heart shadow and both costophrenic angles.		✕	✕		✕	✕	✕	✕
7. Artifacts								
Minimum or no artifacts included on image.				✕				✕
8. Radiation shielding								
Radiation protective shielding over the abdominal area visible in the immediate vicinity of the main radiation beam edge.				✕			✕	✕
9. Anatomical marker								
Lead marker visible, not superimposed over important chest anatomical structures.					✕			✕

Table 2.1 is divided into nine main criterion areas. These criteria refer directly to image quality that is under the control of the radiographer. Only by applying an appropriate positioning technique and preparing for the examination, will a radiographer be able to achieve all of the listed criteria when imaging a neonate. The "x" marks next to the listed criteria indicate the studies that utilised these criteria.

From Table 2.1 it is clear that each author selected a set of criteria that evaluate specific areas of image quality researched in their studies, or that they considered to be important. It is interesting that the visualisation of important anatomical structures due to the optimal use of exposure parameters was included in most of the books and studies.

2.2.6 Exposure indices

The factors listed in Table 2.1 for evaluating image quality did not include exposure indices. An exposure index in the digital radiography environment refers to a value that provides feedback to the radiographer on the estimated amount of exposure that reached the imaging plate. Exposure index is an alternative method for judging the amount of noise (grainy appearance) seen on an image and is an indirect indicator of image quality (Seibert and Morin, 2011:573-574).

The exposure index indicates the amount of "dose" given to the image receptor and not the dose to the patient. However there is a correlation between the two dosages. A high exposure index indicates possible overexposure of the image receptor. The patient is located between the image receptor and the main radiation beam hence, the patient also receives a high radiation dose, though not in direct proportion to the exposure index. Images with overexposure include additional scatter radiation due to the high energy beam which will produce a smooth image with little to no density differences. The principle that applies to underexposed images, is that the patient positioned between the image receptor and the main radiation beam will receive a lower radiation dose in direct proportion to the exposure index. However, here the image produced will show a lack in image density (x-ray quanta) due to the lower amount of radiation producing the image (Lanca & Silva, 2014:1).

Due to the absence of an evaluation criterion in this regard (see Table 2.1) the research instrument, the checklist (Appendix E), included the exposure index recorded on the images.

2.3 METHOD OF DETERMINING NEONATAL CHEST IMAGE QUALITY

The quality of neonatal chest images produced by radiographers in the respective NICUs was determined during the first and third phase of this study as indicated in Figure 1.1. The method by which the image quality was determined will now be described. This description of the research method includes the sampling protocol, research instrument and practical collection method.

2.3.1 Sampling protocol

In each of the three participating institutions all mobile neonatal chest images were included in the study for the duration of the specific phase, or until the necessary sample group size of 150 per institution and phase was reached (total number of 450 images for Phase 1). To this purpose, a simple sampling method was used. Yates *et al.* (2008:148) describe a simple sample as a subject of individuals (sample) chosen from a larger group (population). This simple sampling ensured that each neonatal chest image had the same chance to be included in the sample during the specific time frame of the study phase, as advised by Goddard and Melville (2001:36). Mobile neonatal chest images produced in the NICU's as part of the normal routine examination in the participating institutions during the research period for Phase 1 was included in this study.

2.3.1.1 Inclusion and exclusion criteria utilised

The inclusion and exclusion criteria for Phase 1 of this study were:

- Only neonatal chest images produced in the NICU could be included in the study.

- Neonatal chest images produced with a stationary x-ray unit was excluded from the study. Only neonatal chest images done by a mobile x-ray machine in the NICU were included.
- Chest images requested by a referring physician were evaluated; no additional images were produced for the purpose of this study.
- Chest images were viewed directly after the examination, before permanent archiving was included. Neonatal chest images on the permanent archiving system were excluded from the study.
- Images produced and developed by means of a CR system were included.
- Images produced by a qualified radiographer employed by one of the participating institutions were included. Images produced by a supplementary radiographer and/or student radiographer were excluded from the study.
- The research instrument (checklist) completed in full by the researcher was included in the study. Any checklists with incomplete areas were discarded and not included in the study.

2.3.2 Research tool

The neonatal chest image quality was determined using a checklist as a research tool. This checklist was designed by the researcher and was benchmarked and compiled from available literature. The checklist was available in English only because that is the language preferred by the researcher who was responsible for completing the checklists. The compilation and design of the checklist will be discussed in this section as will the pilot study of this instrument.

2.3.2.1 Compilation and design of the research instrument

The checklist was based on all the different criteria for neonatal chest image quality found and displayed in available literature sources discussed in Section 2.2.5. This checklist reflected the criteria specified by international boards such as the EC, as well as the evaluation criteria described by McQuillen Martensen (2011) and Bontrager and Lampignano (2014). It also contained quality control criteria used in checklists by other researchers in their studies, for example, Loovere *et al.* (2008), Lowe *et al.* (1999), Dougeni *et al.* (2007) and Slade *et al.*

(2005), as well as general guidelines by Morris (2003). The initial checklist, before it was piloted is given in Appendix D.

The reason for using the checklist was that it ensured a constant standard evaluation of image quality, which ensured that the evaluations were reliable and valid (Sections 1.9.1 and 2.4). The checklist enabled the quick ticking of criteria; leading to a time of approximately five minutes spent per image. The checklist contained three basic options that the researcher could select: “yes”, “no” and “partial”. Space was provided for additional comments, if necessary.
The design of the checklist entailed a complicated process that considered various aspects of image quality. Exposure factors, the kilo-voltage (kVp) and milli-ampere (mAs) settings were recorded on the checklist (Appendix D), as was the number of previous chest examinations performed on the specific patient. The correct exposure settings were essential for visualising important anatomy and benchmarking to those utilised during previous chest examinations done on the same patient.

The pathological conditions and possible manifestation of the condition would be visible on previous images and should be taken into consideration. The referring physician should indicate the suspected pathology or other possible justification for the image on the referral letter. Thus the referral letter, as advised by Morris (2003:460-461) was included in the checklist.

The position of the patient’s body during the examination was evaluated by the rotation of the chest cavity, tilt of the main radiation beam visible on the chest image, all relevant anatomy included on the image, no artifacts superimposing relevant anatomy and the centring of the chest cavity in the middle of the image. Specific anatomical relations giving rise to the interpretation of the criteria listed above were found in the radiography books consulted (McQuillen Martensen, 2011:121; Bontrager and Lampignano, 2014:631). Bontrager and Lampignano (2014:631) also indicated the interpretation of a correct breathing technique. The correct breathing technique can be judged by evaluating the posterior ribs as indicated in the checklist and described in the book.

A radiographer should always indicate the correct anatomical sides by including an anatomical lead marker on the image. This important principle was included in a study done by Slade *et al.* (1999:609) and was also included in the checklist of this current study. The exposure parameters, radiation protection and collimation criteria given by the EC were included in this checklist as a whole. These and other criteria listed by the EC in a document, *European guidelines on quality criteria for diagnostic radiographic images in pediatrics* (European Commission, 1996:27) echoed the criteria described in the radiography books written by Bontrager and Lampignano (2014:631) and McQuillen Martensen (2011:121).

Table 2.1 summarises the evaluation criteria that informed the compilation of the checklist as utilised by other authors. The table lists nine main areas of evaluation criteria. These nine areas were rearranged to ensure a systematic evaluation approach into eight main evaluation areas. The eight main evaluation areas on the checklist, and the authors that informed these areas, is summarised below:

- **Request letter** available with a **clinical history** included (Morris, 2003:460-461).
- **Radiographic position** evaluated by five criteria:
    1. Rotation evaluated by the equal distance of the lung border to the spine (European Commission, 1996:27; Morris, 2003:460-461; Slade *et al.*, 2005:609; Loovere *et al.*, 2008:201; McQuillen Martensen, 2011:121-124; Bontrager and Lampignano, 2014:631).
    2. Tilt evaluated by the trapezoid-shaped chest and/or horizontal rib appearance (European Commission, 1996:27; Loovere *et al.*, 2008:201; McQuillen Martensen, 2011:121-124).
    3. All relevant anatomy included on the image (European Commission, 1996:27; Morris, 2003:460-461; Slade *et al.*, 2005:609; Loovere *et al.*, 2008:201; McQuillen Martensen, 2011:121-124; Bontrager and Lampignano, 2014:631).
    4. Artifacts superimposed on chest anatomy including the mandible over lung apices (Morris, 2003:460-461; Loovere *et al.*, 2008:201; McQuillen Martensen, 2011:121-124; Bontrager and Lampignano, 2014:631).

5. Chest centered to the collimated field (Loovere *et al.*, 2008:201; McQuillen Martensen, 2011:121-124; Bontrager and Lampignano, 2014:631).

- **Breathing technique** was evaluated by three criteria:
  1. Suspended inspiration; demonstrated by 8-9 posterior ribs seen above the diaphragm (European Commission, 1996:27; Morris, 2003:460-461; McQuillen Martensen, 2011:121-124; Bontrager and Lampignano, 2014:631).
  2. Normal breathing or respiration; suggested by blurred representation of the diaphragm, heart border and lung markings (Morris, 2003:460-461; Slade *et al.*, 2005:609; Bontrager and Lampignano, 2014:631).
  3. Suspended expiration; demonstrated by 5-6 posterior ribs seen above the diaphragm (McQuillen Martensen, 2011:121-124; Bontrager and Lampignano, 2014:631).
- **Lead marker** was evaluated by two criteria:
  1. Lead marker visibility in the collimated field (Morris, 2003:460-461; Slade *et al.*, 2005:609).
  2. Lead marker placed anatomically correctly (Morris, 2003:460-461; Slade *et al.*, 2005:609).
- **Radiation protection** was evaluated by the lead shielding seen over the abdominal/pelvic area on an image (Morris, 2003:460-461; Loovere *et al.*, 2008:201).
- **Exposure parameters** were evaluated by eleven criteria:
  1. First visual interpretation as under or over exposed.
  2. Vascular pattern seen in the central half of the lung fields (Lowe *et al.*, 1999:56; Slade *et al.*, 2005:609; Dougeni *et al.*, 2007:810; Loovere *et al.*, 2008:201; McQuillen Martensen, 2011:121-124; Bontrager and Lampignano, 2014:631).
  3. Parenchymal markings seen throughout the lung fields (European Commission, 1996:27; Lowe *et al.*, 1999:56; Slade *et al.*, 2005:609; Dougeni *et al.*, 2007:810; Loovere *et al.*, 2008:201; McQuillen Martensen, 2011:121-124; Bontrager and Lampignano, 2014:631).
  4. Penetration of the trachea visible (European Commission, 1996:27; Lowe *et al.*, 1999:56; Slade *et al.*, 2005:609; Dougeni *et al.*,

2007:810; Loovere *et al.*, 2008:201; McQuillen Martensen, 2011:121-124; Bontrager and Lampignano, 2014:631).

5. Penetration of the proximal bronchi visible (European Commission, 1996:27; Lowe *et al.*, 1999:56; Slade *et al.*, 2005:609; Dougeni *et al.*, 2007:810; Loovere *et al.*, 2008:201; McQuillen Martensen, 2011:121-124; Bontrager and Lampignano, 2014:631).
6. Sharp reproduction of the diaphragm and costophrenic angles (McQuillen Martensen, 2011:121-124; Bontrager and Lampignano, 2014:631).
7. Visualise spine and paraspinal structures (European Commission, 1996:27; Lowe *et al.*, 1999:56; Slade *et al.*, 2005:609; Dougeni *et al.*, 2007:810; Loovere *et al.*, 2008:201; McQuillen Martensen, 2011:121-124; Bontrager and Lampignano, 2014:631).
8. Visualise retrocardiac lung (European Commission, 1996:27; Lowe *et al.*, 1999:56; Slade *et al.*, 2005:609; Dougeni *et al.*, 2007:810; Loovere *et al.*, 2008:201; McQuillen Martensen, 2011:121-124; Bontrager and Lampignano, 2014:631).
9. Visualise mediastinum (European Commission, 1996:27; Lowe *et al.*, 1999:56; Slade *et al.*, 2005:609; Dougeni *et al.*, 2007:810; Loovere *et al.*, 2008:201; McQuillen Martensen, 2011:121-124; Bontrager and Lampignano, 2014:631).
10. Visualise any catheter tip in relevant anatomical area (European Commission, 1996:27; Lowe *et al.*, 1999:56; Slade *et al.*, 2005:609; Dougeni *et al.*, 2007:810; Loovere *et al.*, 2008:201; McQuillen Martensen, 2011:121-124; Bontrager and Lampignano, 2014:631).
11. Exposure index within recommended range of manufacturer (Seibert and Morin, 2011:573-574; Lanca & Silva, 2014:1).

- **Collimation** was evaluated by eight criteria:

1. Collimation is visible (European Commission, 1996:27; Morris, 2003:460-461; Slade *et al.*, 2005:609; Loovere *et al.*, 2008:201; McQuillen Martensen, 2011:121-124; Bontrager and Lampignano, 2014:631).

2. Superiorly, cervical vertebra seven is included (European Commission, 1996:27; Morris, 2003:460-461; Slade *et al.*, 2005:609; Loovere *et al.*, 2008:201; McQuillen Martensen, 2011:121-124; Bontrager and Lampignano, 2014:631).
3. Any anatomy above cervical vertebra seven included (European Commission, 1996:27; Morris, 2003:460-461; Slade *et al.*, 2005:609; Loovere *et al.*, 2008:201; McQuillen Martensen, 2011:121-124; Bontrager and Lampignano, 2014:631).
4. Both shoulders are included on both lateral aspects (European Commission, 1996:27; Morris, 2003:460-461; Slade *et al.*, 2005:609; Loovere *et al.*, 2008:201; McQuillen Martensen, 2011:121-124; Bontrager and Lampignano, 2014:631).
5. Any anatomy lateral of the shoulders included (European Commission, 1996:27; Morris, 2003:460-461; Slade *et al.*, 2005:609; Loovere *et al.*, 2008:201; McQuillen Martensen, 2011:121-124; Bontrager and Lampignano, 2014:631).
6. Inferiorly, costophrenic angles are included (European Commission, 1996:27; Morris, 2003:460-461; Slade *et al.*, 2005:609; Loovere *et al.*, 2008:201; McQuillen Martensen, 2011:121-124; Bontrager and Lampignano, 2014:631).
7. Anatomy inferior of the costophrenic angles is included (European Commission, 1996:27; Morris, 2003:460-461; Slade *et al.*, 2005:609; Loovere *et al.*, 2008:201; McQuillen Martensen, 2011:121-124; Bontrager and Lampignano, 2014:631).
8. Bilateral lung fields included (European Commission, 1996:27; Morris, 2003:460-461; Slade *et al.*, 2005:609; Loovere *et al.*, 2008:201; McQuillen Martensen, 2011:121-124; Bontrager and Lampignano, 2014:631).

- **The final evaluation of the radiographer** in relation to the image quality was whether any manipulation of image quality was required during post-processing (Seibert and Morin, 2011:573-574; Lanca & Silva, 2014:1).
  Radiographer was required to **repeat** the image.

2.3.2.2 Pilot study of the checklist

The purpose of the pilot study was to test the checklist and ensure that it was practicable and user friendly. It also enabled the researcher to familiarise herself with the normal routines of the different participating institutions. The researcher was also able to refine the evaluation skills needed to complete the checklist effectively. The pilot study enabled the researcher to benchmark with a radiologist (Venter, 2011) about the knowledge and skills necessary to judge image quality on a neonatal chest image, and to establish the relevance of criteria included in the checklist.

Data gathered from the checklists in the pilot study was not included in the statistical analysis of this study. The reason for the exclusion was that this activity of the study provided a learning curve for the researcher. The researcher visited each participating institution to view and evaluate 20 neonatal mobile chest images with the checklist. This means that a total of 60 neonatal chest images were evaluated in the pilot study, and this gave the researcher time to grow accustomed to the checklist and the specific neonatal anatomy on the images, such as the parenchymal markings and/or vascular pattern of the lung fields.

The time taken to complete the original checklist before the pilot study (Appendix D) was 15 minutes per image due to the fact that additional information had to be located on the hospital and/or radiology information systems (HIS and/or RIS). This additional information included the official diagnosis of the patient and the neonate's birth weight. After careful consultation with the radiologist (Venter, 2011), it became apparent that these two sections of information would not have an impact on the study's proposed education programme or the foreseen results on image quality.

In addition, the exposure parameters that were documented during the pilot study were removed because it became apparent that the researcher would have to accompany all the radiographers on their chest mobile examinations in order to capture these parameters. This would have been time consuming and would also have alerted the radiographers to the fact that the neonatal chest images they were producing were being evaluated. This could have altered their routine examination methods. In addition, the exposure quality of the image was evaluated by 11 different criteria and the exposure index was documented. This gave the researcher a clear picture of the way radiographers utilised exposure parameters without the actual exposure parameters being recorded. After the pilot study had been completed the checklist was finalised (Appendix E).

The final checklist, given in Appendix E, consists of eight main evaluation criteria areas. Under each of the eight areas, various specific evaluation criteria were examined on the images. The areas that were removed where located in the demographical section of each checklist and did not alter the eight main evaluation criterion areas.

2.3.3 Collection method

The researcher visited each institution; these visits were unannounced. During Phase 1 of the study (February 2012 to June 2012) the radiographers were not briefed on the time or reasons for these visits. Neonatal chest images stored on the temporary storage of the CR systems were evaluated by the researcher. Images are stored temporarily on a CR system for a short period of time (± 48 hours) before being deleted or replaced by other images. These temporarily stored images can be viewed in their unprocessed original format before the radiographer has altered the image quality. A log was kept of these visits (Appendix Q).

During a visit, the researcher located a quiet CR system portal that was not in use by radiographers on duty; hence, visits coincided with quiet time at the units. These quiet times were determined during the pilot study and in consultation with institutional management. The CR temporary storing memory was accessed and searched for any neonatal chest images taken that day or previous days. These images were sampled in a simple fashion (Section 2.3.1). Images were opened and evaluated according to the checklist (Appendix E). The images were evaluated systematically, starting from the top of the checklist. Each criterion was evaluated separately and comments made in the space provided as required. Comments included specific body orientations; additional anatomy included and recorded exposure indices. As soon as an evaluation was completed, the image was closed and stored in its unaltered original state on the CR system. Before leaving the specific institution the researcher entered the number of images evaluated at the institution and recorded the duration of the visit in a log book (Appendix Q).

2.3.4 Statistical analysis

Quantitative data was obtained from the “yes”, “no” and “partial” options found on the checklist (Appendix E). Qualitative data was obtained from the comments in the spaces provided. A coding system formed part of the mechanics of analysing the data, designed with the assistance of a statistician. The coding system labeled each criterion of image quality for neonatal chest images utilised in the checklist with an alphabetical letter (Appendix F indicated as A to NN). This enabled the researcher to enter the data directly from each checklist into a database for analysis (Williams, 2003:249). The alphabetical letter allocated to each criterion corresponded to the alphabetical labeled data line in the Excel database where the responses were stored.

The specific tick boxes with matching alphabetical reference numbers are given in the checklist in Appendix F. On the right-hand side of the checklist the alphabetical numbers/tick boxes indicate a new data line, and were listed from top to bottom as can be seen. The different options per data line or tick boxes (“yes”, “no” and “partial”) were allocated a numerical number (1, 2 and 3 respectively). Additional comments were captured separately for each data line. The researcher ensured that comments were made in a consistent fashion, for example, thoracic vertebra 12 consistently, not sometimes given as 12 thoracic vertebra. Similar comments were grouped into categories. The categories were then calculated into frequencies and percentages by a statistician.

2.4 QUALITY ASSURANCE OF RESULTS FROM PHASE 1

The quality assurance of the results has already been described in Section 1.9. In addition, unannounced visits by the researcher insured that participating radiographers were not influenced by the researcher during their normal routine in the NICU. Radiographers were unaware of the image quality evaluation done by the researcher during the first phase of the study. This means that the results obtained for this phase of the study can be considered as rigorous as described by Mays and Pope (1995:110).

Without a structured instrument that ensured consistent evaluation of image quality, free from subjectivity, the data would not be reliable or valid (Denscombe, 2007:252). Only the researcher completed the checklists, hence, only one perception can be found in the results. This ensured a consistent form of results gathered. In addition, responses on the checklist were given in tick boxes, which represent structured responses. These meant the quantitative results could be gathered in a valid and reliable manner.

Due to the nature of the criteria on the checklist subjective bias is unlikely. No criterion was referred to in a vague manner because specific anatomical areas were evaluated consistently from one image to the next. This enabled the researcher to perform the checklist investigation without an additional moderator. The construction and design of the checklist ensured that the data collection would be objective and reliable.

Lastly, the trustworthiness of the qualitative data on the checklist was enhanced, as suggested by Bickman and Rog (1998:93), by the researcher acting as an instrument. The researcher has a radiography background and was therefore sufficiently experienced to record additional information seen on neonatal chest images by adding standardised comments to the checklist (Section 2.3.4). These additional qualitative remarks assisted in explaining the quantitative results obtained through the checklists. These remarks were recorded without bias because they did not involve opinions, but rather recorded observed anatomical structures. For example, the researcher could only comment if additional anatomy was included by stating which specific additional anatomical structure was visible on the image. The decision about what anatomy was considered necessary for inclusion on an image and what as unnecessary additional, was based on literature sources and not on the opinion of the researcher (Section 2.3.2.1).

The pilot study also ensured that any vague or unclear image evaluation criteria areas in the checklist which could have a negative influence on the results were removed (see Section 2.3.2.2). The data obtained from the pilot study allowed the researcher to confirm that the results that would be gathered will contribute to reaching the stated objectives of determining neonatal chest image quality produced by radiographers before and after an education programme. The interview with the radiologist (Venter, 2011) also validated the criteria included in the checklist and enabled the researcher to discard criteria that would not have assisted in reaching the stated objectives of this study. In addition, it also assisted the researcher to benchmark the criteria against a local radiological source, which was essential because all the sources consulted about evaluation criteria to include in the checklist, were from outside SA.

2.5 RESULTS AND DISCUSSION FOR PHASE 1

The descriptive statistics were calculated separately for Phase 1 (pre-educational programme) and Phase 3 (post-educational programme) for each of the institutions. The Phase 1 data are displayed and summarised in graphs and a table (see graphs and Table 2.2). The data presentation are divided into eight sections, namely, demographic information, request letter, radiographic position, breathing technique, lead marker and radiation protection, exposure parameters, collimation and, lastly, the final evaluation by the radiographer. The designation for each section of the data is similar to that of the checklist (Appendix E). All the found checklists were complete in full and none was therefore excluded. The data is summarised as percentages and the exact number of images for each area.

2.5.1 Demographic information

A total number of 450 neonatal chest images were evaluated during Phase 1 of the study. Of these 450 images, 44.4% (200 of the images) were of male neonates and 55.6% (250 of the images) were of female neonates. The median age of these neonates was 8 days, with an inter-quartile range of 2 days (lower quartile) to 19 days (upper quartile). The median number of chest images taken per neonate was 3 chest images, with an inter-quartile range of 2 chest images (lower quartile) to 6 chest images (upper quartile). The maximum number of chest images taken was 25 images on a single neonate.

2.5.2 Request letter

Request letters were available for 99.6% (448) of the images. Of these request letters, a clinical history of the neonate was provided in 6% (26 images) of cases, and 94% (423 images) of these letters contained no clinical history. Table 2.2 sets out the percentage of request letters that provided an indication of the clinical history of the neonate.

Table 2.2: Request letter and clinical history available

Availability	**Percentage**
No request letter provided	0.4%
Request letter provided	99.6%

Availability	**Percentage**
Clinical history provided	6%
No clinical history provided	94%

For one case, no request letter was available but a clinical history was provided. The examination was requested as an emergency examination because the neonate had lowered saturation levels with no known cause. The nursing staff managing the emergency situation of the neonate could not complete the prescribed request letter because they were preoccupied with keeping the neonate saturated. They did however provide a clinical history on the arrival of the radiographer in the NICU. The radiographer completed a request letter herself and indicated the circumstances under which the letter had been composed.

2.5.3 Radiographic position

In this part of the checklist the general position of the neonate as captured on the image was evaluated. Five specific criteria were evaluated, namely, rotation, tilt, included anatomy, artifacts and centring. The data for these five criteria are summarised in Figure 2.1.

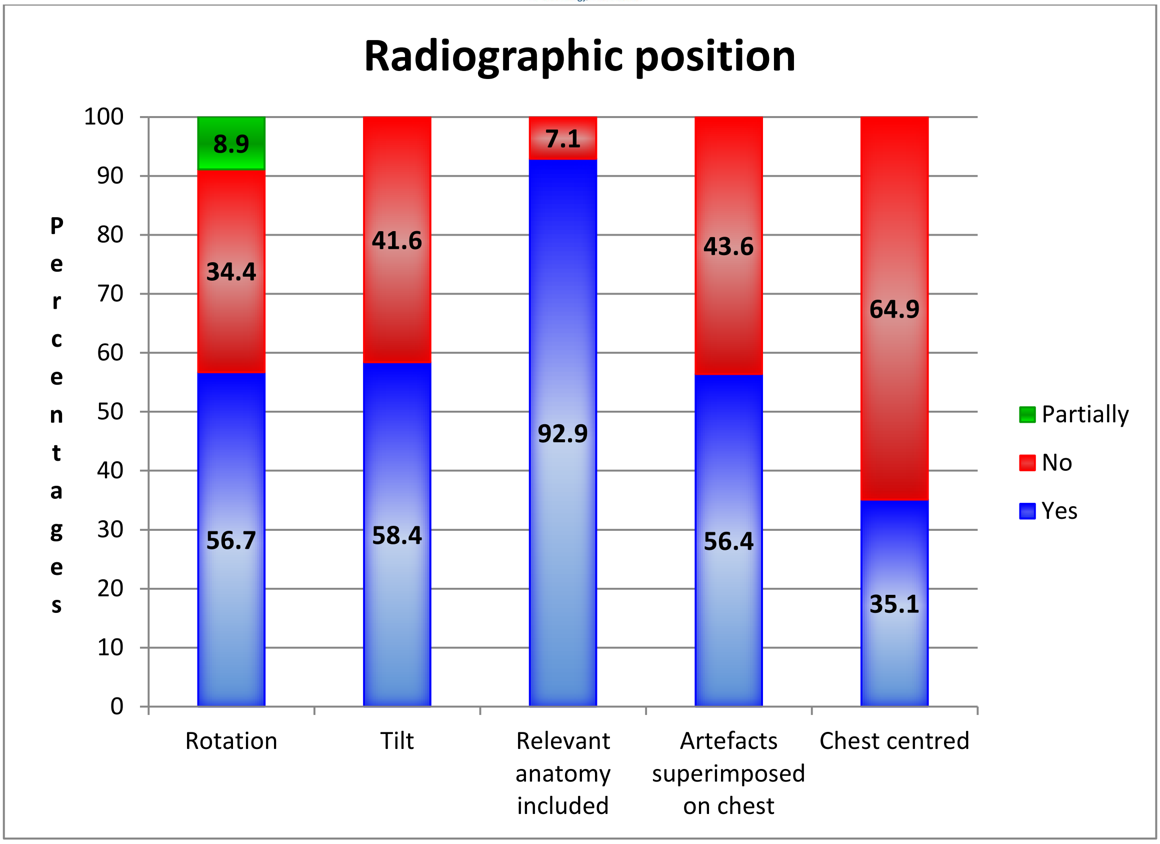


Figure 2.1: Radiographic position

Rotation was evaluated by determining if the vertebral column was at an equal distance from the lung borders (left and right) (European Commission, 1996:27; Morris, 2003:460-461; Slade *et al.*, 2005:609; Loovere *et al.*, 2008:201; McQuillen Martensen, 2011:121; Bontrager and Lampignano, 2014:631). In 56.7% (225) of the images the distance was not the same on the right and left sides, indicating that there was rotation on the image ("yes" response). In 34.4% (155) of images the distance was the same, which indicated that there was no rotation on the image ("no" response). Rotation was partial in 8.9% (40) of the images – these were cases involving anatomical structures above or below the chest showing signs of rotation in addition to the rotated chest. Other rotated anatomical structures that were observed were the skull in an oblique position for 10% which is 4 images of the partially observed images, or in a lateral position for 90% which is 36 images of the partially observed images.

The tilt of the main radiation beam on the neonatal chest images was evaluated by the trapezoid shape of the chest and the horizontal rib appearance (McQuillen and

Martensen, 2011:121). In 58.4% (263) of the images the amount of tilt was correct because the chest visualised as a trapezoid shape, and in 41.6% (187 images), the tilt was evaluated as incorrect due to the horizontal rib appearance that was visualised (Figure 2.1).

All relevant anatomy included was evaluated by determining if the entire lung fields were visualised on the image. In 92.9% (420) of the images all the relevant anatomy was included and in 7.1% (30 images) some of the important anatomy was excluded (Figure 2.1).

Figure 2.2 illustrates the percentage of anatomy that was excluded on these 30 images and about which the researcher commented in the space provided on the checklist. From this figure it can be deduced that the costophrenic angle was the relevant anatomical structure that was most often excluded, either only one – left costophrenic angle (43.3% or 13 images) or right costophrenic angle (33.3% or 10 images) – or both costophrenic angles (3.3% or 1 image); in total costophrenic angles were excluded in 79.9% which is 24 of the 30 images with excluded anatomy. Lung apices were excluded on 16.7% or 5 images. One image (3.3%), the lung apices, left costophrenic angle and a section of the left lung field were excluded.

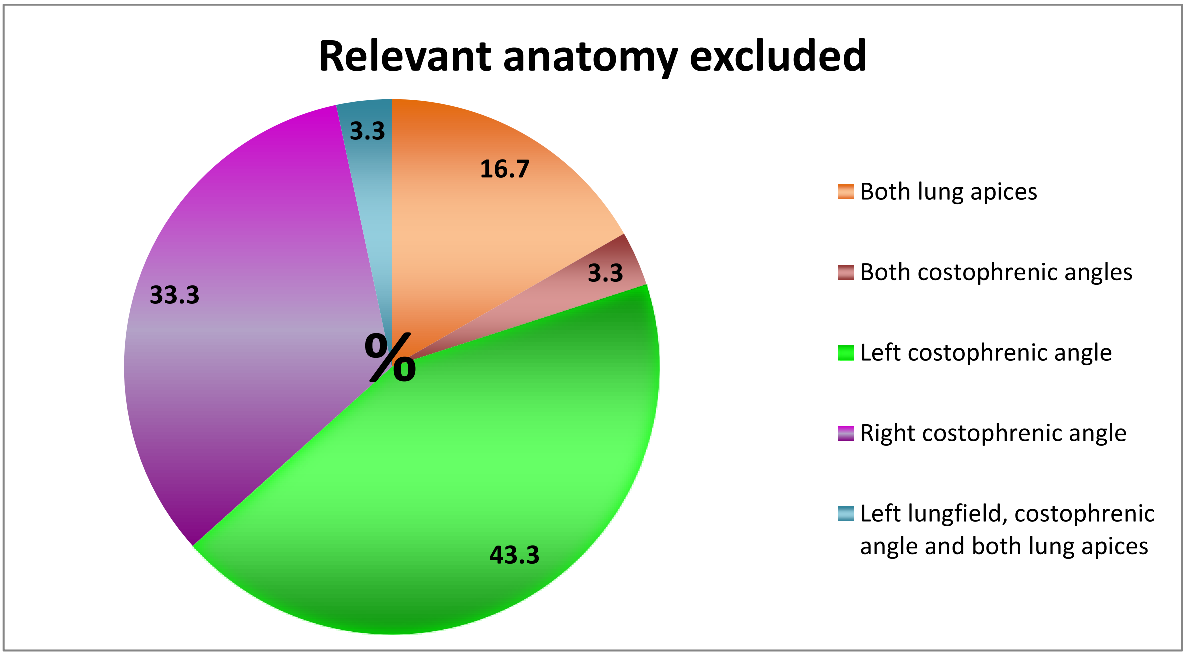


Figure 2.2: Relevant anatomy excluded

After discussing the relevant anatomy excluded on the images, the artefacts superimposed on chest anatomy will receive attention. Artefacts should not be superimposed on the chest anatomy on an image (Morris, 2003:460-461; Loovere *et al.*, 2008:201). Figure 2.1 shows that 56.4% (254) of the images contained artefacts superimposed on the chest anatomy, while 43.6% (196) were free of artefact superimposition. Artefacts that were found to superimpose chest anatomy on 254 images are summarised in Figure 2.3 as percentages. The most common artefacts found on images were electrocardiogram (ECG) lines (61.9% or 157 images), followed by the neonatal mandible (24.4% or 62 images). The remaining superimpositions (13.7% or 35 images) involve clavicle (7 images), incubator ports (1 image), oxygen masks or tubes (11 images) and staff members' hands superimposed over chest anatomy while immobilising the neonate (16 images).

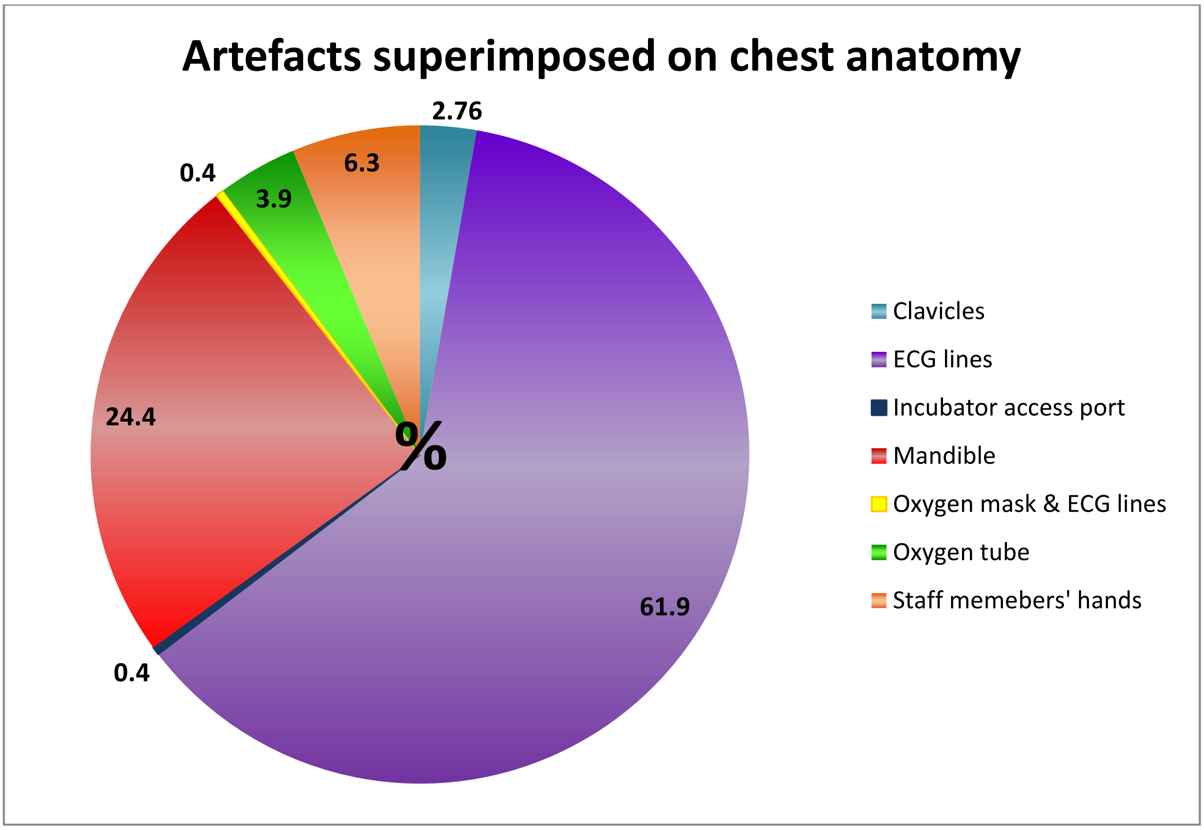


Figure 2.3: Artefacts superimposed on chest anatomy

The last criterion evaluated under radiographic position is the centring of the neonate's body in relation to the main radiation beam. This was evaluated by determining the anatomical structure located in the centre of the image. Centring was deemed correct (yes) if the fourth thoracic vertebra was seen in the middle of the image (Loovere *et al.*, 2008:201; McQuillen Martensen, 2011:121; Bontrager and Lampignano, 2014:631) and in 35.1% or 153 images this was the case, as shown in Figure 2.1. If any other structure was found to be in the centre of the image, centring was deemed incorrect (no), as can be seen in 64.9% or 297 images. Figure 2.4 shows the percentages of anatomical areas found in the centre of the incorrectly centered 297 images as recorded by the researcher on the checklist in the form of a comment. As can be seen in 99.7% or 296 images, the centring was inferior of the required centring location (more towards the abdominal area; with lumber vertebrae two and three in the centre of 11.5% or 34 images, thoracic vertebra 12 in the centre of 55.6% or 165 images, thoracic vertebra nine in 7.7% or 23 images and thoracic vertebra seven in 24.9% or 74 images). The remaining 0.3% or 1 image was centered superior to the required centering location, to thoracic vertebrae two and three area.

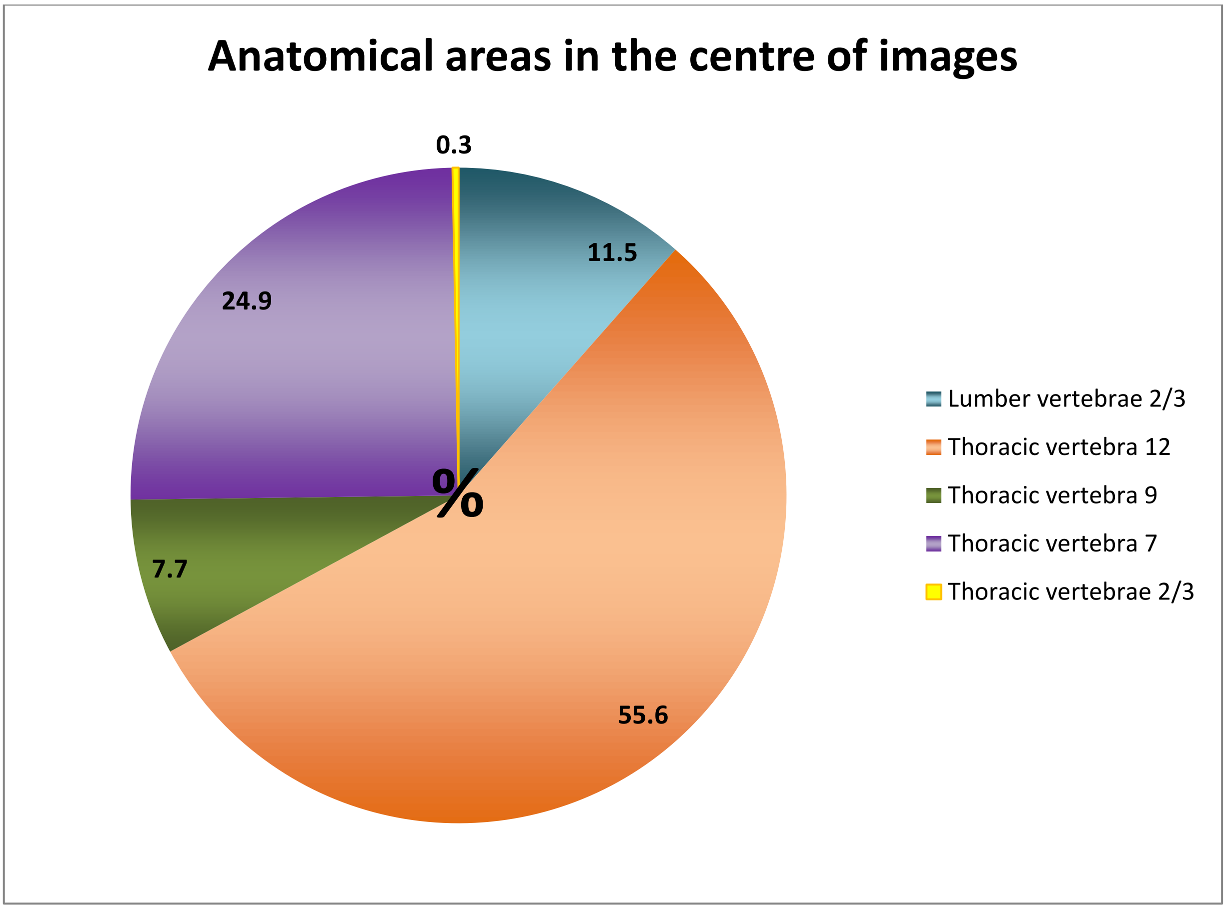


Figure 2.4: Anatomical areas in the centre of images

2.5.4 Breathing techniques

The correct breathing technique for chest radiography is suspended inspiration (European Commission, 1996:27; Morris, 2003:1460-461). This part of the checklist evaluated the breathing technique by determining if the image was produced during suspended inspiration, suspended expiration or normal respiration. Figure 2.5 illustrates the findings regarding the breathing techniques found during Phase 1 as percentages. What can be deduced from this figure is that the correct suspended inspiratory breathing technique was utilised in 54.2% or 244 images. The incorrect breathing techniques observed (45.8% or 206 images) can be subdivided into 30.2% or 136 images with normal respiration and 15.6% or 70 images with suspended expiration.

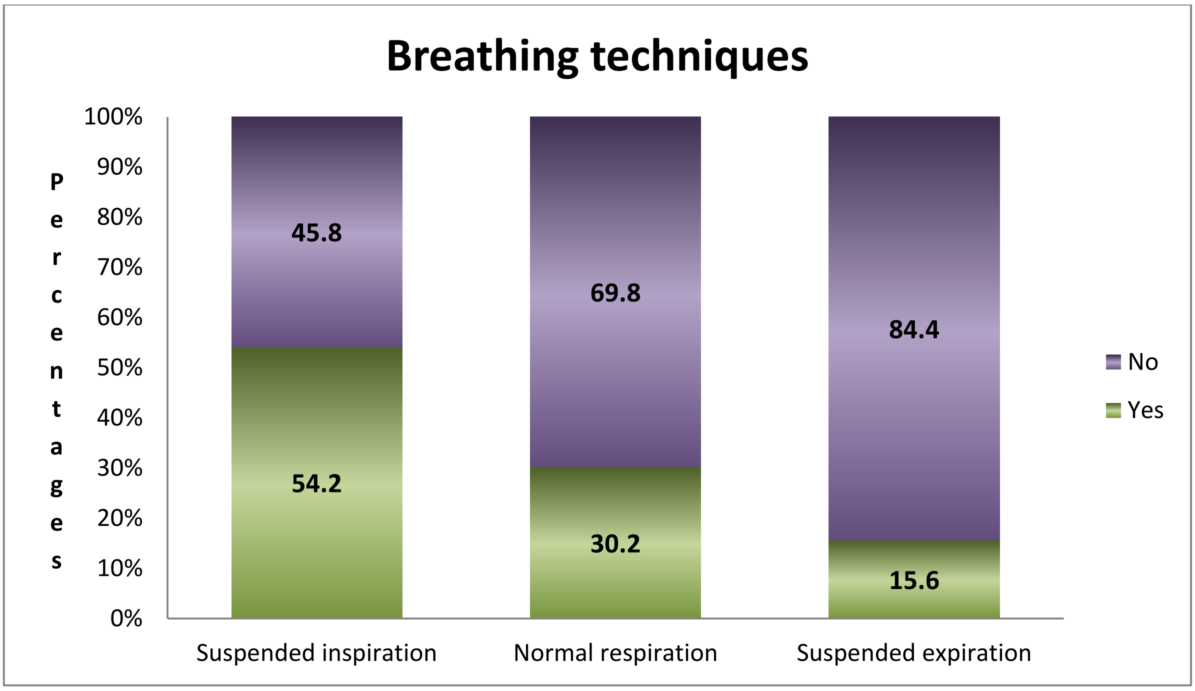


Figure 2.5: Breathing techniques

2.5.5 Lead marker and radiation protection

Regulation defining the scope of the profession of radiography requires that a lead marker be placed on an image in the correct format and without it superimposing any important anatomy as part of patient care and use of equipment (RSA DoH, 1973b:1-2; Morris, 2003:460-461; Slade *et al.*, 2005:609; McQuillen Martensen, 2011:121). Furthermore, regulation requires that the pediatric patient, especially neonates, receive lead shielding over the pelvic region when chest imaging is performed (European Commission, 1996:27; Morris, 2003:460-461; Loovere *et al.*, 2008:201). Figure 2.6 illustrates that a lead marker was visible on the image in 33.6% or 151 images. This figure also indicates that 32.7% or 147 of these images the lead markers were placed correctly. In addition, pelvic lead shielding was visible on 1.33% or 6 images.

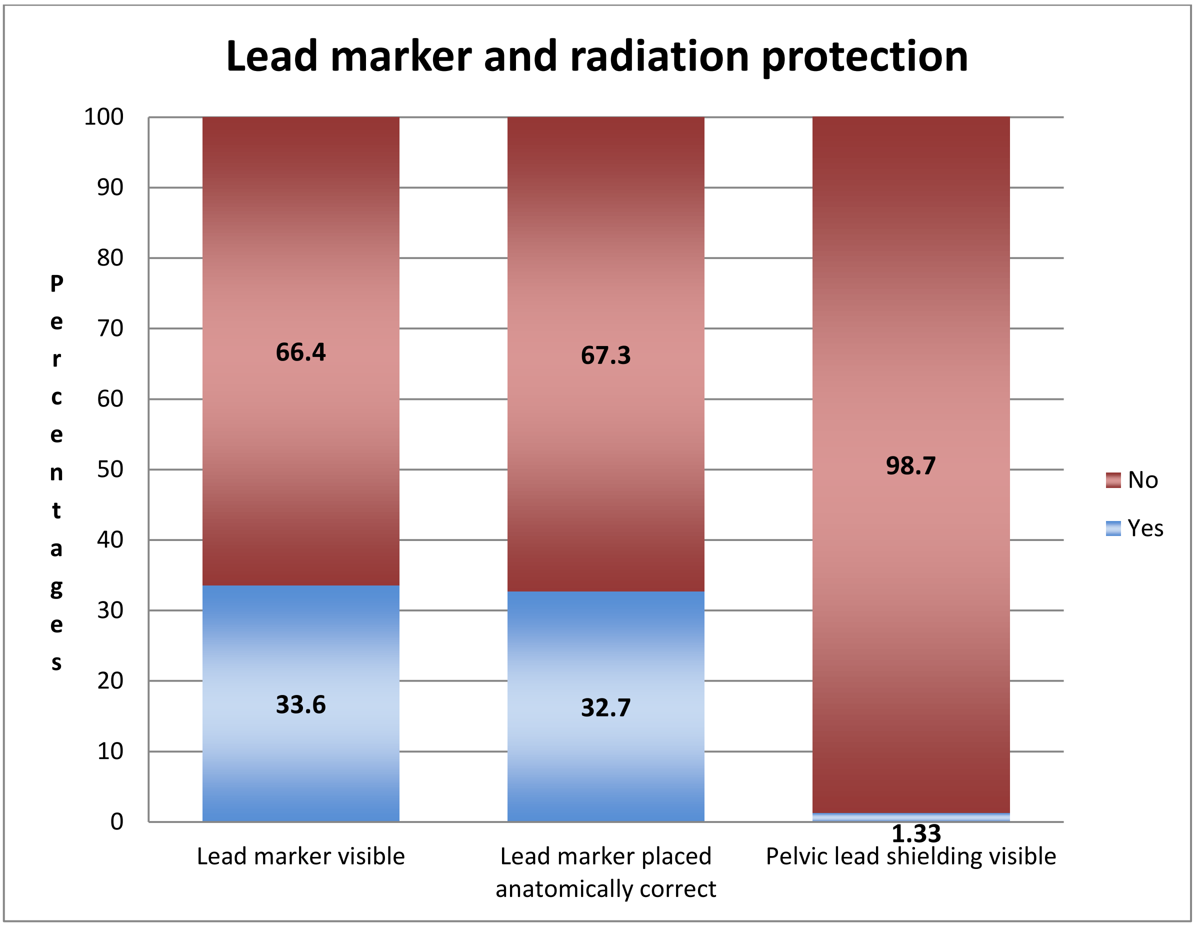


Figure 2.6: Lead marker and radiation protection

2.5.6 Exposure parameters

Exposure parameters were evaluated utilising 11 different criteria (Section 2.3.2.1) – these criteria were included to compensate for the fact that the actual selected exposure parameters were not included in the data accumulation, as discussed in relation to the pilot study (Section 2.3.2.2). This allowed the researcher to compensate for any pathology that might obscure some areas. The image was furthermore evaluated in its original static setting on the CR-system, before any window width or window level manipulation.

If these criteria tested as positive (yes), it indicated the optimal utilisation of exposure parameters. In addition, one criterion referred to the exposure index, which indicated the amount of radiation that reached the image receptor, thereby indirectly indicating whether the ionising radiation exposure to the neonate was within a recommended exposure range (Seibert and Morin, 2011:574).

Optimal exposure parameters will enable a physician to evaluate the condition of the lung tissue itself (McQuillen Martensen, 2011:87). Four of the criteria evaluated lung tissue (pattern) and this data is summarised as percentages in Figure 2.7. If the mAs selection was optimal vascular patterns should be visible in the central half of the lungs (McQuillen Martensen, 2011:87). In 61.1% or 275 images these selections were optimal. In addition, parenchymal markings throughout the lung field should be visible if the mAs were selected correctly (McQuillen Martensen, 2011:88). In 60% or 270 images this was the case. Both these criteria were included in in the checklist to evaluate the selected mAs setting. This inclusion of both criteria compensated for possible pathological conditions that could prevent visualisation of either one or both of these anatomical areas.

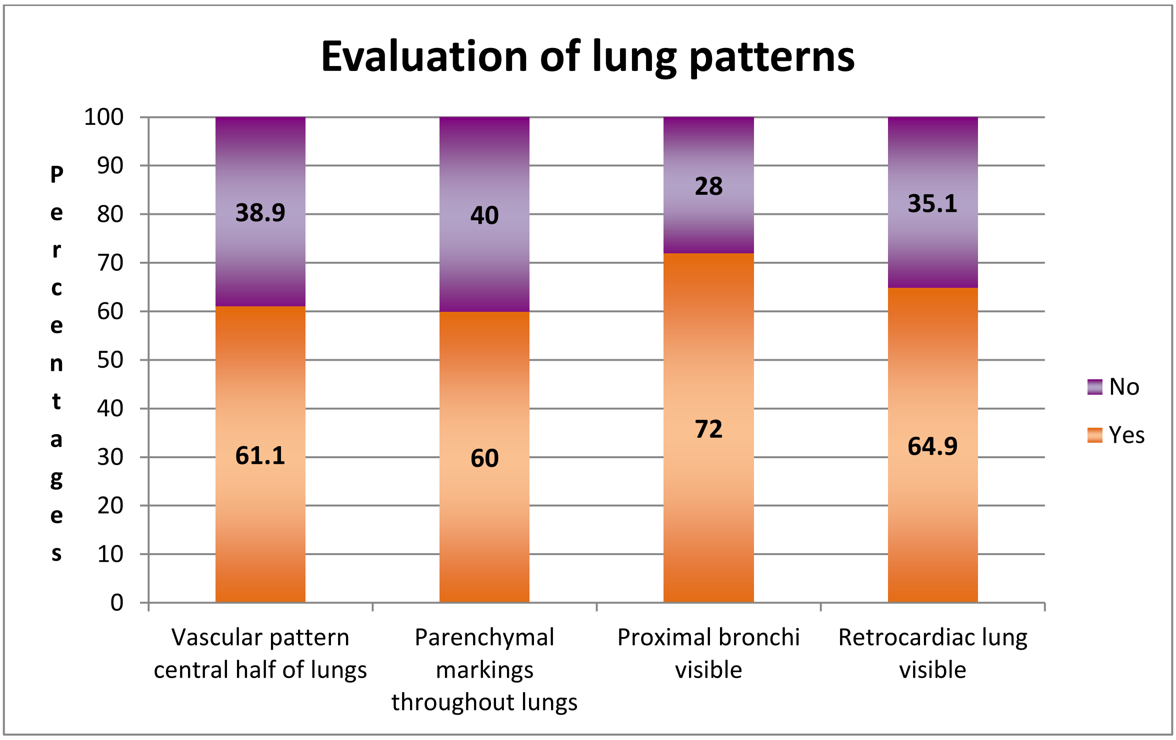


Figure 2.7: Evaluation of lung patterns

The remaining exposure parameter selected by the radiographer, kVp, was evaluated in the lung fields by evaluating the penetration and visibility of the proximal bronchi and retrocardiac lung. If these structures visualised, it indicated an image with optimal kVp selections (McQuillen Martensen, 2011:87-88). In 72% or 326 images the proximal bronchi were visible and in 64.9% or 292 images the retrocardiac lung was visible, as shown in Figure 2.7 as percentages. Both these criteria were included to compensate for possible pathological conditions that could obstruct visualisation of one and/or both these areas.

After discussing the four criteria that evaluated lung tissue, the focus will shift to the five criteria that evaluated the penetration and visibility of important structures. These five criteria focused on the penetration and visibility of important structures located in positions that were superimposed, in or around the lung fields. These five criteria were included to ensure that the evaluation of exposure parameters was done on the basis of optimal visualisation of anatomical structures irrespective of the suspected pathological condition of the lung tissue (Figure 2.7). Pathology can shadow some anatomical structures inside and/or outside the lung field but will shadow all these structures only in advanced stages of infection (McQuillen Martensen, 2011:87-88). Figure 2.8 summarises the data obtained on these five criteria as percentages.

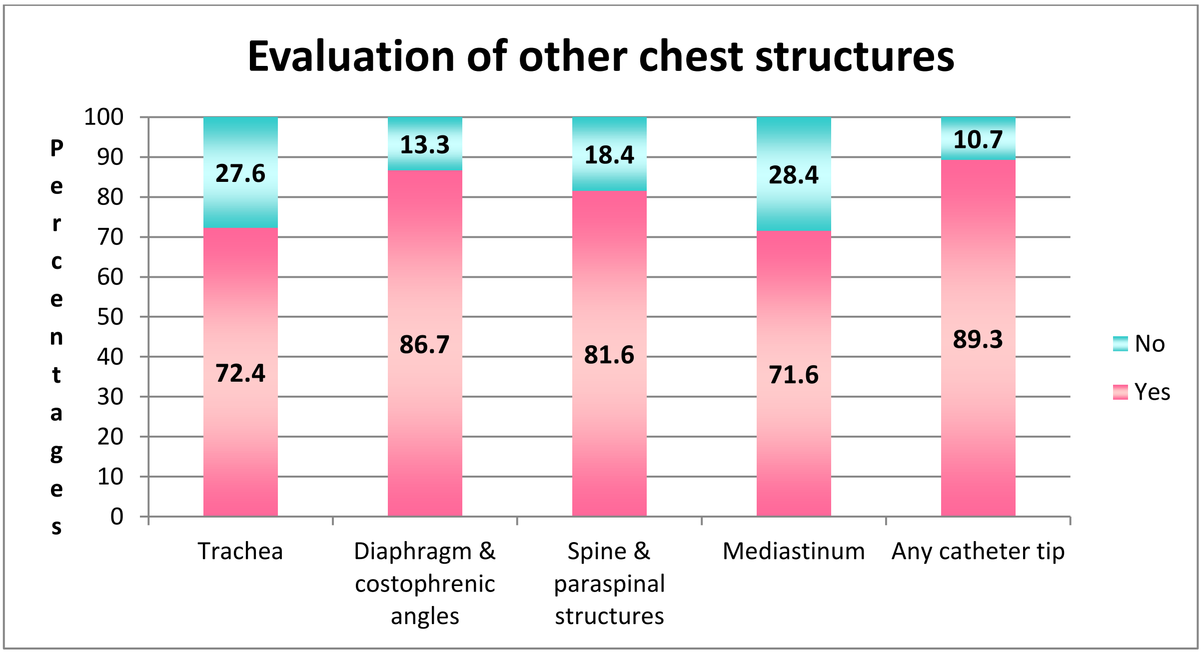


Figure 2.8: Evaluation of other chest structures

Figure 2.8 shows that the trachea was visible in 72.4% or 326 images, which correlates well with the other centrally located mediastinum, which was visible in 71.6% or 322 images. The spine and paraspinal structures were visible on 81.6% or 367 images, with the diaphragm and costophrenic angles well visualised in 86.7% or 390 images. Additionally, catheters inserted for treatment purposes were visualised in 89.3% or 402 images.

The last two criteria summarised the overall perception obtained from the image visibility in relation to the selected exposure parameter and exposure index obtained. Figure 2.9 summarises the observed data for these two criteria as percentages. Optimal exposure parameters were visually noted for 61.8% or 275 images when evaluate with the naked eye; but only 37.3% (168 images) of the recorded exposure indices were in the recommended exposure range, to be discussed later.

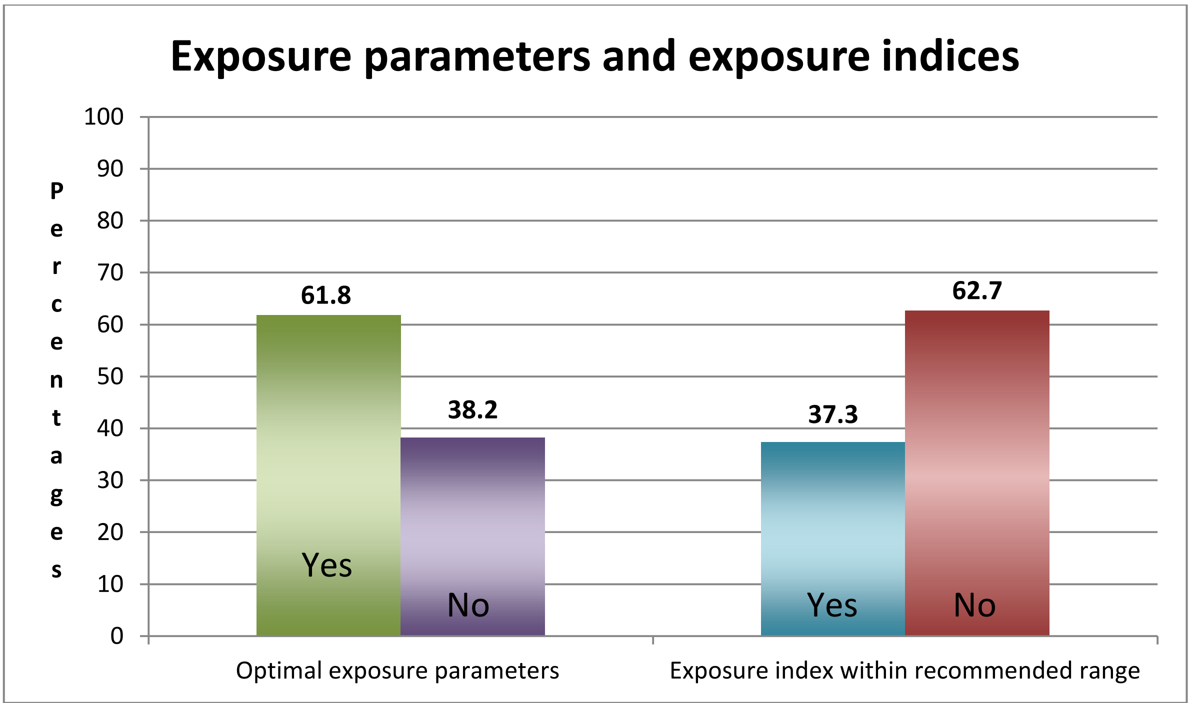


Figure 2.9: Exposure parameters and exposure indices

For the 38.2% or 172 images evaluated with the naked eye as incorrectly exposed (Figure 2.9), the researcher's visual evaluation determined whether the image was perceived as over or under exposed and/or whether the image was incorrectly exposed due to other obvious contributing factors, and a comment was noted.

Figure 2.10 summarises the data found as percentages for these 172 images. As can be seen in Figure 2.10, 48.8% or 84 images were perceived as under exposed, while 50.9% or 87 images were seen as over exposed. One image (0.3%) was seen as overexposed due to scatter radiation. The researcher acknowledges that the perceived degree of under and over exposure will depend on the individual reviewer. The possible limitation of this judgment is balanced by only one person judging the images consistently, as was the case in this study.

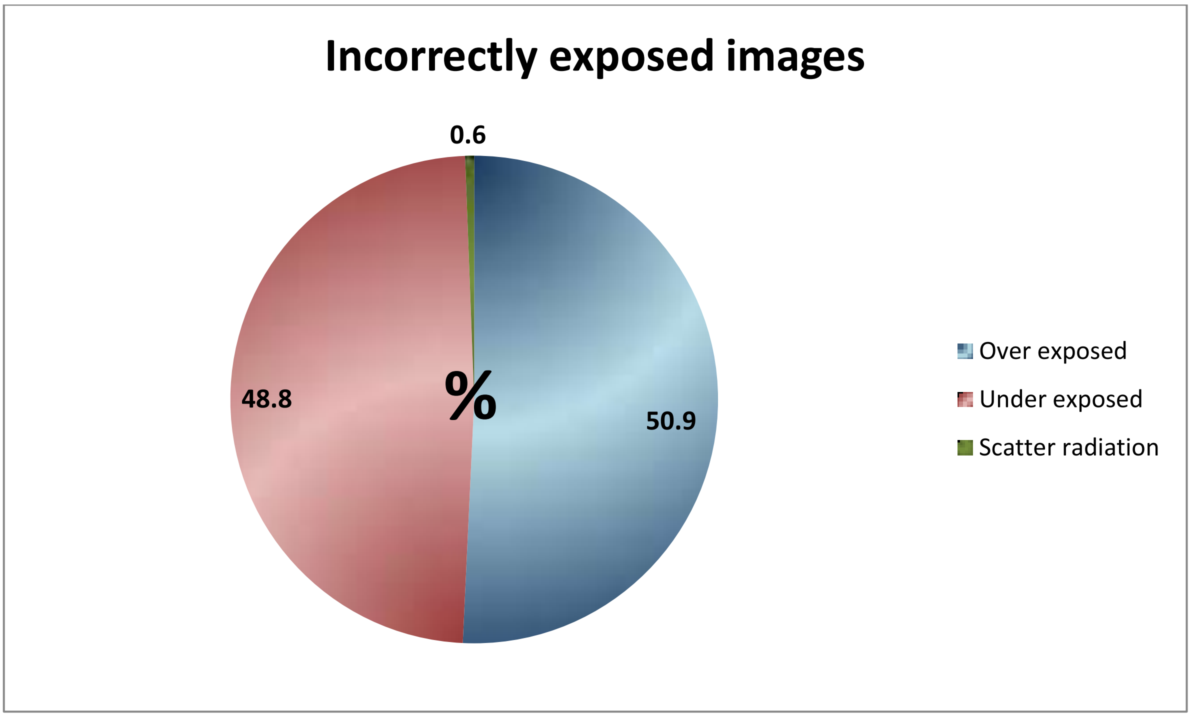


Figure 2.10: Incorrectly exposed images

The exposure indices (EI) of the images were documented. EI values vary between different institutions that utilise equipment of different manufacturers. In this study, two specific manufacturers with two different EI recommendation levels were included. Agfa utilise the Log Median Exposure (LGM) value for Agfa CR-systems (CRCPD, 2010:22). The LGM value shows the deviation of the exposure from the median exposure level as a logarithmic value. For an Agfa image to be optimal a LGM value should be between 1.9 and 2.5 (CRCPD, 2010:22). In Phase 1 of the study 300 images with LGM values were evaluated. The median LGM value for these images was 2, with an inter-quartile range of 1.9 (lower quartile) to 2.2 (upper quartile).

The remaining 150 images were produced utilising a Kodak CR system. This manufacturer utilises the EI value (CRCPD, 2010:22). The acceptable EI value, according to Kodak, is between 1 500 and 1 800 (CRCPD, 2010:22). In Phase 1 of the study the median EI value was 1 747.5, with an inter-quartile range of 1 480 (lower quartile) to 1 900 (upper quartile).

2.5.7 Collimation

According to McQuillen Martensen, (2011:121), four-sided collimation should be visible. Specific chest structures included inside the four-sided collimation are superiorly cervical vertebra number seven, inferiorly the costophrenic angles and both lateral sides the shoulders (European Commission, 1996:27; Morris, 2003:460-461; Slade *et al.*, 2005:609; McQuillen Martensen, 2011:121; Bontrager and Lampignano, 2014:163).

Figure 2.11 represents the data from this part of the checklist as percentages. As can be seen, four-sided collimation was found in 25.1% or 113 images. Most of the required anatomical structures were included inside the collimation of the 450 images evaluated, namely, superior cervical vertebra number seven was seen on 98.4% or 443 images, inferiorly the costophrenic angles were found on 94.7% or 426 images and bilaterally the shoulders were included on 99.6% or 448 images. In addition, both lung fields were included on 94.9% or 427 images.

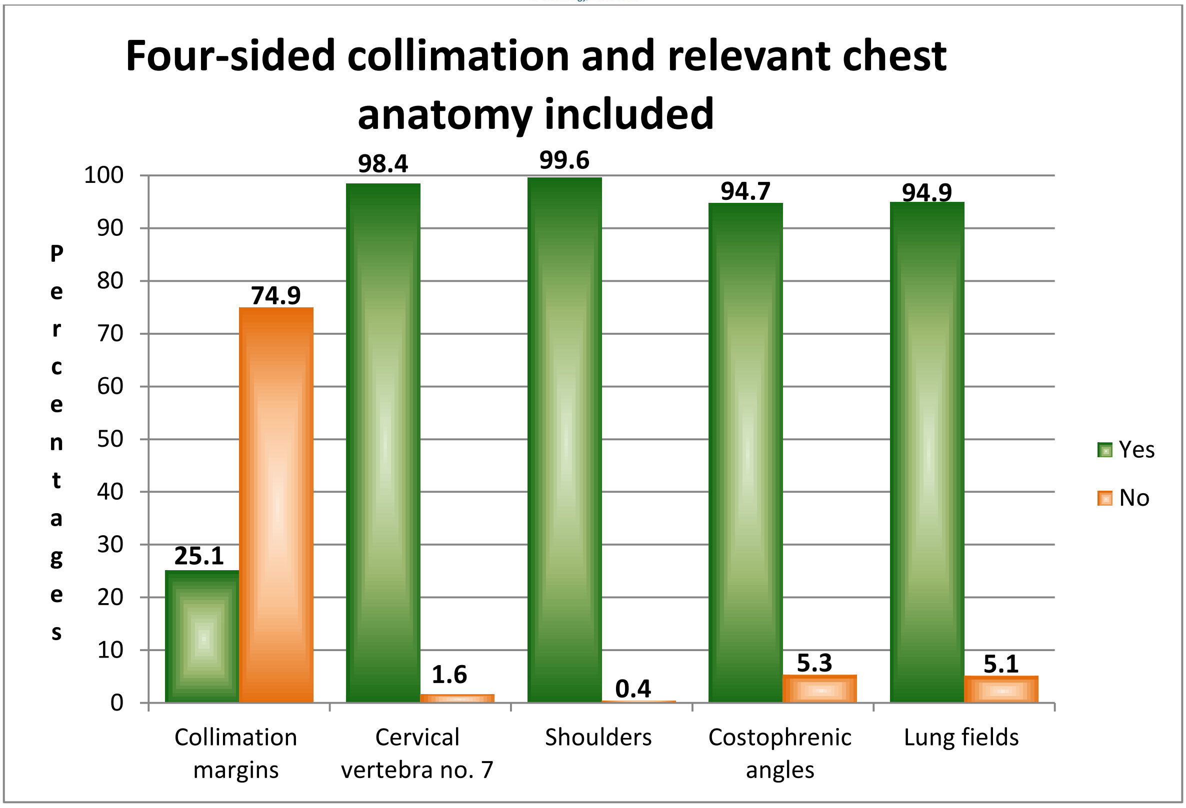


Figure 2.11: Four-sided collimation and relevant chest anatomy included

As shown in Figure 2.11, 1.6% or 7 images did not include cervical vertebra number seven; on these images both the apices of the lung fields were also excluded on the images. For the 0.4% or 2 images that did not include the shoulders bilaterally, the right and left shoulder with underlying right and left lung fields were excluded in equal measure (50% or each on an image). The 5.3% or 24 images that did not include costophrenic angles are illustrated by Figure 2.12 as percentages. As can be seen, 54.2% or 13 images did not include the left costophrenic angle and 41.7% or 10 images did not include the right costophrenic angle, and both angles were excluded on 4.2% or 1 image.

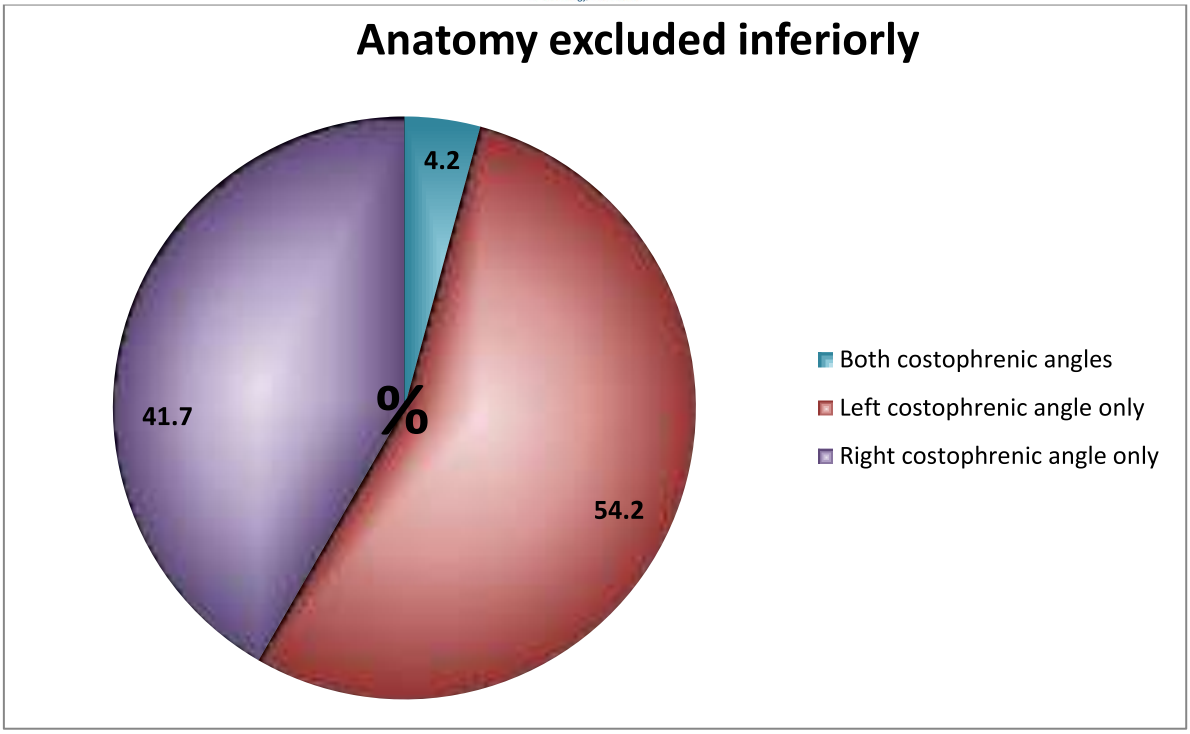


Figure 2.12: Anatomy excluded inferiorly

Collimation is seen as a part of radiation protection (Carlton and Adler, 2014:235). Collimation enables a radiographer to exclude anatomy not important for diagnostic purposes. This anatomy that is excluded will not receive unnecessary radiation, which leads to a lower dose for the patient (Carlton and Adler, 2014:234). In addition, a smaller collimation area ensures that less of the main radiation beam becomes scatter. This scattered main radiation beam only increases patient dose and does not contribute to the formation of the diagnostic image, instead it lowers image quality by increasing noise levels found on the image (Carlton and Adler, 2014:234).

After discussing the recorded anatomy excluded inferiorly on images, as shown in Figure 2.12, the focus now shifts to additional anatomy included on images. Figure 2.13 illustrates the percentages of additional anatomical structures included on the images evaluated as part of Phase 1.

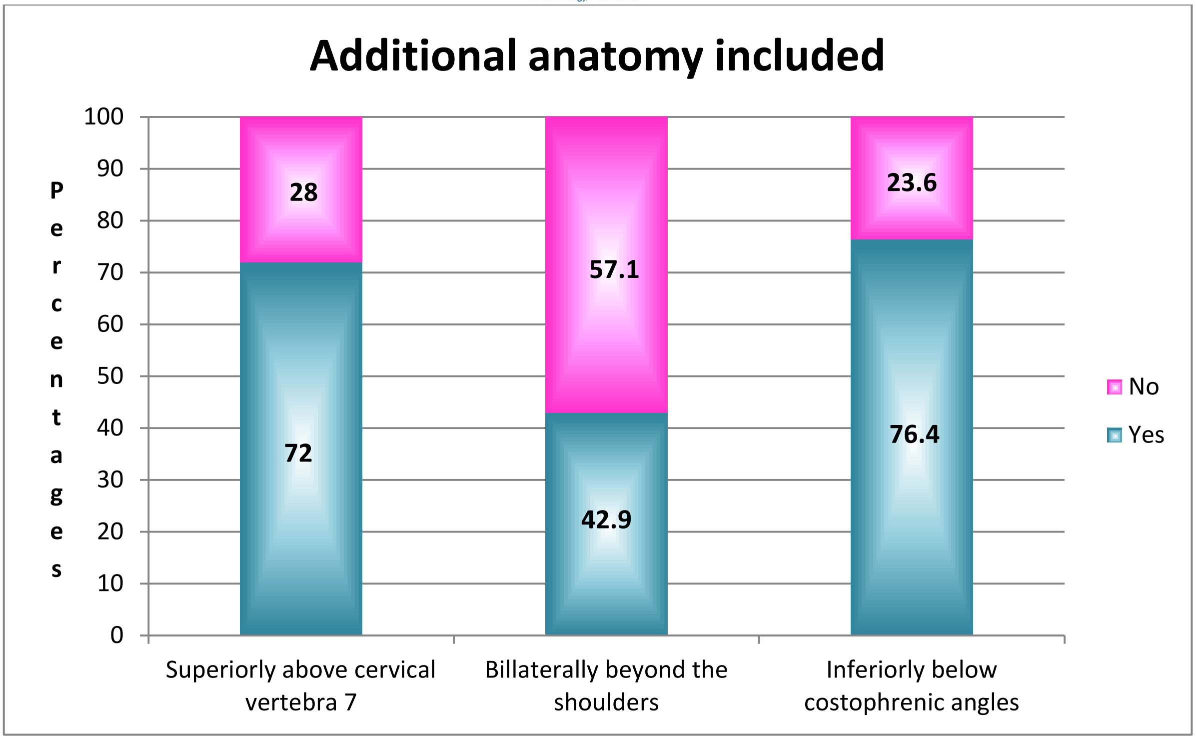


Figure 2.13: Additional anatomy included

Figure 2.13 shows that 72% or 324 images included additional anatomy above cervical vertebra number seven. McQuillen Martensen (2011:90-91) indicates that, in reference to neonatal chest imaging specifically, a referring physician prefers to see more of the cervical spine region in order to evaluate endotracheal tube (ETT) positions. Furthermore, according to this author, to evaluate the ETT a radiographer should include anatomy up to the inferior lip of the patient on an image.

Figure 2.14 summarises the additional anatomical structures that were included on the 72% (324 images) indicated in Figure 2.13, as percentages. From Figure 2.14 it can be deduced that 141 images (43.7%) included the cervical spine and mandible additionally. The entire skull, mandible and cervical spine were included on 18% or 58 images. In some instances cervical vertebra one (35% or 114 images) and four (3.4% or 11 images) were also included additionally.

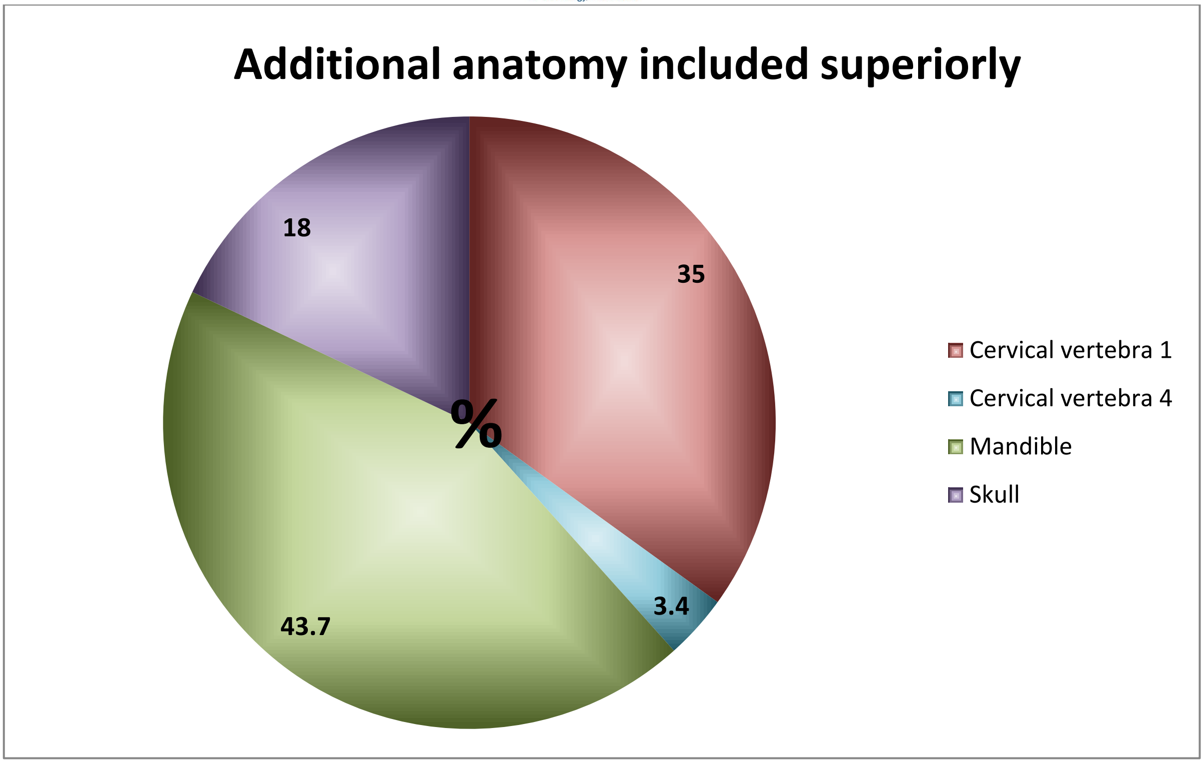


Figure 2.14: Additional anatomy included superiorly

Figure 2.13 also shows that, in 42.9% or 193 images, additional anatomy and/or structures lateral of the shoulders was included. The specific anatomy and/or structures included additionally is summarised in Figure 2.15 as percentages. In 63.4% or 123 images the humeri were included. These 123 images include 9 images with only the left humerus (4 images) and only the right humerus (5 images) on. The elbows and humeri were both included in 15% or 29 images. The area from the fingers to the humeri was included in 11.9% or 22 images and this included 3 images that included only the area from the left fingers to the humerus. Hands of staff members that immobilised the neonate were included in 6.7% or 13 images. The staff members' hands were noted to be superimposed on the neonates' elbows (2 images), entire arms (1 image), humeri (9 images) and on the wrist (1 image). Lastly, 3.1% or 6 images included from the wrist of the neonate superiorly to the humeri.

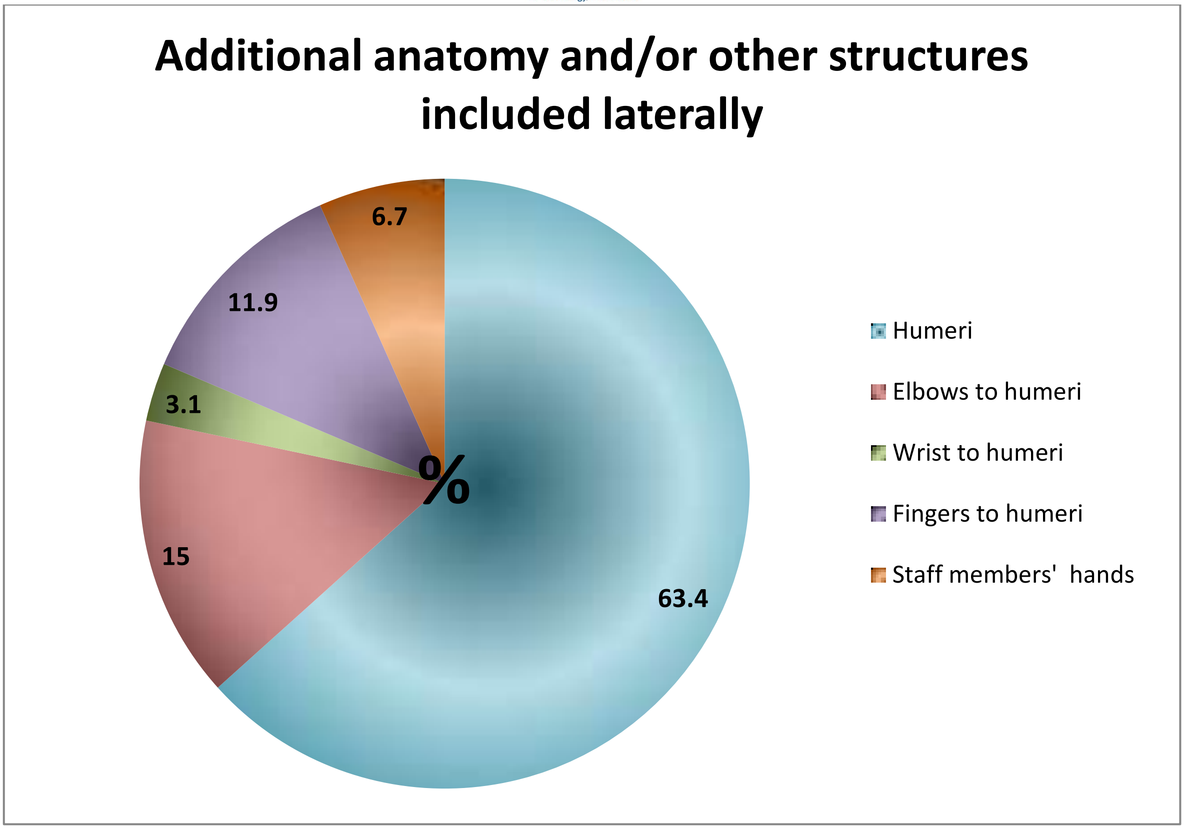


Figure 2.15: Additional anatomy and/or other structures included laterally

Figure 2.13 indicates that 76.4% or 344 images showed the inclusion of additional anatomy inferior of the costophrenic angles. Figure 2.16 summarises the percentages of additional anatomy included inferiorly that is seen on these 344 images. The leading additionally included anatomy inferiorly was the iliac crest of the pelvis (31.8% or 110 images), the whole pelvis (30.6% or 106 images) and the femurs from above the knees (28.6% or 99 images). The remaining 9% (30 images) of additionally included anatomy refers to the lower costal margin (3.8% or 13 images), lumber vertebra three (0.3% or 1 image), anterior superior iliac spine (0.3% or 1 image), knees (2% or 6 images), lower leg (0.9% or 3 images) and feet (1.7% or 6 images).

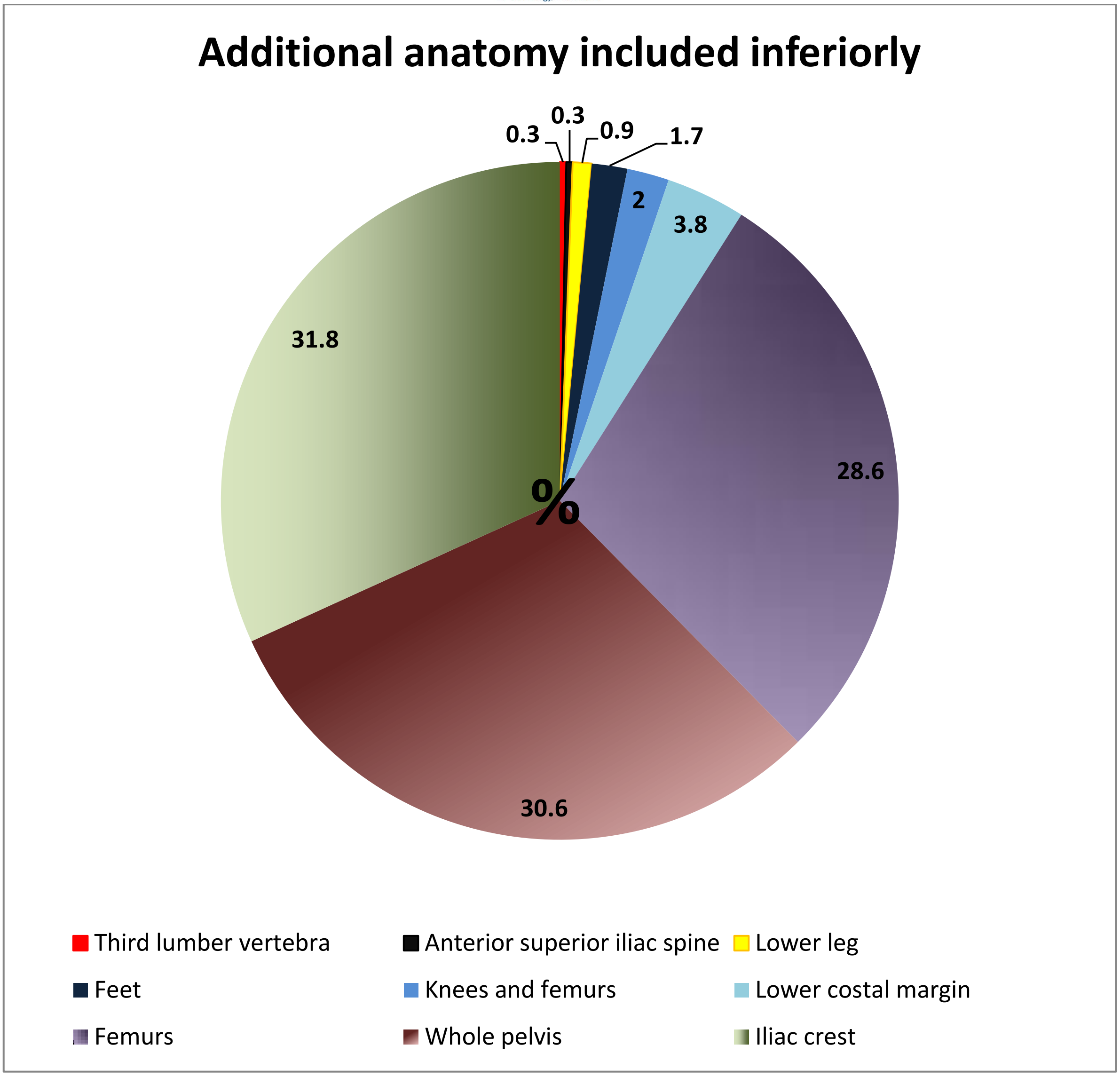


Figure 2.16: Additional anatomy included inferiorly

2.5.8 Final evaluation by the radiographer

Lastly, the radiographer will evaluate the image to decide whether it needs to be reproduced. If the image is deemed adequate, the radiographer may manipulate the image to ensure optimal image quality is displayed when it is viewed by a radiologist or referring physician. After the necessary changes have been made the image is stored in a permanent archive so that it the physician can view it. Hence, the original image (static setting) will not be available to the physician, only the manipulated image is available (Carlton and Adler, 2014:324). Figure 2.17 illustrates the evaluation and adjustments made by the participating radiographers as percentages.

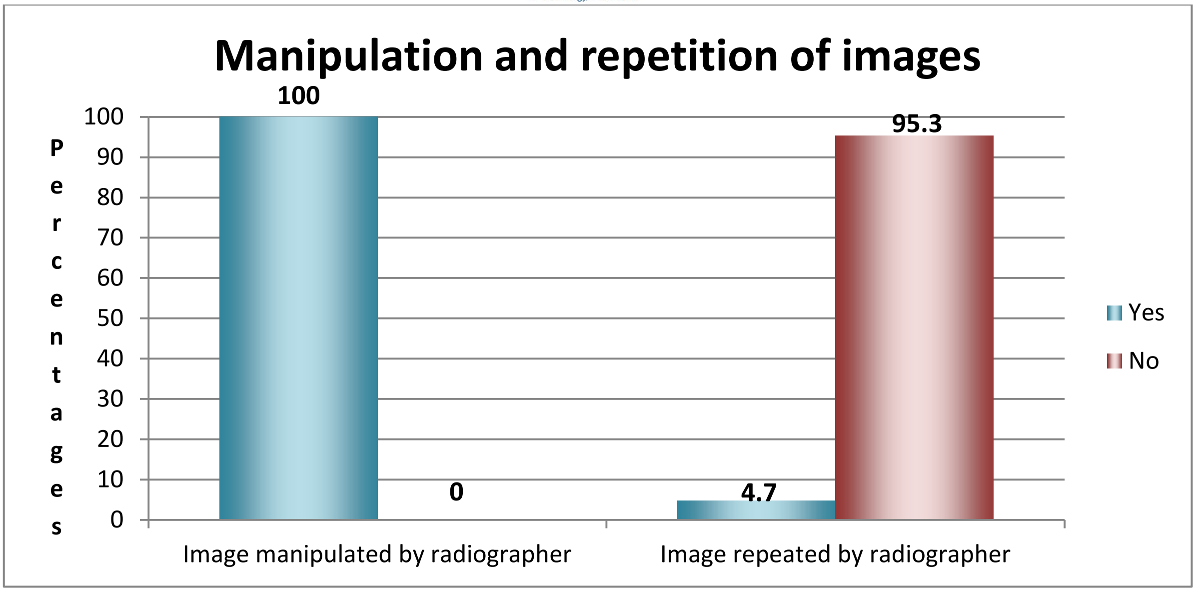


Figure 2.17: Manipulation and repetition of images

Radiographers manipulated all the images evaluated for this study during Phase 1. Only 4.7% or 22 images were repeated, for various reasons; these reasons are summarised in Figure 2.18 as percentages. Images were repeated when a costophrenic angle (right 36.4% or 8 images and left 40.9% or 9 images) or angles (4.6% or 1 image) and apices (9.1 or 2 images) were not included. In addition, images were repeated for rotation (4.6% or 1 image) and when the examination should actually have been an abdominal image (4.6% or 1 image).

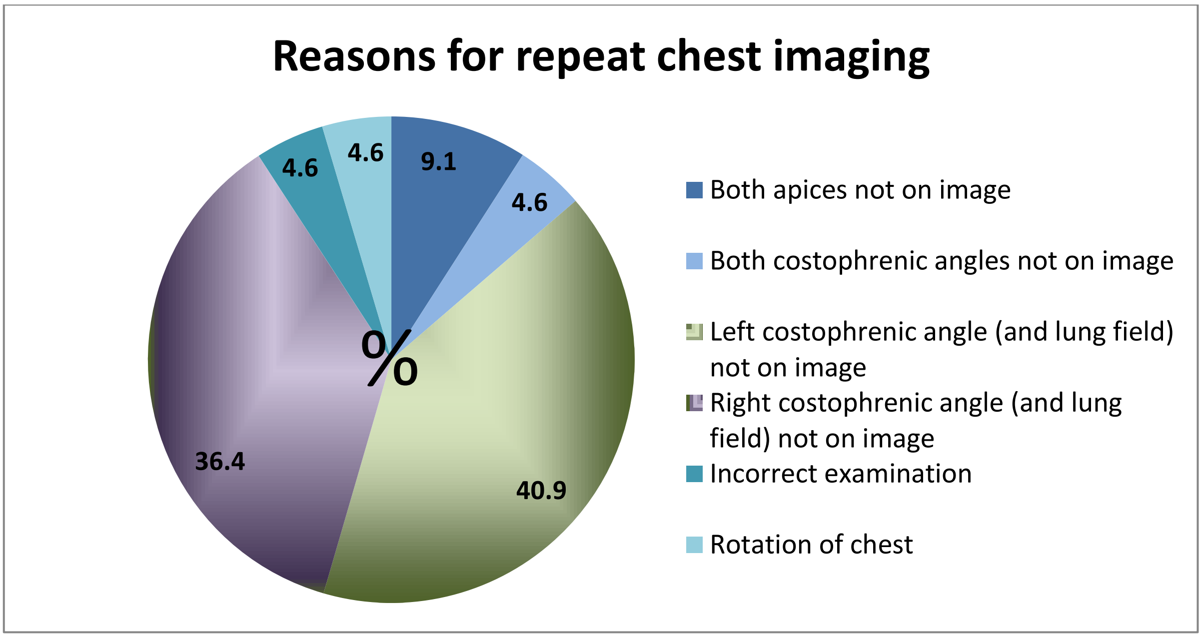


Figure 2.18: Reasons for repeat chest imaging

2.6 SYNOPSIS OF INITIAL NEONATAL CHEST IMAGE QUALITY OBSERVED DURING PHASE 1

Phase 1 of the study enabled the researcher to determine the quality of initial neonatal chest images before any form of intervention had been attempted. The data from Phase 1 can be discussed according to areas of image quality that can be enhanced (inadequate image quality) and areas of image quality that is already considered optimal (optimal image quality).

2.6.1 Inadequate chest image quality

The criteria of the checklist evaluated specific image quality areas (see headings in checklist, Appendix E). The criteria that showed a statistically frequent inadequate percentage are summarised in Table 2.3 in a descending percentage order. A percentage was considered to be statistically suboptimal if it was recorded as below 80%.

For an image to be considered optimal, it should conform to all the listed evaluation criteria. An incidence below 80% showed that fewer than 360 of the evaluated 450 images complied with the specific evaluation criterion. The various image quality criteria were numbered in the table based on the area of image quality a criterion refers to in the checklist, for example, No. 5 indicates lead shielding and No. 3 refers to breathing technique.

No. 8 and No. 1 in Table 2.3 reflect on general areas that may influence image quality. As can be deduced in Table 2.3, radiographers manipulated images in 100% of the images produced. This indicates that for all the images of Phase 1, one or more image quality areas required alteration by the radiographer after production of the image.

Clinical history was not provided for 94% of examinations. Tough a proper clinical; history does not relate directly to image quality, without it, a radiographer cannot fully determine which anatomical structures to include on the image, nor can he/she determine how the exposure parameters should be adjusted for the pathological condition(s) presented in the neonate (Bontrager and Lampignano, 2014:85).

Table 2.3: Synopsis of inadequate image quality findings

No.	Criterion	%
8	Radiographer had to manipulate images	100
5	Radiation shielding not visible over pelvic area	98.7
1	No clinical history provided on request letters	94.0
7	Anatomy inferior to the costophrenic angles included on images	76.4
7	Collimation not visible on image	74.9
7	Anatomy superior to cervical vertebra seven included on images	72.0
4	Lead marker placed incorrectly when added on image	67.3
4	Lead marker not included on image	66.4
2	Chest not in the centre of the image	64.9
6	Exposure indices outside the recommended ranges	62.7
2	Artifacts superimposed on chest anatomy	61.9
2	Rotation found on images	56.7
3	Incorrect breathing technique applied	45.8
7	Anatomy lateral to the shoulders included on images	42.9
2	Tilt was absent on images (incorrectly absent)	41.6
6	Parenchymal lung markings not visible throughout lungs	40.0
6	Vascular pattern not visible in the central half of the lungs	38.9
6	Exposure evaluated visually and judged as incorrect	38.2
6	Retrocardiac lung not visible	35.1
6	Mediastinum not visible	28.4
6	Proximal bronchi not visible	28.0
6	Trachea not visible	27.6

No. 5 and No. 4 refer to radiation protection and lead marker position. As can be seen in Table 2.3, lead shielding, which is part of radiation control regulations (RSA DoH, 1973:8), was not visible on 98.7% of the images, neither was a lead marker included on 66.4% of images. The reader is reminded that with 67.3% of images that did display lead markers presented with incorrectly placed lead markers.

Collimation (No. 7 in Table 2.3) was not visible on 74.9% of the produced images. This means that these images did not show any signs of collimation because an outside border of collimation was not visible on the image – the entire image receptor was exposed to the main radiation beam. Table 2.3 shows that collimation was not optimal inferiorly for 76.4% of images because anatomy beneath the required costophrenic angles were included. The anatomy most commonly included inferiorly was the iliac crests (top brim of the pelvis, 31.8%) and the whole pelvis (30.6%). Generally, more than the required cervical vertebra seven was included superiorly (72% of the images), with the mandible (43.7%) as the anatomical structure included additionally. On the lateral margins of the chest, only the lateral lung fields and shoulders should be included. During this phase 42.9% of images included additional anatomy beyond the shoulders, generally the humeri (63.4%). The above indicates that collimation in general can be enhanced.

The positioning technique visible on the images is represented by No. 2 (Table 2.3). As can be seen, incorrect rotation of the chest was found on 56.7% of the images and insufficient tilt of the main radiation beam on 41.6% of images. In addition, 64.9% of the images produced were incorrectly centered; with thoracic vertebra 12 found in the centre of 55.6% of these images instead of thoracic vertebra four. Artefacts were superimposed over chest anatomy in 61.9% of the images, with ECG lines the most commonly included artefact (61.9%). These positioning errors indicate that some areas of the chest anatomy appeared distorted or superimposed by other structures, which caused impaired visibility for a referring physician. Underlying pathology in these areas would therefore have been overlooked due to poor radiographic positioning techniques. Improvement in radiographers positioning techniques may address image quality in these areas.

The exposure parameters also showed levels in need of improvement, indicated as No. 6 in Table 2.3. The exposure indices that were recorded outside the recommended range indicated additional dose to the neonates. This was the case in 62.7% of the produced images. In addition, specific areas in the chest cavity, or supporting the chest cavity, were not always visible (see several last rows of Table 2.3). This could be due to incorrect exposure parameters, insufficient collimation or underlying pathological conditions. Attention could be given to this area to optimise exposure so that it falls within the recommended exposure ranges.

Finally, the breathing technique visible on the images is represented in Table 2.3 as No. 3. As can be seen, incorrect breathing methods were visible on 45.8% of the images. This percentage was divided by normal respiration (30.2%) images and expiratory respiration (15.6%) images. A neonatal chest image without optimal suspended inspiration will make it impossible for a referring physician to evaluate lung fields not filled with air. This image quality area also therefore requires improvement by addressing this area through an educational programme to enhance the radiographers technique.

2.6.2 Optimal chest image quality

The image quality criteria that were found optimal during this phase of the study are illustrated in Table 2.4. As part of examination justification, referral letters were available for 99.6% of the images taken. It is, however, important to note that, for the cases represented by these letters, only 6% included clinical histories. Referral letters availability does not relate directly to image quality but involves the justification for the examination and is therefore relevant to note. Radiographers maintained a small percentage of repeat images, with 95.3% of the images included in this study not requiring a second image. This is an indication of attempts by the radiographers to keep radiation dose as low as possible for the neonatal patients.

Most of the images (92.9%) showed proper inclusion of the relevant anatomy. The cervical vertebra (98.4%), bilateral shoulders (99.6%), lung fields (94.9%) and costophrenic angles (94.7%) were consistently found on most of the images. This data compared well with the collimation data presented in Table 2.3, which indicates high levels of additional anatomy included on images, because collimation areas appeared to be large in most images (74.9%).

The exposure parameters selected by the radiographers proved to be optimal, because inserted catheter tips (89.3%), diaphragms and costophrenic angles (86.7%), as well as the spinal and paraspinal structures (81.6%) were visible. This could be because these structures provide better contrast with lung fields due to their denser composition when compared to the less dense tissue of lungs.

Table 2.4: Synopsis of optimal image quality findings

Criterion	%
Referral letters available	99.6
Bilateral shoulders included on image	99.6
Cervical vertebra seven included on image	98.4
No repeat of image required	95.3
Lung fields included on image	94.9
Costophrenic angles included on image	94.7
All relevant anatomy included	92.9
All inserted catheter tips visible on image	89.3
Diaphragm and costophrenic angles visible on image	86.7
Spine and paraspinal structures visible on image	81.6

2.7 CONCLUSION

Chapter two provided the information that enabled the researcher to determine neonatal chest image quality before an intervention took place, and to inform the education programme. The results for this phase of the study found the image quality areas that were inadequate and that could be addressed. Radiation shielding was absent on 98.7% of images and collimation was not included in 74.9% of the images. This means that, for 74.9% of images, the entire image receptor was exposed, with a probability of 98.7% that such an image had been taken without radiation protection. In addition, lead markers were not utilised in the production of 66.4% of images. The second phase of the study, which refers to the design and presentation of an education programme as a form of intervention, will be discussed in Chapter 3. Chapter 3 will describe the presentation of the programme as well as the content of the programme as it links to the data found in this chapter.

CHAPTER 3

DESIGN AND PRESENTATION OF THE EDUCATIONAL PROGRAMME

3.1 INTRODUCTION

The ARSPI gives recognition, in the Image Gently campaign, to the special imaging needs of pediatric patients (Image Gently, 2014:online). In the last five years more than 30 professional organisations have joined this Alliance, among which the International Society of Radiographers and Radiological Technologists (ISRRT) and the World Federation of Pediatric Imaging (WFPI). The main purpose of the Alliance is to raise awareness in the radiological community of the need to adjust radiation doses when imaging children, with the main goal being to change general practice (Willis, 2009:266–267; Image Gently, 2014:online).

Neonatal chest image quality was determined during Phase 1 of this study in order to establish areas of image quality in need of improvement. The aim of this chapter is to outline the design and presentation of an educational programme, as an effort to possibly change general practice by raising awareness of neonatal chest image quality areas in need of enhancement, in accordance with the main purpose of the Image Gently campaign (2014:online). This second phase of the study, described in this chapter, provides a literature orientation to the components that were included in the educational programme.

These components include background to continuing professional development (CPD) as it relates to the educational programme, the NICU environment in which radiographic positioning techniques are applied, the general principles of mobile chest radiography positioning, as well as specific radiographic positioning techniques for neonates. The method utilised to design the educational programme and the presentation of the programme that was designed is included. The chapter concludes with feedback from the radiographers provided during and after the presentation of the educational programme.

3.2 LITERATURE ORIENTATION AND BACKGROUND TO THE EDUCATIONAL PROGRAMME

According to Goske *et al.* (2010:617-619) even perfectly designed equipment can be unsafe when the radiographer operating the equipment has not had adequate training. Radiographers will benefit from training that is practical, concise, straightforward and user friendly. Additional training must form part of a larger quality assurance plan (Goske *et al.*, 2010:617-619). Loovere *et al.* (2008:202) and Goske *et al.* (2010:617-619) refer to the value of additional training, especially for radiographic procedures such as neonatal chest mobile radiography.

Section 2.2.5 amongst others, describes a quality improvement study conducted in Canada by Loovere *et al.* (2008:202). The study is based on the evaluation of images according to established radiographic principles and techniques. Areas for improvement were identified and addressed through educational sessions, printed pamphlets and emails. The outcome of the educational sessions appeared to be valuable and it seemed to be a sustainable method for achieving improvement of image quality (Loovere *et al.*, 2008:202).

The literature provides a background to the term "educational programme" as it is applied in this study. The link between the educational programme and the presentation thereof in the context of the radiographic profession is consequently made through the discussion of CPD. This literature section furthermore includes a description of the NICU, general mobile radiography examination principles, and the specific positioning technique utilised for neonates. The specific positioning technique included in the literature orientation helped to inform the content of the educational programme that was designed to address neonatal chest image quality.

3.2.1 Educational programme background

There are various descriptions of educational programmes in literature. According to The Council on Higher Education (CHE) of South Africa, educational programmes can be defined "as a purposeful and structural sets of learning experiences that lead to one or more qualifications; in an outcome-based system, a programme is designed to enable learners to achieve pre-specified exit level outcomes" (SAQA, 2013a:online).

Hay (2005:117) highlights some of the important characteristics of an educational programme, namely, it should involve "sequential learning activities leading to the awarding of particular qualifications", and "it should be planned, coherent and integrated". The New Academic Policy (NAP) as developed by the CHE also elaborates on these characteristics by advising integration between knowledge and skills (CHE, 2002:7). An educational programme should be designed with the needs of prospective students and employers in mind. It should be designed in such a manner that it is easily accessible and alert to changing environments. The learning strategy and assessment method should be applicable to the purpose and planned outcomes of the programme (Massyn, 2005:115).

The programme in this study was defined by the Criteria and Guidelines for Short Courses and Skills Programmes documented by SAQA (2004:14), described in Chapter 1 (Section 1.3). The educational programme designed for this study was a non-credit-bearing short course, not accredited by SAQA, but accredited by the Health Professions Council of South Africa (HPCSA) as a CPD activity (Appendix O). The programme was designed with a specific profession and its employers in mind; namely radiographers.

The educational programme was informed by Bontrager and Lampignano (2014:40), who list four basic generic requirements for producing an image of optimal quality. These requirements are the ability or skill to i) decide on an acceptable radiographic technique, ii) to utilise that technique optimally and iii) according to department protocol with iv) proper evaluation of the utilised technique (evaluation criteria). The educational programme included literature content provided in Section 3.2.5, relating to the optimal positioning technique, as well as literature described in Section 2.2.5, which informed the evaluation criteria of the checklist (Appendix E). The results from Phase 1 (Section 2.5) were also incorporated in the educational programme, as seen in Section 3.3.2.

3.2.2 Continuing professional development (CPD)

The Health Professions Act No. 56 of 1974 recognises CPD as a means to ensure that the standard of health service provided to the South African public is of the highest possible quality and aligned with the emerging health needs of the country. In order to comply with the Act stated above, the HPCSA created specific guidelines for CPD (HPCSA, 2008a:online).

The HPCSA defines activities that can be considered to be developmental in perspective. These activities include conference presentations, workshops through structured courses, and quality assurance audits of professionals in their work environments. CPD activities must meet educational goals as set out by the HPCSA. These educational goals include that any CPD activity should ensure the acquisition or maintenance of new and current knowledge, relevant professional skills and ethical professional attitudes with an end benefit to the patient (HPCSA, 2008b:online).

Each activity is accredited by the HPCSA service provider with a number of continuing educational units (CEUs). The number of CEUs with which an activity is credited depends on the length of a planned educational session. One CEU is equal to an hour of educational activity. All radiographers and other individual health care providers must obtain and have certified proof of attending CPD activities to the value 30 CEUs in a 24-month cycle. Of the 30 CEUs, 5 CEUs must be for ethics, human rights and medical-law activities (HPCSA, 2008b:online).

The relation between the educational programme designed for this study and CPD activities described above is that the current programme can be utilised as described by the CPD guidelines given above (HPCSA, 2008b:online). The focus of the educational programme that was designed was on the maintenance and acquisition of knowledge in relation to a relevant professional skill, which is the production of optimal neonatal chest image quality through the utilisation of optimal positioning techniques and radiation protection.

As previously discussed (Section 2.2.2), image quality is influenced by technical errors, procedural problems or equipment malfunctions, which may become visible on the image (Carlton and Adler, 2014:460). In order to understand the procedural or positioning technique recommended by other authors and academic books, it is imperative to understand the NICU environment and, in addition, have an idea of the principles involved in a standardised mobile chest radiography procedure.

3.2.3 NICU environment

Neonates in the NICU suffer from a variety of intricate illnesses. These neonates are often premature and ill equipped to face the outside world. Premature neonates are also at risk of iatrogenic disease in the hospital. A source of iatrogenic disease is their surrounding environment. Potential sources of danger include light, sound, radiation, and inactive ingredients in medications and chemicals. Premature neonates are mainly at risk due to their developing organ systems (Lai and Bearer, 2008:163).

The layout of NICUs should be done to minimises iatrogenic disease exposure by simulating an environment very similar to a mother's womb (Ramachandrappa and Jain, 2008:2). To simulate or maintain the required environmental conditions, an incubator is employed (Mutch and Wentworth, 2007:902). Two basic designs for neonatal incubators exist, namely closed and open incubators (Hull and Wheldon, 1986:108-109). The three institutions that participated in the study utilised both types of neonatal incubators.

According to Hull and Wheldon (1986:108-109) a closed incubator blows air from the top of the apparatus onto the neonate. Heat is lost to the periphery of the incubator and temperature is controlled by the NICU staff or by a temperature monitor attached to the neonate's skin. The incubator consists of a plastic box in which the neonate is housed. Access to the enclosed environment is obtained through portal holes in the side of the box, which remain closed if not in use.

The open incubator also radiates heat from the top canopy but it is not an enclosed box. Heat losses are greater in this incubator due to the fact that it is an open structure and the surrounding air is usually room temperature. The temperature of the neonate in this incubator can only be monitored by a temperature apparatus attached directly to the neonate's skin. An advantage of this open environment is the easy and fast access it provides the NICU staff to the neonate, because staff do not have to work via a portal hole (Hull and Wheldon, 1986:108-109).

Ramachandrappa and Jain (2008:1-2) furthermore indicate that, in addition to the incubator in which the neonate is housed, various other medical apparatus monitor and maintain the neonate's body functions. These apparatus include, according to these authors, oxygen supplementation by mechanical ventilators, head hoods or nasal cannula, climate-controlled thermometers to ensure a consistently warm environment and provision of nutrition or medication through intravenous or nasogastric tubes. Mutch and Wentworth (2007:902) include monitoring equipment, for example, blood pressure and heart rate monitors as well.

A study by Linn, Horowitz and Fox (1985:407-408) showed that NICUs should be as dark and quiet as possible. Low lighting and a lower sound environment encourages a neonate that is relaxed and not overstimulated by his/her surroundings. Individual neonates require different stimulation levels, based on their development and needs.

Important ground rules that a radiographer should keep in mind when visiting an NICU, according to Fuller (2009a:online), is washing hands before entering the unit, when exiting the unit and between neonates imaged. Care should also be taken to prevent a collision between the mobile unit and the incubator, because even a mild collision can cause haemorrhage in a neonate. The radiographer must use the image receptor (IR) tray; if available, in the incubator. Hardy and Boynes (2003:95-96) state that it is important to request assistance from the NICU nursing staff, as they are the specialists who know each specific neonate, what illnesses the neonate suffers from, and they are skilled at handling a neonate. The radiographer must not move a neonate without the nursing staff's permission. Hardy and Boynes (2003:95-96) as well as Fuller (2009a:online) warn that the radiographer must consider radiation protection for self, the nursing staff and the neonate.

Ballinger and Frank (1999:140) describe the greatest danger that faces all neonates as hypothermia. Hypothermia can be described as a lower than normal body temperature. The danger of hypothermia for neonates lies in their inability to prevent body temperature loss, because of their greater surface area in comparison to body mass. Fuller (2009a:online) advises that, to prevent hypothermia, radiographers performing neonatal examinations in the infant's incubator should work fast and effectively to prevent temperature loss. Contact between the neonatal skin and IR should also be avoided, to prevent loss of body temperature (Ballinger and Frank, 1999:140; Hardy and Boynes, 2003:95-96).

The above-mentioned ground rules for radiographers working in the NICU, with a discussion of the different types of incubator and environmental considerations were addressed in the educational programme to ensure understanding by the participating radiographers of their role when working in the NICU.

3.2.4 Principles of a mobile chest radiography procedure

Mobile radiography, as defined by Bontrager and Lampignano (2014:565), is the production of images outside the radiology department because a patient's condition prohibits the transportation of the patient to the radiology department. To obtain these images outside the radiology department a specialised mobile or portable x-ray unit is utilised. A mobile unit (Ballinger and Frank, 1999:140-143) consists of an x-ray machine that is mounted on a dual-drive motor with two drive wheels. The machine has a braking system directly under the control of the radiographer. The mobile unit can be charged by connecting it to an electrical source.

Positioning principles for mobile radiography are very similar to those of general radiography. Some variations that must be taken into consideration are that optimal alignment of the x-ray tube, anatomical part and image receptor may not always be possible with the mobile unit; hence mobile images commonly have an amount of distortion present (Ballinger and Frank, 1999:140-143). Bontrager and Lampignano (2014:570) indicate that a radiographer should strive to ensure optimal alignment without endangering the often critical ill patient.

Usually only one projection, for example, an anterior-posterior projection (AP), is obtained during a mobile examination, which differs from the positioning principle that calls for two projections at 90º angles to each other (Ballinger and Frank, 1999:140-143; McQuillen Martensen, 2011:12; Bontrager and Lampignano, 2014:570). Radiographers are only requested to obtain an additional lateral mobile projection, should a referring physician require the additional projection to solidify a suspected pathological process. This lateral projection is usually taken with the aid of a horisontal beam instead of rotating the critically ill patient in a lateral position.

The last principle that is adapted for mobile radiography refers to the radiation safety of the patient, health care workers and public. Because mobile radiography is executed outside the normal radiation safety barriers of a radiology department, Ballinger and Frank (1999:140-143) and Bontrager and Lampignano (2014:570) advise certain steps that need to be followed by a radiographer to ensure proper safety for him/herself, the surrounding public and the patient.

According to Bontrager and Lampignano (2014:577), a mobile radiography examination commonly starts with a request letter sent to the radiology department by a referring physician. The request will contain the clinical history of a patient as well as a description of the required projection(s) to be taken in one of the hospital wards on the specified patient. A radiographer assigned to mobile radiography will take a mobile unit and an IR to the hospital ward.

Hardy and Boynes (2003:95-96) advises that the radiographer, on arrival at the patient's bedside, should wipe down the mobile unit and IR with an antiseptic cleaning agent, to prevent cross infecting the patient, and wash his/her hands thoroughly. The next step (Bontrager and Lampignano, 2014:577) is to identify the patient by means of his/her patient file and patient wristband (an ankle band is also commonly used in neonatal patients). The radiographer should then request the assistance of the nursing staff to ensure proper placement of the IR without causing injury to the patient.

Hardy and Boynes (2003:96, 118) suggest covering the IR with a waterproof protective layer and placing it directly below the anatomical area of interest. The anatomical part is positioned in relation to the IR to ensure that no rotation or unnecessary tilt will be present on the image; the x-ray tube is centered to the IR and anatomical area; an anatomical marker is placed on the IR; the main radiation beam (housed in the x-ray tube) collimated to include only anatomical structures of interest; and the necessary lead projection attire is placed over the patient's body.

The radiographer and nursing staff within the proximity of the x-ray exposure will dress in full radiation protection attire and the radiographer will issue a loud verbal warning to the remaining nursing staff members to move outside the radiation area. Thereafter the radiation exposure is made while the patient's breathing is observed to ensure the image is timed to the required respiration interval (Bontrager and Lampignano, 2014:577).

After the exposure has been made, the radiographer and the assisting nursing staff member will remove the IR. The radiographer will disinfect the mobile unit and the IR; wash his/her hands again, and return to the radiology department with both the mobile unit and the IR (Bontrager and Lampignano, 2014:577).

3.2.5 Recommended exposure and positioning technique for neonates

Optimal positioning and the production of a high quality image are achieved by considering a wide variety of influential factors. These factors have been researched and discussed by various authors in radiographic textbooks and research articles. In this section of the literature overview, principles of important neonatal positioning techniques that formed part of the educational programme will be discussed.

This section is divided into six main positioning technique principles, namely, patient and part position, breathing technique, lead marker, radiation protection, exposure parameters and collimation. Each of these principles will be discussed individually.

3.2.5.1 Patient and part position

Hardy and Boynes (2003:118) agree with Bontrager and Lampignano (2014:577, 631) that an optimal position for a neonatal chest must incorporate the following: careful consideration of possible anatomical rotation, main radiation beam angulation (tilt), centring of the chest, artefacts superimposed on the chest in the field of view, important anatomical structures that should be included on the image, the exclusion of the mandible and rotation of the scapulae free from the lung fields.

Hardy and Boynes (2003:118) further indicate that a true AP positioning can be achieved by ensuring absence of rotation of the thorax or pelvis, by ensuring the neonate’s shoulders are in contact with the incubator bed surface with no additional support structure (drip bag, for example) underneath the neonate. On the chest image, rotation can be evaluated by determining the distance between the bilateral lung fields from the lateral rib margins to the spine in the centre. This criterion is mentioned by various authors, among whom Slade *et al.* (2005:609), Loovere *et al.* (2008:201) and McQuillen Martensen (2011:21-124), listed in Table 2.1 and included in the checklist (Appendix E).

The image is produced with the neonate in a supine body position with the sternum not as a rule parallel to the IR because of the body position. To ensure proper parallel alignment of the chest, the main radiation beam can be tilted 5º to 10º degrees caudally (direction of feet), alternatively the tray of the bed on which the neonate is recumbent can be tilted until the sternum is parallel to the IR or perpendicular to the main radiation beam (Swallow *et al.*, 1986:141). The correct angulation of the main radiation beam can be evaluated on the image by the anterior rib ends demonstrating inferior of the posterior rib ends (ribs therefore not horisontal), and with a superior bowed contour for the posterior rib ends which gives the chest a trapezoid shape. The checklist (Appendix E) includes this criterion as found in Table 2.1 and is identified by the European Commission (1996:27), Loovere *et al.* (2008:201) and McQuillen Martensen (2011:21-124).

Bontrager and Lampignano (2014:631) advise that the centre indicator of the main radiation beam should be focused to the centre of the chest in the mammillary (nipple) line, which is the topographic landmark for the level of thoracic vertebra four in neonates. Hardy and Boynes (2003:118-119), Loovere *et al.* (2008:201) and McQuillen Martensen (2011:21-124) agree that the fourth thoracic vertebra will be seen in the centre of the collimated area if centring was done correctly, and this criterion is therefore included in the checklist (Appendix E) and Table 2.1.

Loovere *et al.* (2008:179) and Fuller (2009a:online) advises that artefacts, such as electrocardiogram (ECG) lines, cardio-respiratory monitoring leads, oxygen apparatus, staff members' hands and supporting additional linen should be removed, if possible and/or allowed. Artefacts are seen as foreign objects superimposed on the normal chest anatomy and impairs the visibility of anatomy (Hardy and Boynes, 2003:1180), which is why this criterion is included in the checklist (Appendix E), in Table 2.1 and by authors Loovere *et al.* (2008:179) and Morris (2003:460-461).

Hardy and Boynes (2003:118) have a reference for the event of including all important anatomical structures in the collimation, and that is when the reference collimation light field is set to include the bilateral skin margin of the thorax on inspiration, and also if the collimated area superiorly includes the vertebral prominence (spinous process of cervical vertebra number 7) in conjunction with the correct centring of the main radiation beam. According to the European Commission (1996:27), Morris (2003:460-461), Slade *et al.* (2005:609), Loovere *et al.* (2008:201), McQuillen Martensen (2011:21-124) and Bontrager and Lampignano (2014:631) the collimation edge on the image will only include cervical vertebra seven superiorly, the soft tissue margins bilaterally and the costophrenic angles inferiorly if collimation was done as indicated by Hardy and Boynes (2003:118). This important criterion is included in the checklist (Appendix E) as indicated by the above mentioned authors in Table 2.1.

Arthur (2001:311), however, states that additional anatomical areas may be included on the image on request of the referring doctor. Additional inclusions are generally requested to evaluate the position of medical lines, tubes and catheters or to evaluate specific pathological conditions, such as bowel obstruction. The accurate location of the different neonatal lines, tubes and catheters found in neonates is summarised in Table 3.1, as described by Arthur (2001:311); Hardy and Boynes (2003:115-118); Fuller (2009c:online) and McQuillen Martensen (2011:91-94).

Table 3.1: Neonatal lines, tubes and catheters: Desired locations (Arthur, 2001:311; Hardy and Boynes, 2003:115-118; Fuller, 2009c:online and McQuillen Martensen, 2011:91-94).

Line, tube or catheter	**Abbreviation of line, tube or catheter (as found on referral letter)**	**Desired location in neonate**
Endotracheal tube	ETT	Level of thoracic vertebra 4 (midway between Carina and thoracic inlet).
Umbilical artery catheter	UAC	Level of thoracic vertebrae 6 to 9 or lumber vertebrae 3 to 4.
Umbilical vein catheter	UVC	Junction between the inferior border of the right atrium (heart) and the right hemi-diaphragm.
Nasogastric tube	NGT	In the stomach, on the level of lumber vertebrae 2 to 3.

As observed in Table 3.1, a request by a referring physician to establish optimal medical line, tube and catheter placement requires a radiographer to include abdominal anatomy up to the level of the third to fourth lumber vertebra. The third to fourth lumber vertebra, according to Ballinger and Frank (1999:140-143), who are in agreement with Bontrager and Lampignano (2014:111), is on the level of the lower costal margin, which is a palpable topographic landmark. Any additional inclusion beyond lumber vertebra three to four only adds to the radiation dose of the neonate without contributing to the diagnostic purpose of the produced image.

McQuillen Martensen (2011:91) indicates the importance of ensuring that the neonatal mandible is not rotated from side to side, and in addition, elevated to ensure that it does not superimpose over the lung apices. Hardy and Boynes (2003:118) state that, should the mandible be rotated to the side, it can displace the ETT, making it difficult to evaluate correct tube placement. Therefore, this important criterion is included in Table 2.1 and in the checklist (Appendix E) this was noted as an artifact when visible on an image. The correct position of the mandible is obtained by first ensuring that there is no rotation of the head and then elevating the neonate's chin, done by a NICU staff member during the production of the chest image (Bontrager and Lampignano, 2014:631).

The neonate's arms should be extended to remove the scapulae from the lung fields (Bontrager and Lampignano, 2014:631). In addition, the internal rotation of both hands can also ensure displacement of the scapulae outside the lung fields (Ballinger and Frank, 1999:142). On the image, this positioning technique will ensure that lung fields are clearly visible without any superimposition by the scapulae. If the arms of the neonate are moved away from the collimated area, the amount of scatter radiation produced will be minimised, which inherently lowers the radiation dose to the neonate (Carlton and Adler, 2014:234). This criterion was not include in the checklist (Appendix E) and is seen as limitation (Section 5.4).

3.2.5.2 Breathing technique

Ballinger and Frank (1999:142) advise that the IR must be exposed on suspended inspiration to produce an image considered optimal because of aerated lung fields. According to Bontrager and Lampignano (2014:631) an image on suspended inspiration can be obtained by observing the neonate's breathing for a few seconds. Inspiration is evident when the sternum rises, the abdominal cavity expands or the neonate stops crying (Swallow *et al.*, 1986:143). An exposure should be made immediately after a full inspiratory breath (Hardy and Boynes, 2003:118). The criterion used to evaluate breathing technique is ensuring that eight to nine posterior ribs are visible above the diaphragm, as indicated by the European Commission (1996:27) and Morris (2003:460-461). In addition, to ensure that the image was produced during suspended breathing, Lowe *et al.* (1999:56) and Slade *et al.* (2005:609) stipulate that the heart shadow, costophrenic angles, rib margins and diaphragm should appear sharp. This criterion is also included in the checklist (Appendix E) and in Table 2.1.

3.2.5.3 Anatomical lead marker

The RSA DoH (1973b:1-2) considers the utilisation of lead markers as part of patient care and optimal utilisation of equipment, also in the NICU, as of the utmost importance. The main obstacle is that a lead marker on the image can appear to be almost as big as the premature neonate's skull and may superimpose important anatomy. Dedicated neonatal lead markers that are smaller in size are a practical but an expensive solution to ensure no superimposition by the lead marker (Fuller, 2009b:online). Another solution is to incorporate lead markers with collimation as discussed in Section 3.2.5.4 (Baker Cones). The inclusion and visibility of lead markers on the image was included as a criterion on the recommendation of Morris (2005:460-461) and Slade *et al.* (2005:629), and also included in Table 2.1 and the checklist (Appendix E).

3.2.5.4 Collimation

As a general consideration Bontrager and Lampignano (2014:53) and Hardy and Boynes (2003:23) advise radiographers to restrict the main radiation beam closely to ensure optimal image quality. Ballinger and Frank (1999:140) agree with this consideration and also emphasise that bone marrow, which is active in blood cell formation, is distributed throughout a neonatal patient skeleton and that blood cell damage is associated with ionising radiation. The radiographer should take cognisance of this fact each and every time before a neonate is exposed to ionising radiation.

Many imaging departments still fail to use recommended radiographic collimation parameters during imaging of neonates. A study by Duggan, Warren-Forward, Smith and Kron (2003:232) aimed to investigate dose reduction techniques for neonates in the NICU. The study recommended that radiographers collimate precisely to the region of interest, taking care to avoid excluding relevant anatomy. Literature on neonatal dose limitation indicates that poor collimation is the most significant mistake made by diagnostic radiographers when imaging neonates (Duggan *et al.*, 2003:232; Smans, Struelens, Smet, Bosmans and Vanhavere, 2008:147; Willis, 2009:273). Insufficient collimation gives rise to an unnecessarily high patient dose, and affects image quality negatively. A too large field size will impair contrast and resolution by adding unnecessary scatter radiation to the image. The area irradiated should also be kept as small as possible to keep the dose to the patient tissue as low as possible, as prescribed by the ALARA principle (Smans *et al.*, 2008:147; Willis, 2009:273).

The importance of optimal collimation ensured the inclusion of this criterion in the checklist (Appendix E) and its summary in Table 2.1. Collimation was evaluated by ensuring that only the necessary anatomical areas were visible within the collimated field, as discussed in Section 3.2.5.1 and indicated by the European Commission (1996:27), Morris (2003:460-461), Slade *et al.* (2005:609), Loovere *et al.* (2008:201), McQuillen Martensen (2011:21-124) and Bontrager and Lampignano (2014:631). Any additional inclusions were noted as comments.

A radiographer can ensure correct collimation of the main beam by exercising adequate knowledge of the external anatomical landmarks (Smans *et al.*, 2008:147; Willis, 2009:273). The external landmarks that should be utilised for mobile radiography of a neonatal chest are summarised in Table 3.2. The information presented in this table is based on literature by Swallow *et al.* (1986:145), Ballinger and Frank (1999:140) and Bontrager and Lampignano (2014:631). The restrictor cones of the overhead collimator should hence be closed to include only the anatomical landmarks that overlap the anatomical structures of interest (Section 3.2.5.1).

Table 3.2: External landmarks for mobile radiography of neonatal chests (Swallow *et al.*, 1986:145; Ballinger and Frank, 1999:140; Bontrager and Lampignano, 2014:631)

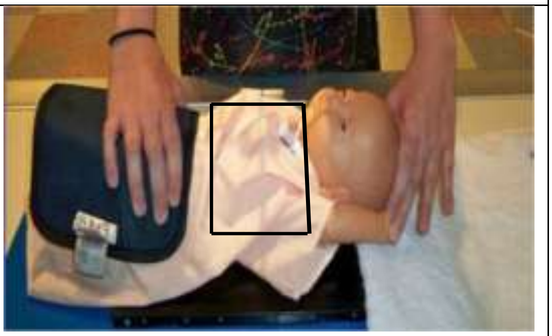
Thoracic area	External landmark	On illustration (correct position shown by the black lines)
Superiorly	Upper margin of the thyroid cartilage/mid-cervical (neck) area	
Bilaterally	To the soft tissue line	
Inferiorly	To the lower costal margin	

Table 3.2 shows that the collimated area will still include unnecessary soft tissue and bone areas of the humeri, due to the fact that the overhead collimation can only close in a rectangular shape. Additional collimation can be applied to the neonate in the form of shadow shielding (Jones, Palarm and Negus, 2001:920; Fuller, 2009b:online). Two different types of shadow shielding are available for the respective types of incubators (open and closed incubators). Both types of incubators are found in the participating institutions' NICUs.

For closed incubators Jones *et al.* (2001:924) advise that lead strips (2 mm thick) should be placed on the lid of the incubator. These lead strips should be placed to follow the skin line of the neonatal chest, as illustrated by Figure 3.1. Figure 3.1 illustrates the placement of the lead strips in a graphical format for chest and abdominal imaging, and for a combination of the two images (babygram).

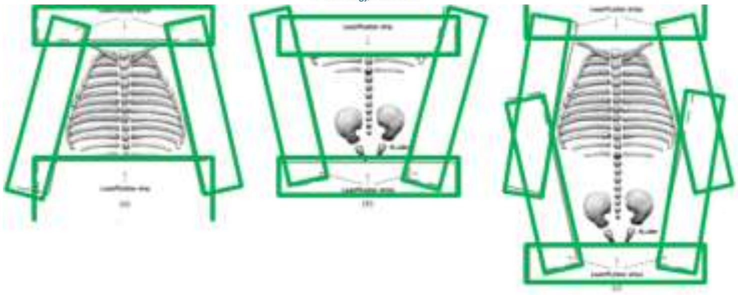


Figure 3.1: Closed environment shadow shielding (courtesy of Jones *et al*, 2001:924)

The open incubator has no upper lid. To accommodate shadow shielding Jan Baker, a British radiographer, created the Baker Cone apparatus. This device ensures shadow shielding and allows for optimal lead marker placement without the lead shieling or lead marker coming into contact with the neonate's skin (Fuller, 2009b:online). Baker cones consist of lead strips (see Figure 3.2) and a holder device (shown in Figure 3.3). Baker cones are essentially made out of lead strip pieces that have been punctured on either the left or right side with an appropriate right or left description (Fuller, 2009b:online). The punctured description is then displayed on the image, as indicated in Figure 3.2. It is crucial to place the punctured lead strip on the correct anatomical side (Fuller, 2009b:online).

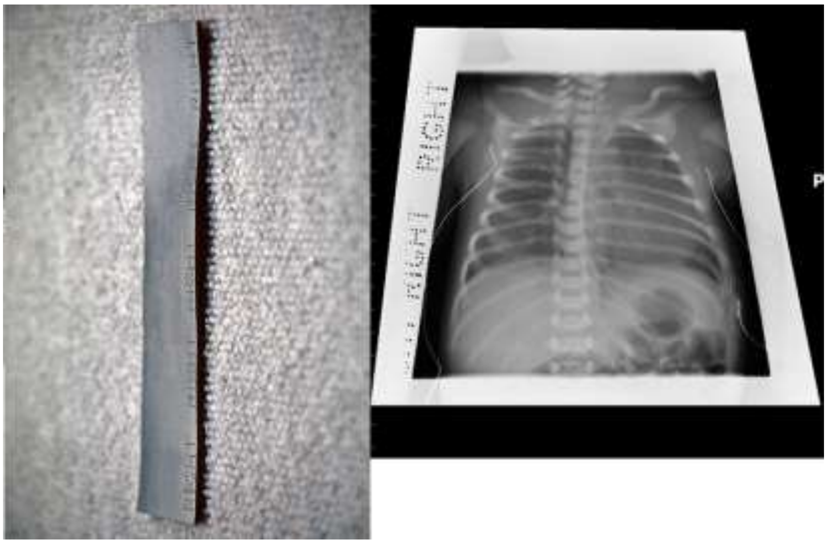


Figure 3.2: Baker cones lead strips (courtesy of Fuller, 2009b:online)

The Baker cones holder device is a custom-made centring unit. It has an IR holder in its base, which is placed under the neonates' mattress, and a centring point marked on the Perspex lid (Fuller, 2009b:online). As can be seen in Figure 3.3 the base slides under the mattress, and is moved to the centre of the neonate's chest; then additional Baker Cones can be placed on the Perspex lid to collimate according to the prescribed diameter (Fuller, 2009b:online).

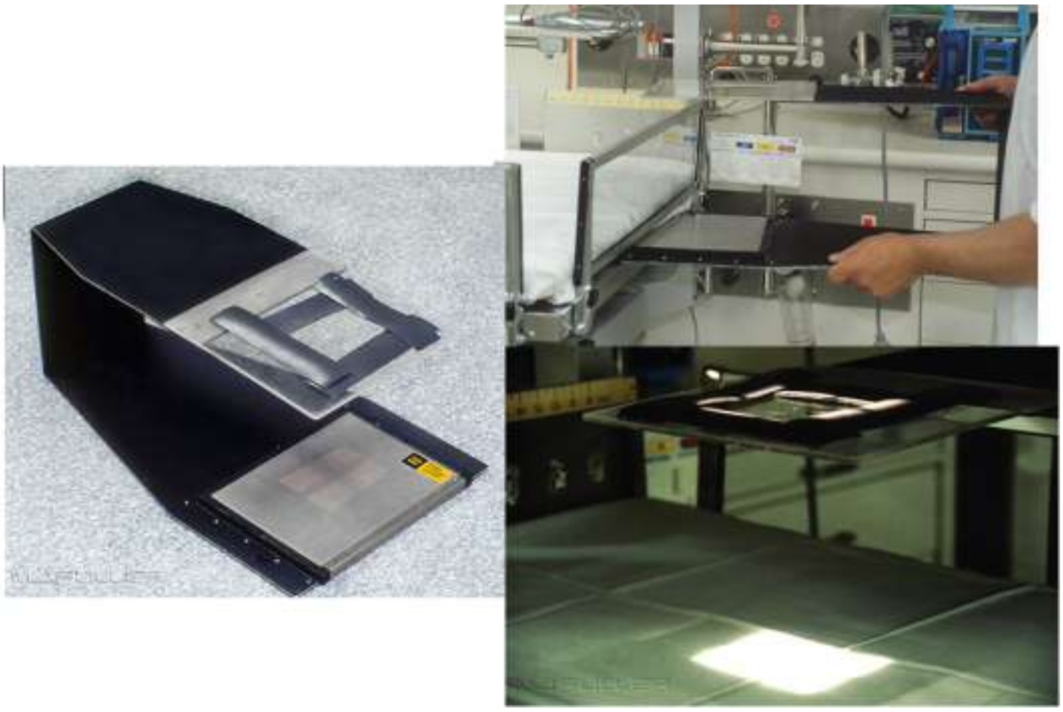


Figure 3.3: Open environment Baker Cones shadow shielding
(courtesy of Fuller, 2009b:online)

Possible disadvantages of utilising the described device are that it can only be used with the IR holder. It does not work very well for neonates who don't stay still. The device can possibly also be dropped on a neonate (Fuller, 2009b:online).

Bontrager and Lampignano (2014, 61) indicate that a radiographer can reduce the radiation exposure to the patient in several ways: by keeping repeat imaging to a minimum, utilising appropriate filtration in the x-ray machine tube, using optimal exposure parameters, collimating as small as possible and placing a lead shield directly over radiosensitive organs. Placement of gonadal shielding will now be described.

3.2.5.5 Radiation protection: Area shielding

Gonadal shielding is mandatory for all studies according to the Directorate of Radiation Control in South Africa (RSA DoH, 1973:8). Gonadal shielding should only be removed if explicitly requested by the referring physician. There are three methods by which a radiographer can shield a neonate during mobile radiography.

The first is using a lead-lined collimator. The second is to place lead strips on the incubator (Swallow *et al.*, 1986:143) or by hanging a lead shadow from the collimator – this type of shielding casts a shadow and protects the area under the shadow from the primary beam. For the open environment, the previously discussed Baker Cone can be considered a form of shadow shielding. The final and easiest method is to place a lead vinyl rubber shield directly on the neonate's body (Entrepreneur, 1997:online; Bontrager and Lampignano, 2014:61).

A specific direct contact shield designed for shielding neonatal patients' gonads is the "Save the Gonads" shield (see Figure 3.4). This shield consists of a thickness of 1 mm lead shaped like a heart, which can be used for both male and female patients. This shield is also infection-control friendly and lightweight for patient comfort (Natus, 2005:online).

Figure 3.4: "Save the gonads" shield (Natus, 2005:online)

Bader *et al.* (2007:584) identified shortcomings in the guidance that professionals who work with preterm infants receive. These shortcomings, combined with a usually heavy work load and unintentional neglect of existing guidelines, may lead to radiographers failing to use gonadal shielding and collimation. Because gonadal shielding is mandated by the Directorate Radiation Control South Africa (RSA DoH, 1973:8), the visibility thereof was included in the checklist as an criterion (Appendix E) as indicated by European Commission (1996:27) and Loovere *et al.* (2008:201) , and in Table 2.1.

3.2.5.6 Exposure parameters

Bontrager and Lampignano (2014:61) perceive exposure parameters as the kVp, mA and time (in seconds) selected by the radiographer. A high optimal kVp with lowest optimal mAs should be selected. The exposure time should be very short, to compensate for involuntary motion (beating of the heart). In addition, Hardy and Boynes (2003:118) indicate that the selected exposure parameters should be within the manufacturer's recommended exposure range.

CR systems have replaced most screen-film systems and have an indirect tool for monitoring patient exposure. The exposure index (EI) calculates the dose to the image receptor. It does not indicate the exposure value used, but is an index to track the compliancy of the exposure to predetermined target exposure factors. Compliance to predetermined target exposure indices will ensure that "exposure creep" does not occur in a radiography department (Cohen, Cooper, Piersall and Apgar, 2010:592; Goske *et al.*, 2010:611). Exposure creep, as defined by Gibson and Davidson (2012:458), is the systematical increase in exposure parameters selected by radiographers, which results in increased radiation dose. It is a phenomenon that results from the wide-exposure latitude of CR systems.

As a specific digital image consideration, Bontrager and Lampignano (2014:47) advise radiographers to evaluate the EI values for previous images. The EI value verifies that previously utilised exposures are in the correct exposure range. This exposure range should ensure optimal image quality with the least amount of radiation dose to the neonate. When a radiographer encounters an EI value outside the recommended range, the necessary exposure parameters must be adjusted. The checklist for this study included the exposure indices of each image evaluated.

Dougeni *et al.* (2007:814) found that high kVp techniques resulted in lower entrance skin dose (ESD) with no significant loss in image quality during chest radiography of neonatal patients. Carlton and Adler (2014:488) advise all radiology departments to compile exposure charts to ensure the production of consistent high quality images at the lowest possible dose to the patient. Such an exposure chart should include patient anatomical thickness measurements, kVp parameters, mAs parameters as well as the expected EI value (Carlton and Adler, 2014:333).

To include the evaluation of selected exposure parameters (kVp and mAs) on the image, the following evaluation criteria were included in the checklist (Appendix E):

- The kVp-setting, also known as the penetrability of the main radiation beam (Carlton and Adler, 2014:234), was evaluated by observing the spine, paraspinal structures, retrocardiac lung, trachea and proximal bronchi on the image. These areas were also evaluated for exposure parameters by the authors listed in Table 2.1, namely, the European Commission (1996:27), Lowe *et al.* (1999:56), Slade *et al.* (2005:609), Dougeni *et al.* (2007:810), Loovere *et al.* (2008:201), McQuillen Martensen (2011:121-124) as well as Bontrager and Lampignano (2014:631).
- Density differences between soft-tissue, air and bone, which indicates optimal mAs-settings (Carlton and Adler, 2014:234), was evaluated by the visibility of vascular patterns in the central half of the lungs. These vascular patterns include the hila and lung markings found in the central half of the lung fields. Other anatomical areas evaluated for mAs include the visibility of the mediastinum, any inserted catheter tips and the parenchymal (lung) markings within the entire lung fields. These areas were also evaluated for exposure parameters by the authors given in Table 2.1, namely, the European Commission (1996:27), Lowe *et al.* (1999:56), Slade *et al.* (2005:609), Dougeni *et al.* (2007:810), Loovere *et al.* (2008:201), McQuillen Martensen (2011:121-124) as well as Bontrager and Lampignano (2014:631).

3.3 METHOD FOR THE DESIGN AND PRESENTATION OF THE EDUCATIONAL PROGRAMME

The method utilised in Phase 2 of the study entailed the design and presentation of an educational programme for qualified radiographers on neonatal mobile chest image quality. This section will describe the population of this phase, the design and content of the educational programme as well as the support learning material, which was comprised of posters. The presentation of the educational programme will conclude this section of the chapter.

3.3.1 Population

The study population for the second phase of the study consisted of qualified radiographers at each participating institution. Although the ideal would have been to include all the radiographers employed at each of the participating institutions, a minimum of five radiographers per institution were considered as statistically required to be included in the study (total of 15 radiographers). The educational programme was presented to 56 qualified radiographers at the three participating institutions (16 radiographers at a private institution, 22 radiographers at one government institution and 18 radiographers at a second governmental institution) over a period of the two months, June and July 2012 (Appendix G).

The qualified radiographers were the population for this phase of the study because they are the imaging specialists responsible for producing high quality neonatal chest images. These radiographers could therefore benefit from additional knowledge and skills training for neonatal radiography through an educational programme. The same educational programme was presented to all participating institutions. The radiographer participants gave written consent after they read an information document (Appendix C). Participation in this study was voluntary and participation could have been withdrawn at any time. All information of the radiographers was kept confidential to ensure their privacy.

The inclusion criteria for the radiographers were as follows: only qualified radiographers working at one of the participating institutions, rotating through the mobile radiography unit and the NICU utilising a CR system to produce neonatal chest images could partake in this study. During the first phase of the study (preliminary evaluation of image quality), images produced by all the radiographers working at the participating institutions were included, however during the third phase of the study (re-evaluation of image quality), only images produced by radiographers who had completed the educational programme and consented to participate, were evaluated. These images were identified by the radiographers' identification codes that were linked to the images on the CR system.

3.3.2 Educational programme

The design of the educational programme took place from April to June 2012. This educational programme was presented at all the participating institutions from mid-June to end of July 2012. To ensure that radiographers regarded this study as valuable, the programme was CPD accredited during May 2012 (Appendix O). Support learning material in the form of posters (Appendices M and N) and PowerPoint slideshows (Appendices I, J and K) were utilised to create awareness of the research study in the hospitals' radiology departments. The educational programme also included practical demonstrations to address the skills component of the radiographic technique. Each of these aspects will be discussed in the following sections.

3.3.2.1 Design and content of the educational programme

The non-credit-bearing educational programme aimed to address existing radiographic knowledge and skills and therefore was designed keeping the exit-level outcomes of the Bachelor degree in diagnostic radiography as published by the South African Qualification Authority (SAQA) (2013b:online) with specific focus on providing the necessary training for radiographers to ensure that the welfare of patients is maintained and optimal image quality is produced, in mind.

The educational programme designed was informed by three aspect namely, i) specific positioning techniques found in relevant literature (Section 3.2.5), ii) the evaluation criteria utilised to evaluate images as included in the checklist (Appendix E), which are based on literature (Section 2.2.5), and iii) the results from Phase 1 (Section 2.5). This study therefore builds on existing literature and theories, as advised by Denscombe (2007:250).

As described in the literature orientation of Chapter 2, image quality depends on a wide variety of factors (Carlton and Adler, 2014:460). To address image quality properly these factors must be taken into consideration. Hence the educational programme was designed to include the factors under the control of a radiographer, namely, the radiographic positioning technique utilised to produce the image (Section 3.2.5). The positioning techniques were discussed in relation to the evaluation criteria utilised to evaluate the specific positioning technique. Hence the positioning techniques were divided into six areas that relate to the image evaluation criteria areas assessed on the images according to the checklist (Appendix E), namely, positioning technique, breathing technique, lead marker, radiation protection, exposure parameters and collimation. The checklist also included two other evaluation areas that were not included in the educational programme, namely, the availability of a referral letter providing clinical history, and the final evaluation made by the radiographer in relation to the image produced.

A radiographer must be able to evaluate the quality of an image and decide on areas that can be enhanced in the future or in repeat images. To facilitate this ability, the evaluation criteria utilised in the checklist (Appendix E) were also included in the educational programme. By supplying the specific positioning technique that will ensure each criterion in the checklist is met optimally, the value of each criterion was demonstrated by clearly showing how radiographic technique, along with image quality, influences the treatment of a neonate. The six areas of image quality found on the checklist (Appendix E) were discussed in relation to their individual positioning techniques.

The results from Phase 1 were included in the educational programme. This allowed radiographers to take cognisance of the image quality areas in need of enhancement through feedback. The data (Section 2.5) that indicated a need for enhancement included:

- Radiation protection not visible for 98.7% of images;
- Anatomical lead markers not visible for 66.4% of images;
- Anatomical lead markers incorrectly placed for 67.3% of images;
- Insufficient collimation with unnecessary additional anatomy included on an average of 70% of images;
- Improper centring found on 64.9% of images;
- Rotation found on 56.7% of images;

- Main radiation beam tilt not found on 41.6% of images;
- Incorrect breathing technique visible on 45.8% of images;
- Inadequately exposed images seen on an average of 40% of images; and
- Incorrect EI values recorded for 62.7% of images.

The list above includes all the image quality evaluation criteria areas found in the checklist. Therefore, the educational programme included all the areas evaluated in the first phase of the study, with the exception of the captured referral letters and the final evaluation made by radiographers in relation to repeating an image.

3.3.2.2 Support learning material: Posters

Two posters (Appendices M and N) were designed to accompany the programme content discussed during theoretical sessions. Both posters illustrated practical areas found to be generally lacking during Phase 1 of the study (Section 2.5). As the data indicates, an average 70% of radiographers included unnecessary additional anatomy. The first poster (Appendix M) showed medical line, tube and catheter placements, to remind radiographers to include only the necessary anatomical structures. This poster was included in order to raise awareness amongst the radiographers in relation to the importance of obtaining a clinical history, even if such a history is not presented on the request letter. The second poster (Appendix N) was based on the lack of collimation (70%) and absence of radiation protection (98.7%). The poster made radiographers aware of support equipment options available to radiographers. It is however expected that each department do provide some or other option in this regard to their radiographers. This poster reminded radiographers about these important aspects of image quality.

The posters were placed on notice boards in imaging radiology departments of each participating institution. Electronic copies of the posters were also supplied to the management of the radiology departments of the three participating institutions, for future reference and utilisation. The main goal of the posters was to create awareness amongst radiographers about the content of the educational programme.

3.3.2.3 CPD accreditation of the educational programme

When the educational programme was designed it was submitted for CPD accreditation, which was obtained on 15 May 2012. The accreditation included two CEUs, one for each theoretical session. Appendix O contains the letter granting CPD accreditation (RCT038/) for the educational programme. After the educational programme had been presented successfully, each participating radiographer received a CPD certificate from the researcher (Appendix P).

3.3.3 Presentation of the educational programme

The presentation of this programme was executed at three participating institutions, two government and one private. The sessions in which these presentations where made were planned (Appendix R). The schedule plan for the educational programme was discussed with the management of each participating institution. The researcher scheduled contact sessions according to the specific requirements of each institution. This ensured that the institutions' daily activities could proceed as usual. The researcher was thus assured of complete cooperation by institutional management.

The educational programme was divided into one introductory session, two theoretical sessions (CEU accredited), two practical sessions and two discussion sessions. Radiographers were invited through their management (head radiographer) to attend an information session in relation to participation in a research study. This information or introductory sessions (Appendix I) consisted of PowerPoint slideshows introducing the participating radiographers to the research study. This session's goal was to request the radiographer's participation and to obtain written consent. The session included the dates set for the other sessions of the educational programme. The duration of the presentation for the introductory session was 30 minutes and the researcher constructed and presented the presentation. The radiographers were given 20 minutes to read through the information document that was supplied and to ask any questions in relation to the study.

After consent had been obtained from the radiographers, two theoretical sessions facilitated by PowerPoint slideshows (Appendices J and K) were held. The duration of each session was one hour and each was accompanied by a discussion and practical session of 30 minutes, scheduled on the same day. The discussion and practical sessions were presented directly after the theoretical sessions to encourage interaction among and participation by the radiographers. Personal experiences were discussed and areas identified by the group as problematic in their specific facility were brainstormed. These discussions were captured by the researcher as research notes. In addition, presenting all three sessions on one day enabled radiographers to attend all the sessions without having to travel again, or requiring further planning from them or the management of the institution. All sessions were designed, presented and facilitated by the researcher.

The first theoretical session focused on the first three areas identified in the educational programme namely positioning technique, breathing technique and lead marker (Appendix J). The practical session that followed involved radiographic demonstrations in the NICU, and focused on these three areas. The practical sessions were presented with the aid of an unoccupied incubator, mobile x-ray unit and neonatal phantom, as illustrated in Figure 3.5.

Figure 3.5: Practical sessions

The second theoretical session focused on the remaining three areas, namely, radiation protection, exposure parameters and collimation. Practical demonstration sessions (Figure 3.5) were once again offered after a 30 minute discussion session. The same regime as for the first set of sessions was followed.

The discussion sessions were informal and interactive. The radiographers talked about the areas discussed in the theoretical session and highlighted challenges they experienced. The main challenges identified by the different groups were summarised by the researcher as research notes taken during the discussion sessions. Possible solutions to the challenges noted were discussed by the participants, and are included in Table 3.3.

The discussion sessions were followed by practical sessions. These practical sessions were conducted in smaller groups of two to three radiographers because it took place in the NICUs. Smaller groups ensured that the practical sessions did not disturb the normal running of the units. During these practical sessions a demonstration was given of the areas discussed in the theoretical sessions, facilitated and monitored by the researcher. Only interested radiographers attended these sessions. Attendance was not compulsory for the practical sessions.

Appendix R summarises the format and schedule plan that was followed for the educational programme. The staff at the two participating government academic training institutions are allowed academic-free hours every week. The researcher scheduled the contact sessions within these academic-free hours. In the remaining private institution, the patient flow-rate is high, with little to no free hours during the week. Here the researcher offered more than one session for each specific content section. This enabled all the radiographers to attend one of the sessions on a rotating basis, ensuring that the patient flow-rate was maintained when contact sessions were in progress. These sessions were scheduled early in the morning (07:00) before normal working hours commenced.

For all theoretical and discussion contact sessions, an attendance register was completed (Appendix L). This enabled the researcher to monitor the attendance of participating radiographers. After each of the theoretical and discussion sessions, the participants were requested to evaluate the session utilising the evaluation form that had been designed (Appendix H). This evaluation form was available only in English, because the educational programme was presented in English.

After these sessions had been completed, the posters (Appendix M and N) were given to the head radiographers of the participating departments. These A3 size posters were printed in color. The posters reminded radiographers of the content discussed during the contact session. The posters were placed on notice boards these radiographers consulted for work rosters and CPD information.

3.3.4 Statistical analysis

The results of the educational programme are described in relation to the research notes taken and evaluation forms completed by participating radiographers. The discussion session's feedback comprised of research notes describing possible solutions identified by radiographers for recorded problematic areas; the research notes had been taken by the researcher. The statistical analysis of the research notes involved arranging the challenges and solutions into categories. These categories are displayed in Table 3.3.

The results of the evaluation form (Appendix H) represents anonymous feedback from the radiographers regarding the quality and content of the educational programme. Percentiles were calculated for quantitative data found in the evaluation form. This was done by calculating the percentage of participants who considered the educational programme as excellent, acceptable or poor. Percentiles were also calculated for qualitative data recorded by the evaluation form, by categorising the comments made. The different categories were identified and comments sorted accordingly with the assistance of a statistician. The statistician calculated the total number of responses per question and contributed that as the n-value for the specific question. Percentages could then be calculated by determining the number of participants who made similar comments (sorted by researcher into a category) divided from the total number of participants that choose to provide comments on the specific question (n-value).

3.4 QUALITY ASSURANCE OF RESULTS FROM PHASE 2

As described above, the educational programme was designed according to literature sources and results from Phase 1 of this study (Section 2.5). The educational programme included all the positioning techniques that ensured that the evaluation criteria of the checklist could be met, as well as an indication of the frequency evaluation criteria were recorded as optimal in Phase 1. This made the content of the educational programme trustworthy (Section 1.9.2).

The educational programme was presented in the same manner at all the participating hospitals, according to a schedule plan (Appendix R) and with the aid of PowerPoint slide show presentations (Appendices I, J and K). The discussion sessions, which took place after the presentations, were facilitated by the researcher (Section 3.3.3). These discussion sessions ensured communication between the participants and the researcher. Results obtained from the checklist evaluations (Section 2.5) were discussed and the researcher was able to obtain insight into the challenges participants experienced that lead to inadequate image quality areas recorded during phase one (Section 2.6.1).

Research notes made during these sessions only referred to challenging circumstances identified by participants in their own work environment (Table 3.3) and responses could not be influenced by the researcher. The means by which challenges were addressed were solutions identified by the participants, and not suggested by the researcher. The solutions were only recorded in the research notes (Table 3.3). The challenges experienced at participating hospitals could be compared because more than one hospital participated (Section 1.6). From the qualitative research note results (Table 3.3), it can be seen that the results were similar in some instances, which, according to Hasson, Keeney and McKenna (2000:1013), indicates that the results recorded were trustworthy and not influenced by the researcher during visits to the different hospitals.

The evaluation form (Appendix H) completed by the participants assisted in determining the trustworthiness of the educational programme. This form contained open-ended (qualitative) as well as closed (quantitative) questions. The quantitative results were valid and reliable because participants could select options by making an anonymous tick mark. The qualitative results were trustworthy because participants gave responses that reflected their opinions in relation to the educational programme and they were not influenced by the researcher.

3.5 RESULTS AND DISCUSSION OF PHASE 2

The participating radiographers consisted of 56 qualified individuals. From the private institution, 16 radiographers participated, 22 radiographers participated at one government institution and 18 radiographers at a second government institution. No specific demographic information, for example age or professional experience, was captured for the participating radiographers. The feedback obtained from the participants as research notes and completed evaluation forms will now be described.

3.5.1 Research notes

The research notes recorded are summarised in Table 3.3. The table refers to the two theory sessions that were discussed. The number of hospitals that recorded the same challenges, as indicated by the participants of each institution, is shown in the second column. Challenges experienced in direct relation to radiographic technique related to difficulty ensuring a proper inspiratory image. Radiographers acknowledge that the theoretical session provided them with some new solutions, which they will implement. The bright natural lighting of the NICU made it difficult for some radiographers to visualise the collimated area. The practical solution provided was that the blinds of the NICU can be closed, thereby dimming the natural lighting. Challenges experienced in relation to recommended EI values as well as the availability of an exposure chart was resolved by finding the relevant EI values in the CR system guide and creating an exposure chart.

However, some solutions required support and intervention by the managerial staff of the institution, since it required resources and funds. As can be seen in Table 3.3, the need to purchase a specialised type of radiation shielding was identified. The Baker cones that formed part of the presentation sessions were identified as optimal and the radiographers indicated that such a purchase will assist in optimising radiation protection. In addition, the radiographers saw the advantage of preventing cross infection when utilising the Baker cones and the inclusion of anatomical lead markers in the Baker cones.

Some of the other challenges related to assistance given by nursing staff in the NICU. Radiographers indicated the general lack by nursing staff members to assist them with positioning techniques. Without proper positioning, image quality will not be adequate. The conclusion was that NICU nursing staff can be requested to assist, and a professional, respectful request will be sufficient to address challenges in this regard. In addition, radiographers raised the challenge posed by nursing staff that ignore radiation protection guidelines. The resolution was that the radiographers will not make an exposure and will cancel the examination until the radiation warning is acknowledged and properly reacted upon.

Table 3.3: Discussion sessions – challenges identified by radiographers

Session	Number of institutions	Challenges	Addressing challenges
1st	3	Nursing staff do not assist with positioning of neonate – they leave the NICU when the radiographer arrives.	Request assistance verbally from nursing staff, even if the radiographer must fetch him/her from outside. If nursing staff members refuse to assist, cancel mobile examination and advise nursing staff that the radiographer is more than willing to perform the examination but only when the necessary assistance is provided.
	2	Nursing staff ignore radiographers' warnings about exposure and complain about it afterwards.	Do not expose, cancel the examination and advise nursing staff that the radiographer is more than willing to perform the examination but only if the warning regarding exposure will be acknowledged by all nursing staff members.
	3	Cannot place lead marker on image due to cross-infection policy in the institution.	Make Baker cones lead strips and purchase supporting device – purchase must be approved by institutional management.
	2	Neonates have many lines, tubes and catheters that superimpose the thorax. Without the nursing staff present, difficult to know which lines, tubes and catheters can be repositioned.	Request assistance verbally from nursing staff, even if the radiographer must fetch him/her from outside. If nursing staff members refuse to assist, cancel mobile examination and advise nursing staff that the radiographer is more than willing to perform the examination, but only when the necessary assistance is provided.
	1	Neonates are very mobile, it is difficult to follow respiration rate and to expose on suspended inspiration.	Practice handy techniques presented in theoretical presentation.

Session	Number of institutions	Challenges	Addressing challenges
2nd	3	Due to cross-infection policy, no lead strips can be placed over neonate.	Make Baker cones lead strips and purchase supporting device – purchase must be approved by institutional management
	3	No shadow shielding device is available.	Make Baker cones lead strips and purchase supporting device – purchase must be approved by institutional management
	1	NICU very bright, radiographer cannot see collimator lights.	Close blinds before commencing with examination, dim lights if possible.
	2	Do not know recommended EI values.	EI values can be obtained from CR support technician and CR guide manual.
	1	Do not have exposure chart available on mobile units, only in Radiology Department.	Request quality assurance officer in Radiology Department to create an exposure chart aligned to the EI values for the mobile units specifically (place on units).

3.5.2 Evaluation form

The evaluation form (Appendix H) enabled radiographers to reflect on their perception of the theoretical contact sessions. The total number of radiographers that completed the evaluation forms was 56 (N=56). The form was completed anonymously and submitted to the researcher via a submission box only opened by the researcher after all submissions for the specific contact session had been made. Figure 3.6 represents the closed question result section of the evaluation form.

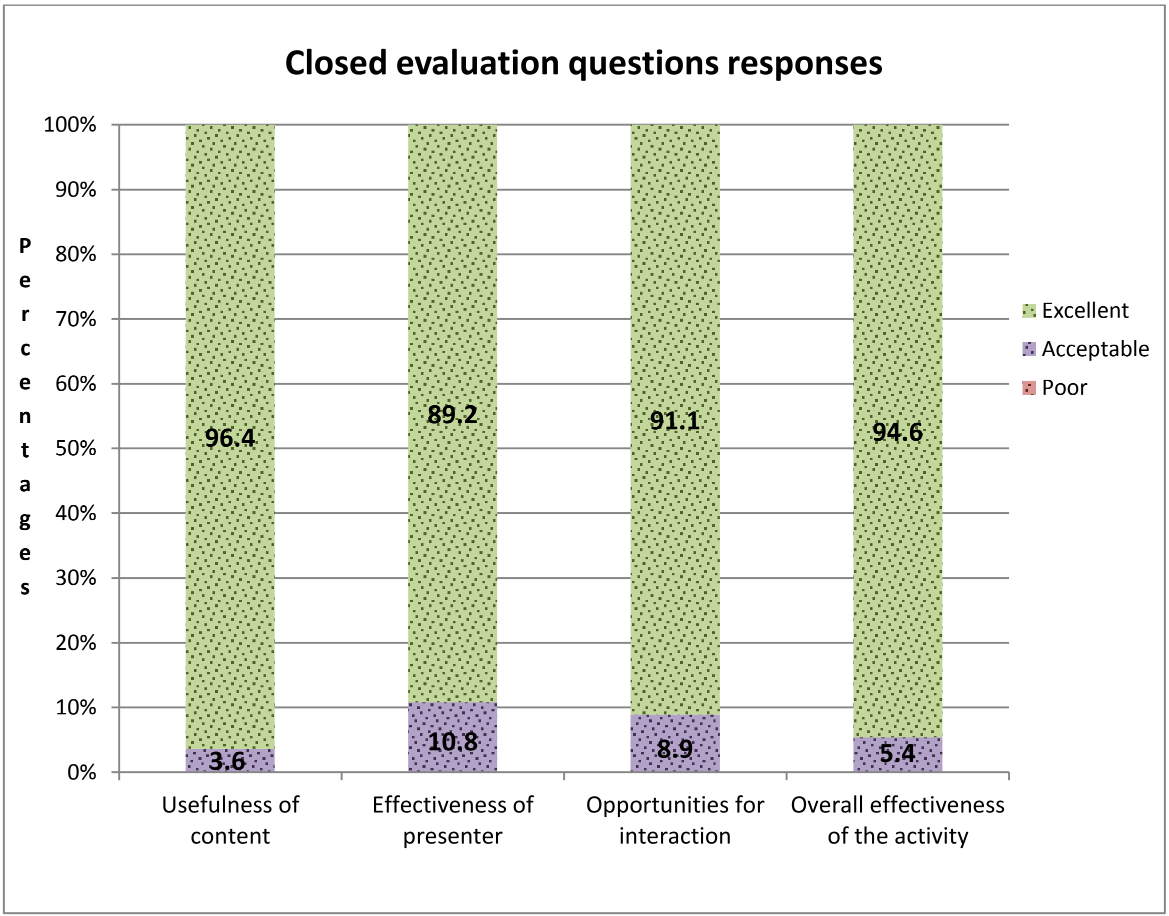


Figure 3.6: Closed evaluation questions responses

Figure 3.6 illustrates that the presentation of the educational programme was perceived by most radiographers to be excellent. Ratings of 96.4% (or rated as such by 54 radiographers) were given for the usefulness of content and 89.2% (or rated as such by 50 radiographers) for the effectiveness of the presenter, the opportunities for interaction, 91.1% (or rated as such by 51 radiographers) and the overall effectiveness of the activity, 94.6% (or rated as such by 53 radiographers) in the excellent option. This graph indicates the perception of the radiographers, which was that the educational programme was useful and effective. Finding the programme useful and effective does not, however, necessarily mean that it leads to improved radiographic techniques.

Three open-ended questions were included in the evaluation form (Appendix H). The three questions enabled the radiographers to express their individual opinions about the content they learned about and how this educational programme can be improved, and provided opportunity to mention any additional information they would like to receive. Not all the radiographers completed this section of the questionnaire. The different remarks have been categorised and are presented in graphs. Figure 3.7 illustrates the content areas 55 radiographers indicated they could apply in their daily work (n-value = 55).

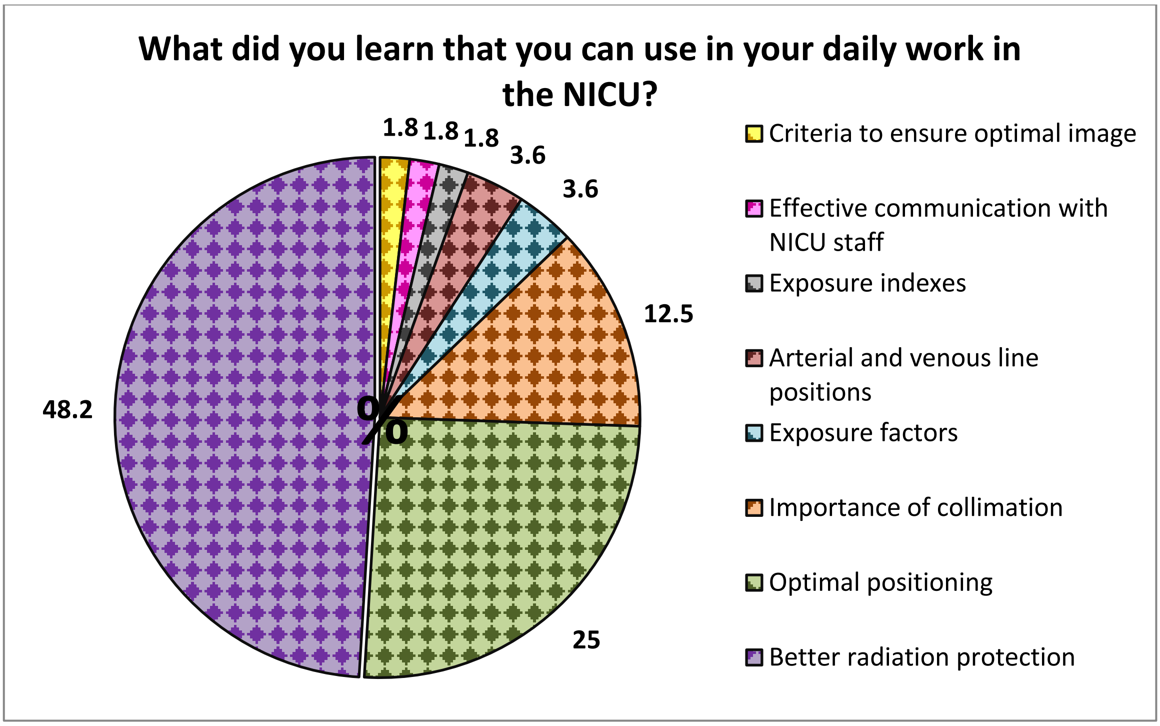


Figure 3.7: Open-ended question:
What did you learn that you can use in your daily work in the NICU?

Figure 3.7 shows the different content areas that the 55 radiographers have expressed useful and consider to be implementable. As can be seen, 48.2% or 27 radiographers realise that they have to improve patient protection from radiation and, in addition, agreed that radiation protection was implementable with the assistance from department management. A quarter (25% or 14) of the radiographers identified areas in which they can improve their positioning technique. Collimation was seen by 12.5% or 7 radiographers as an area where they can improve.

The second open-ended question asked the radiographers to indicate means by which the researcher could improve the educational programme. Only five radiographers answered this question, giving a response rate of 9%. Two of the five radiographers indicated that, after attending the practical sessions, they have a need for more practical sessions in the form of demonstrations. The remaining three commented respectively that some information is very repetitive, that more time should be spent on each session, and that more attention should be given to troubleshooting of challenges experienced in their individual institutions. Figure 3.8 displays the results of the final open-ended question (Appendix H).

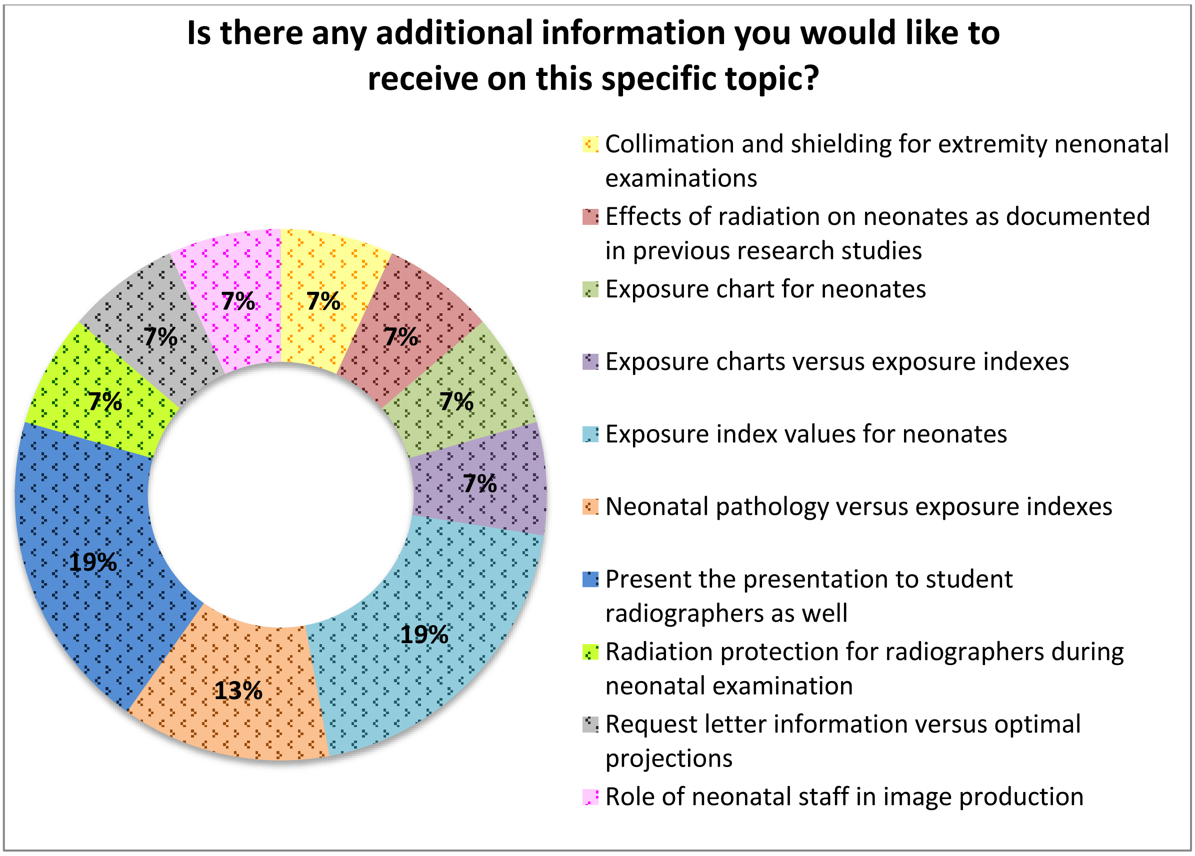


Figure 3.8: Open-ended question:

Is there any additional information you would like to receive on this specific topic?

The final open-ended questions were answered by 15 radiographers. The question required radiographers to indicate any additional information that should be added in the educational programme. As can be seen in Figure 3.8, 19% or 3 radiographers who completed this question were of the opinion that student radiographers should also be exposed to this educational programme and 3 (19%) other radiographers were of the opinion that more content on EI values should be included in the programme. In addition, 13% or 2 radiographers would like to see the correlation between neonatal pathology and EI values. The remaining comments indicated as 7% on Figure 3.8 were made by individual radiographers and their opinions did not fall in a single category.

3.6 CONCLUSION

The radiographers experienced the educational programme as beneficial to their professional performance. The percentage (96.4%) awarded to the educational programme content on the closed evaluation form questions indicate that this programme was experienced as excellent by 54 radiographers. Of the 54 radiographers, 27 radiographers realised that they have to improve radiation protection, 14 radiographers identified areas in which they can improve their positioning technique and 7 radiographers realized that they can collimate more.
A number of radiographers (15 participants out of 56 participants) indicated possible adjustments to the educational programme. Only 8 of the 15 radiographers in indicated that pathological appearance and exposure indices should receive more attention. The adjustments recommended are of such a nature that future presentations of this programme can include these suggestions.

Future presentations can benefit from benchmarking with other radiographic educationalists through observation during the presentation. The content of the educational programme can also be moderated by a colleague for benchmarking purposes. These activities will ensure that the design, content and presentation of the educational programme remain valid and reliable. In Chapter 4 the value of this educational programme will be established by the re-evaluation of neonatal chest images, as in Chapter 2. Even though the data in Chapter 3 indicated that radiographers considered the educational programme to be well designed and perceived as contributing significantly to knowledge and skills relating to radiography (more than 80% excellent response recorded on evaluation form), the success of the programme can only be realised by improved neonatal chest image quality, which will be evaluated in Chapter 4.

CHAPTER 4

RE-EVALUATION OF MOBILE NEONATAL CHEST IMAGE QUALITY

4.1 INTRODUCTION

This study investigated whether mobile neonatal chest image quality was addressed through an educational programme. The imaging of neonates is both challenging and interesting because of the exclusive diseases encountered in neonates, in addition to neonates' small size, delicate nature and heightened susceptibility to the harmful effects of radiation. Because of these effects of radiation on neonates, any exposure to radiation must be justified. When justified imaging is undertaken, attention to detail is a prerequisite. Attention to detail requires dedicated staff and spesialised equipment which will ensure a high quality radiological examination but with a low-dose technique incorporating sufficient lead protection (Morris, 2003:460).

Chapter 3 described the educational programme that was designed, and its presentation. In this chapter, the focus moves to Phase 3 of the study, namely, the research objective relating to the re-evaluation of the mobile neonatal chest images produced in the NICU after the educational programme had been presented. The results that will be described in this chapter refer to the reapplication of the checklist on newly produced mobile neonatal images; the results will reflect the impact (if any) of the educational programme by comparing the data obtained from Phase 1 (before the educational programme) to the data obtained in Phase 3 (after the educational programme).

This chapter starts with an overview of the literature that lists guidelines, rules and regulations of different governing bodies in relation to neonatal and/or pediatric radiography. This is followed by a short summary of the data collection process reported on in this chapter. Lastly, the chapter contains a discussion section (Section 4.6) on the image quality evaluated before the presentation of the educational programme and the image quality after the presentation of the educational programme.

4.2 LITERATURE ORIENTATION AND BACKGROUND TO GOVERNING BODIES AND RELATED RESEACH

The literature that is relevant to this chapter was described in Chapter 2. This chapter's literature section will refer to governmental regulations not discussed in Chapter 1 and pertaining to both the South African and to the international environment. These guidelines and codes of practice are described by various governing bodies, such as the Pan African Congress of Radiology and Imaging (PACORI). The literature study concludes with a short summary of research studies that used the same evaluation models as applied in this study, to reflect on their success rates compared to those found by this study.

4.2.1 Guidelines, regulations and codes of practice

The WHO recognises and supports ICRP in relation to guidelines supplied for radiological diagnostic procedures on children. The ICRP recommends restricting radiological diagnostic procedures on children to a minimum. According to the ICRP, it is compulsory to use lead shielding devices, for example lead aprons or strips, when working with pediatric patients. The correct radiographic techniques are considered to be vital and justification is essential when deciding to do an ionising examination on pediatric patients (ICRP, 2013:online).

Finland implemented a decree (423/2000 of Finnish Ministry of Social Affairs and Health) concerning patients, and a law (1142/1998) concerning radiological personnel. According to this decree, specific lead shielding radiation protection is needed for imaging during childhood and pregnancy. Additional requirements relating to protection stipulate the correct utilisation of radiological apparatus, optimal applied practical techniques and incorporation of ancillary immobilisation equipment for the medical exposure of children (Kettunen, 2004:12).

The EC produced a document containing guidelines for "good radiographic techniques". The aim of these guidelines is to lower entrance skin dose (ESD) in the context of optimal image quality for common, everyday pediatric examinations. These guidelines assist to balance dose and image quality

(European Commission, 1996:12; Lowe *et al.*, 1999:55; Dougeni *et al.*, 2007:808).

The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) specifies that the recommended dose limits for children should be lower than that of adults due to children's increased lifetime risk. In addition, this agency pays close attention to the justification for a diagnostic ionising examination of pediatric patients. Radiation protection and dose optimisation also receive attention in the regulations stipulated by this agency (ARPANSA, 2002:online).

The Pan American Health Organisation recognises and embodies the same regulations specified by the ICRP. The former organisation includes similar criteria for radiation protection, on the basis of recent studies performed by the WHO, and those incorporated in the recommendations of the ICRP. The Pan American Health Organisation also emphasises the importance of limiting radiation dose to a minimum for pediatric patients, with specific requirements in relation to justification, risk-versus-benefit analysis, dose optimisation and specialised equipment (Pan American Health Organisation, 2012:online).

The PACORI along with other organisations representing radiation health workers in Africa launched the AFROSAFE campaign, of which the main goal is to identify and address medical radiation protection concerns in Africa. The stimulus for AFROSAFE was the Bonn Call-for-Action, which is a joint statement by the WHO and the IAEA (IAEA, 2015:online). The Bonn Call-for-Action (2013:online) is aimed at strengthening the application of radiation protection for patients, attaining the highest benefit-to-risk ratio for all patients through appropriate medical radiation utilisation, ensuring the integration of radiation protection throughout the health care system, increasing patient awareness by means of discussions with patients about benefit-to-risk ratios and, lastly, enhancing the safety of quality radiological procedures in medicine. In order to achieve the stated aims, the Bonn Call-for-Action encourages health care workers to take action during the next decade by participating in 10 main actions. Two of the 10 main Bonn Call-for-Action actions relate directly to this study. The Bonn Call-for-Action (2013: online) requires health care workers to promote the implementation of the optimisation principle in relation to protection and safety when working with children. This action includes regular updates in relation to reference dose levels for children. Health care workers are also called upon to strengthen radiation protection education and training. This action involves further professional development through continuous training opportunities, especially with regard to implementation of new technologies.

The South African government (RSA DoH, 1973:8) published a Public Health Amendment Act (1971) with special reference to the medical exposure of any individual under the age of 18. According to this Act, examinations to patients in this age group should only be done when absolutely required and then only with the most optimal of radiographic techniques. These techniques should include the radiation worker applying dose optimisation principles to the best of his/her ability. Dose optimisation includes radiation protection, optimal collimation and optimal exposure parameters (RSA DoH, 1973:8).

In SA, health services are striving to develop and improve service delivery. This objective is driven by educationists at higher education institutions (HEI) during the training of health care professionals (HPCSA, 2008a: 14). In addition to undergoing thorough training, all health care professionals must be registered with the HPCSA. The HPCSA strives to protect the South African public by ensuring good quality care and treatment, delivered by registered health care professionals. This statutory body requires registration as a professional with the required education and training, practising ethical conduct, continuous development of skills and conformation to health care standards, as set out by the SA Health Professions Act (RSA DoH, 1974a: 14-16).

Governmental regulations and codes reflect the emphasis of international as well as local health bodies on the correct imaging of pediatric patients. All these bodies indicate that imaging of pediatric patients, including neonatal patients, should be done only when justified. If such an examination is justified, it should be completed with the correct equipment to ensure the lowest possible radiation dose to the patient, but with the production of an optimal image to ensure optimisation of the examination.

4.2.2 Related research that utilised educational interventions

Hlabangana (2012:14) completed a study involving a short training course (in the form of a poster) with evaluation of pediatric chest image quality before and after the short course. The results of this study showed improved levels of image quality directly after the short course. Two months after the short course a steady decline in image quality was observed. Specific areas identified by Hlabangana (2012:14) for enhancement included poor collimation, incorrectly tilted images and rotation found on images.

In contrast to the study done by Hlabangana (2012:14), a study by Loovere *et al.* (2008:197) found improved image quality one year after completion of an interventional programme. In the study by Loovere *et al.* (2008:197), 93 chest images were evaluated before the interventional programme and 76 chest images were evaluated after the programme by means of the criteria listed in Chapter 2 (Section 2.2.5).

The interventional programme was aimed at radiographers, NICU physicians, NICU nursing staff and advance practice NICU nursing staff. The programme consisted of various short educational sessions, pamphlets and email reminders. A reduction in rotation, improved collimation to the area of interest, more frequent gonadal shielding and a decrease in artefacts were observed one year after completion of the interventional programme.

The above two studies are the only two research studies found by the researcher during the compilation of this dissertation, that utilised educational interventions to address the quality of pediatric or neonatal radiographic images. Literature searches were done with search engines such as Medline, Science Direct and Proquest, using keywords such as image quality, radiation dose, newborn, neonates, lead shielding, radiation protection, criteria, guidelines and international standards. References with some or all of these keywords were found. None of these references had information on a study in SA regarding an intervention for neonatal chest imaging that involves an educational programme focused specifically on improving image quality during the empirical study timeframe (2011 to 2012).

4.3 METHOD TO RE-EVALUATE NEONATAL CHEST IMAGE QUALITY

The initial quality of neonatal chest images produced by radiographers during mobile radiography in the NICUs was determined during the first phase of this study and was discussed in Chapter 2 (Section 2.3). During the final and third phase of the study, the impact of the educational programme (Chapter 3) was determined.

Between August 2012 and December 2012 the researcher paid unannounced visits to the three participating institutions to gather data for this phase of the study. As before, the radiographers were not informed of the time of these visitations but they were aware of the reasons for the visitations. The same number of neonatal chest images was evaluated (450 images, 150 per institution) and the time taken to complete these evaluations was captured in the log book (Appendix Q). The same checklist used during Phase 1 was also used during this phase. This excluded variables and ensured that the data collected from the two phases can be compared.

The only additional exclusion criteria in the sampling protocol (Section 2.3.1.1) was that only mobile neonatal chest images produced by participating radiographers who had completed the educational programme in Phase 2 and consented to participate, were evaluated during Phase 3. These images were identified by the radiographers' identification codes as indicated on the CR system. Hence, a purposive sampling method was utilised during Phase 3 for the neonatal chest images. Strydom (2011:232) described purposive sampling as a sample comprised out of population elements that serve the purpose of the study – the sample is selected with a specific purpose in mind. In this phase, the mobile neonatal chest images evaluated were produced by radiographers that completed the educational programme and were therefore purposively selected.

4.3.1 Statistical analysis

The statistical analysis of Phase 3 of the study was similar to that of Phase 1, described in Chapter 2 (Section 2.3.4). The data for Phase 3 are displayed and summarised in graphs. Descriptive statistics, namely frequencies and percentages, were calculated for categorical data. Means and standard deviations or medians and percentiles were calculated for numerical data. Frequencies or median values from Phases 1 and 3 were compared using either the Chi-Square test or the Krushal-Wallis test.

The Chi-square test was used to determine whether there was a significant difference between the recorded frequencies. This test should be applied to quantitative data, there should be one or more category in the data, the sample should be of an adequate size (more than 10), simple sampling is preferred, data must be shown in frequency form, and all observations must be used (Maben, 2014:online).

The Kruskal-Wallis test evaluates differences between median values. This test requires three or more conditions. This test will indicate whether the differences between Phase 1 and Phase 3 data are large enough to eliminate chance as the only cause of difference (Hole, 2011:online).

According to Viljoen (2014) both the Chi-Square test and the Krushal-Wallis test refer to the ρ–value. A ρ-value larger than 0.05 indicates the absence of a significant difference between the data. On the other hand, a ρ-value smaller than 0.05 indicates that there is a significant statistical difference between the data of Phases 1 and 3.

4.4 QUALITY ASSURANCE OF THE RESULTS FROM PHASE 3

The quality assurance of the results was described in Chapter 1, (Section 1.9) and Chapter 2, (Section 2.4). Visits after completion of the educational programme were unannounced, to ensure that participating radiographers' were not influenced by the researcher during their normal routine practices in the NICU. In addition, radiographers were unaware which images were evaluated during this phase of the study.

As previously indicated only neonatal chest images produced by radiographers who had attended and completed the educational programme were included in this phase of the study. This ensured that the results obtained reflected the impact of the educational programme on image quality and this ensured that the comparison of results is valid.

4.5 RESULTS AND DISCUSSION FOR PHASE 3

The data presentation for Phase 3 is divided into the same eight sections used in Chapter 2 (Section 2.5). No incomplete checklists were found to exclude from the data (Section 2.3.1.1). The data for Phase 3 is discussed as percentages and includes the exact number of images per area.

4.5.1 Demographic information

A total number of 450 neonatal chest images were evaluated during Phase 3 of the study. Of these 450 images, 43.1% (194 images) were of male neonates and 56.9% (256 images) were of female neonates. The median age of these neonates was 23 days, with an inter-quartile range of 9 days (lower quartile) to 37 days (upper quartile). The median number of chest images taken per neonate was 5 chest images, with an inter-quartile range of 2 chest images (lower quartile) to 9 chest images (upper quartile). The maximum number of images taken on a neonate was 31.

4.5.2 Request letter

Table 4.1 summarises the percentages of request letters found in this phase of the study as well as the clinical history indicated on these letters. Request letters were available for 99.1% (446) of the images, as seen in Table 4.1. For these 99.1% of request letters, a clinical history of the neonate was provided for 3.3% (15 images) of the letters, and 96.7% (435 images) of these letters had no clinical history indicated.

Table 4.1: Request letter and clinical history available

Available	Percentage
No request letter provided	0.9%
Request letter provided	99.1%

Available	Percentage
Clinical history provided	3.3%
No clinical history provided	96.7%

4.5.3 Radiographic position

The five specific criteria evaluated in this part of the checklist are summarised in Figure 4.1 as percentages. As can be seen on this figure, rotation was evident in 61.3% (276) of the images, with 28.9% (130 images) free of any rotation, and 9.8% (44 images) exhibiting partial rotation. The additional rotated, observed anatomical structure was the skull: visible in an oblique position in 31.8% which is 14 images of the partially rotated images or in a lateral position in 68.1% which is 30 images the partially rotated images.

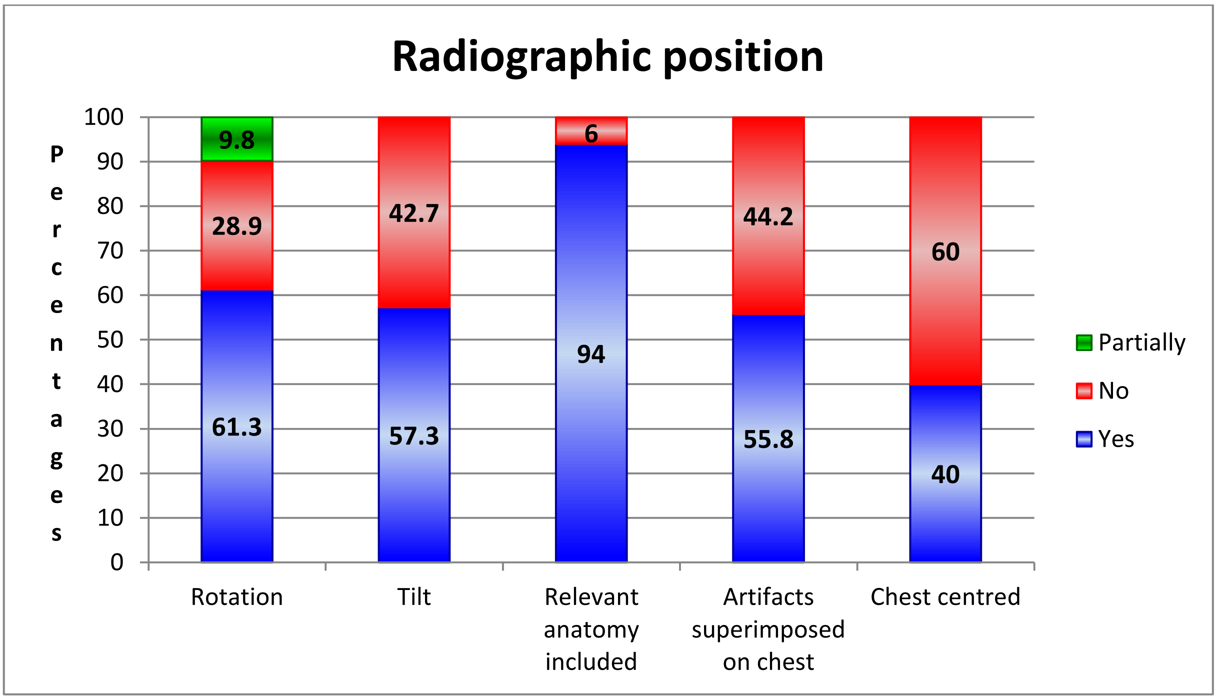


Figure 4.1: Radiographic position

The next criterion presented on Figure 4.1, after rotation, is tilt. On the neonatal chest images correct tilt was indicated in 57.3% (258) of the images, and incorrect tilt in 42.7% (192) of the images. All relevant anatomy was included in 94% (423) of the images and in 6% (27 images) some of the important anatomy was excluded (Figure 4.1). Figure 4.2 illustrates the percentage of anatomy that was excluded from these 27 images. The anatomy structures excluded on 74% or 20 of the images were the right (29.6% or 8 images) and left (44.4% or 12 images) costophrenic angles. In addition, 22.2% or 6 images showed exclusion of the lung apices. One image (3.7%), the lung apices, left costophrenic angle and a section of the left lung field was excluded.

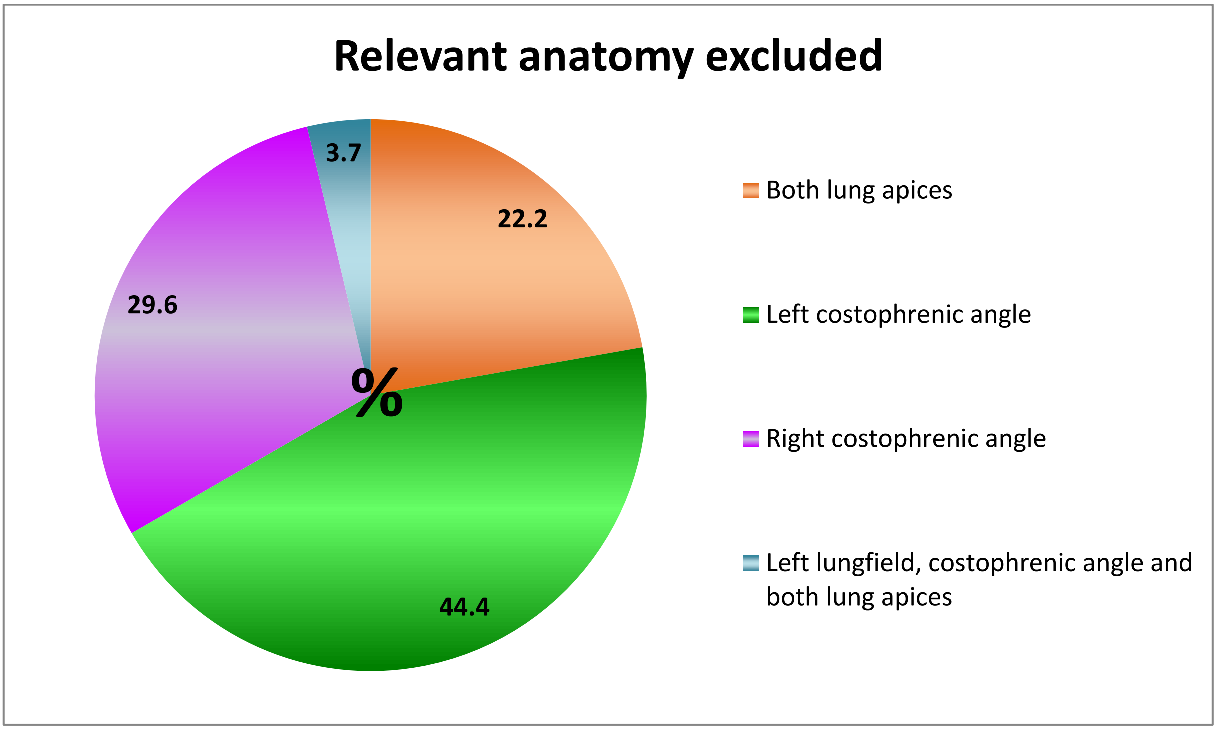


Figure 4.2: Relevant anatomy excluded

Figure 4.1 shows that, in 55.8% (251) of the images artefacts were superimposed on the chest anatomy, while 44.2% (199) of the images were free from artefact superimposition. Artefacts that were found to superimpose chest anatomy on 251 images are summarised in Figure 4.3 as percentages. ECG lines were found superimposed on chest anatomy in 41.8% or 105 images, the mandible of the neonates was found superimposed over lung apices in 33% or 83 images. The remaining 25.2% or 63 images with artefacts were related to oxygen masks or tubes (1.6% or 4 images and 12.4% or 31 images respectively), staff members' hands immobilising the neonate (6.8% or 17 images), or clavicles (4.4% or 11 images).

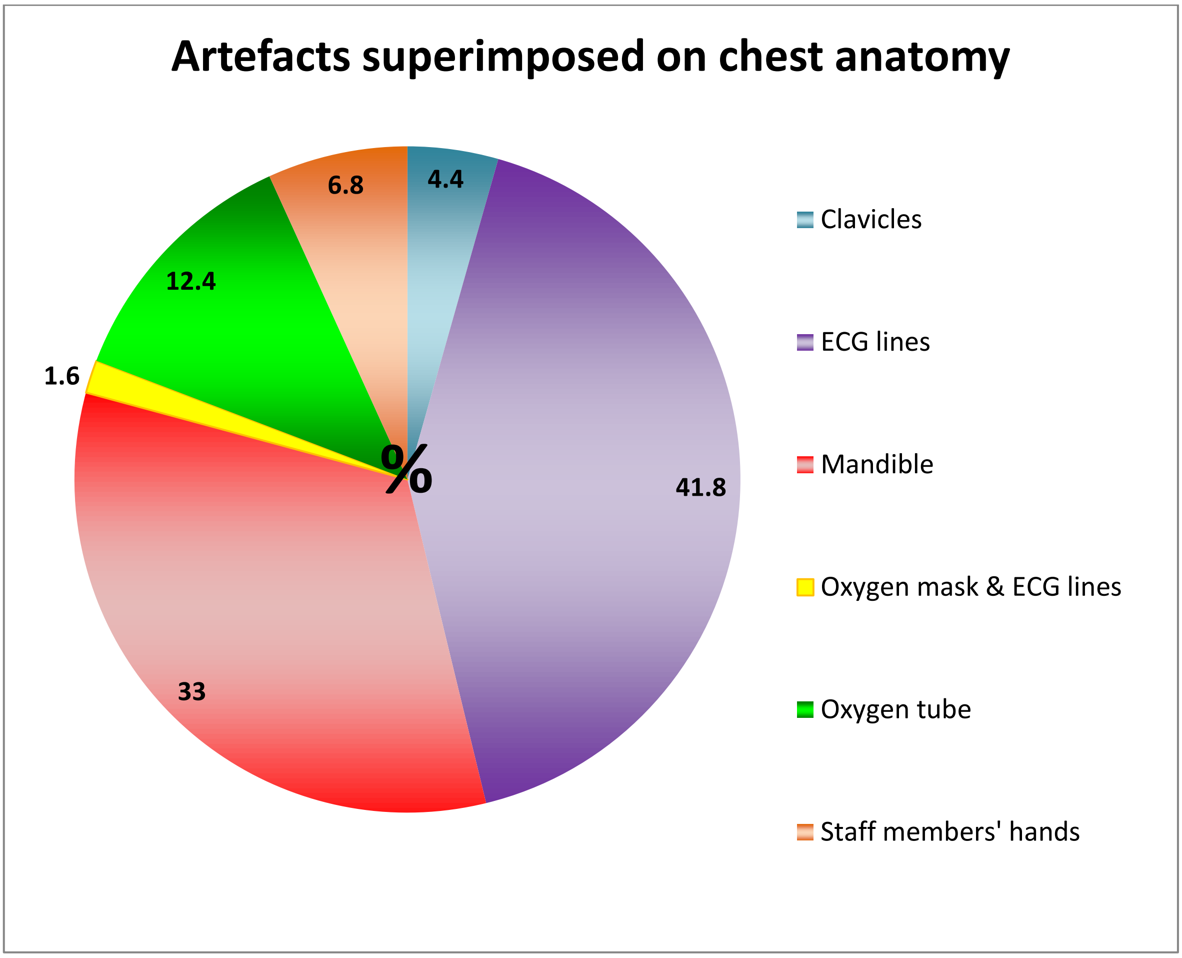


Figure 4.3: Artefacts superimposed on chest anatomy

As illustrated in Figure 4.1, the centring was correct in 40% or 180 images. Figure 4.4 demonstrates the percentage anatomical areas found in the centre of incorrectly centered images, which represented 60% or 270 images. As can be seen in 100% or all 270 images, the centring was inferior to the required centring point of thoracic vertebra four (Loovere *et al.*, 2008:201). Lumber vertebrae two and three in the centre of 10.1% or 28 images, thoracic vertebra 12 in the centre of 30.9% or 84 images, thoracic vertebra nine in 29.5% or 79 images and thoracic vertebra seven in 29.5% or 79 images.

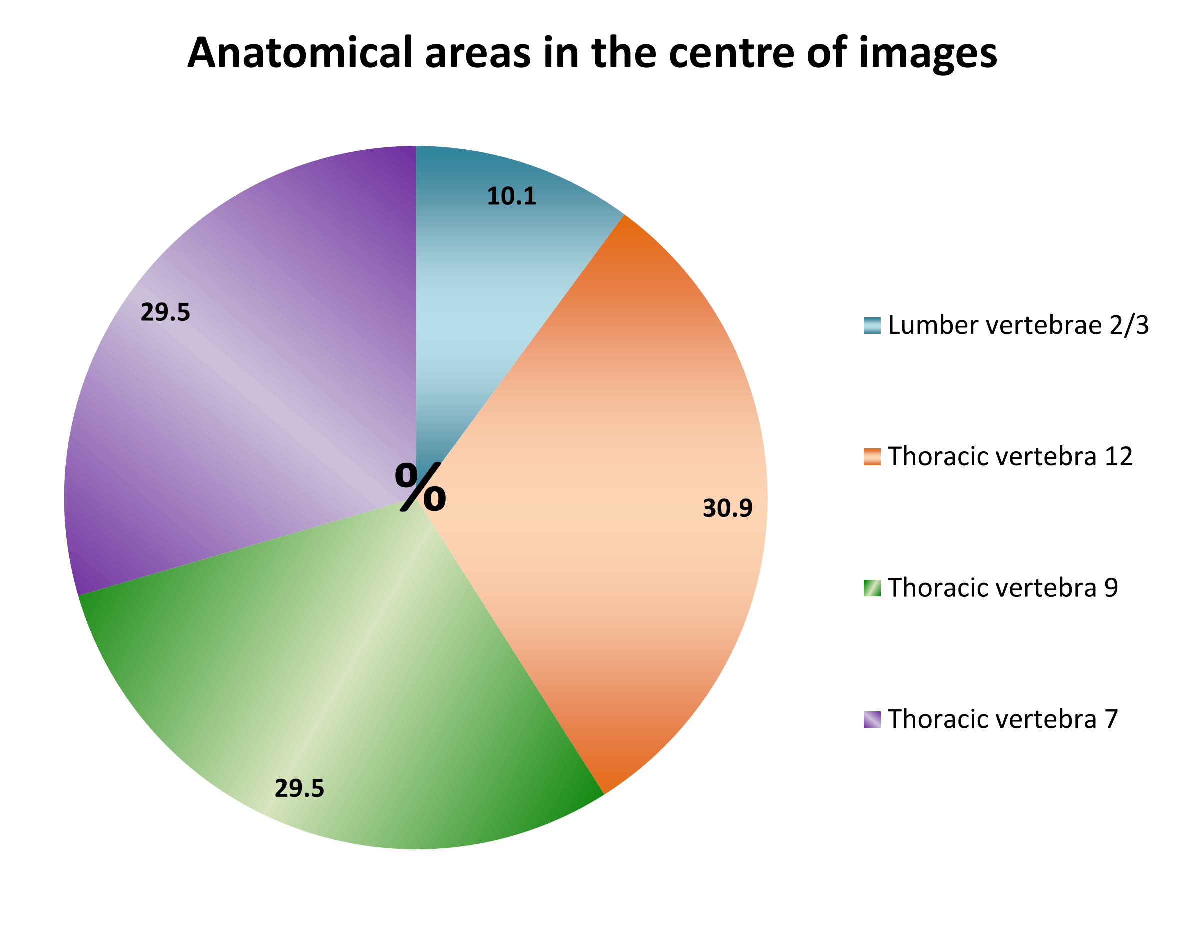


Figure 4.4: Anatomical areas in the centre of images

4.5.4 Breathing techniques

Figure 4.5 illustrates the results for the evaluation of the breathing techniques as percentages. From this figure it can be seen that the correct suspended inspiratory breathing technique was present in 43.1% or 194 images. The incorrect techniques were seen in 56.9% or 256 images; this percentage can be divided into 35.1% or 158 images for normal breathing (respiration) and 21.8% or 98 images for suspended expiration.

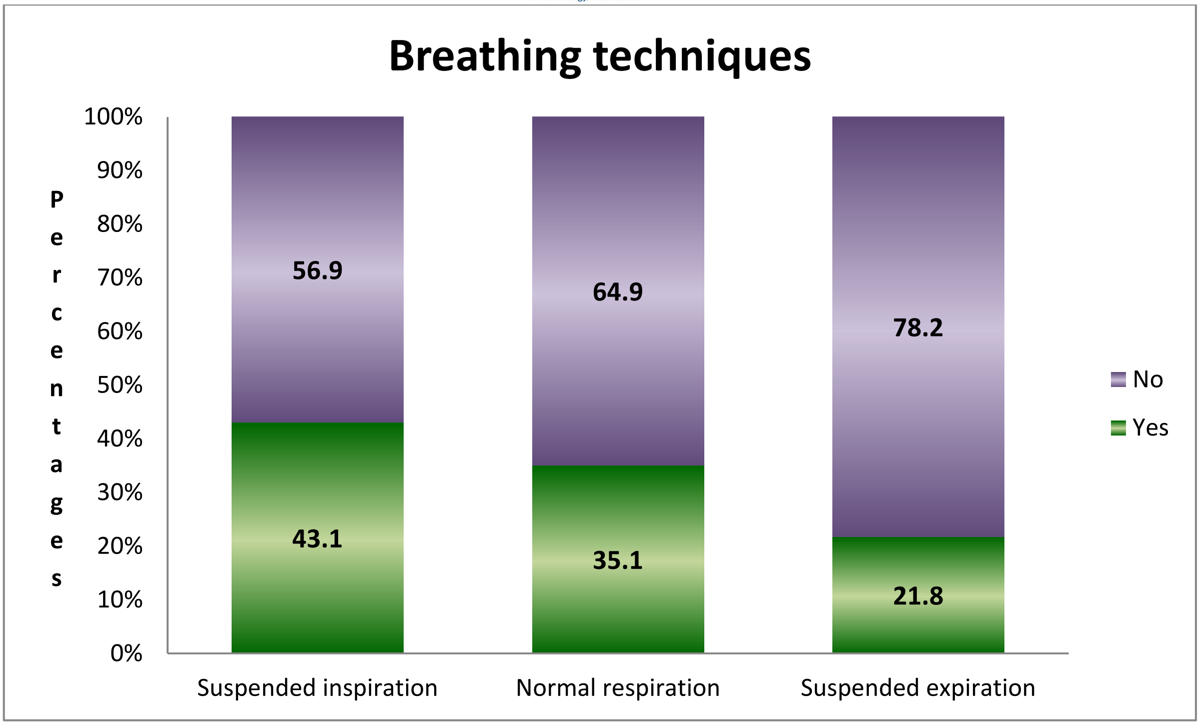


Figure 4.5: Breathing techniques

4.5.5 Lead marker and radiation protection

Figure 4.6 illustrates that, in 36.9% or in a 166 images, a lead marker was present on the image. In 32.4% (146) of these images the lead markers were placed correctly. Lead shielding was visible on 1.11% or 5 images.

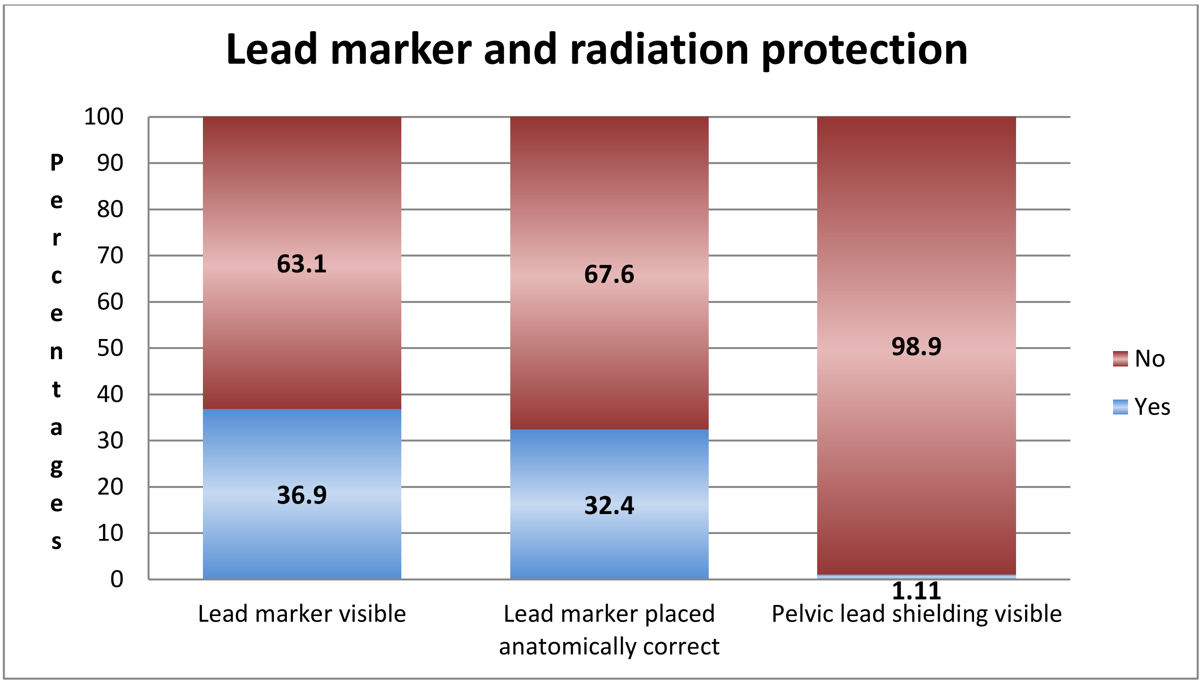


Figure 4.6: Lead marker and radiation protection

4.5.6 Exposure parameters

The images were evaluated in their original static setting on the CR-system, before any window width or window level manipulation. The four criteria that evaluate lung tissue are summarised in Figure 4.7 as percentages. In 59.1% or 266 images the vascular pattern in the central half of the lungs was visible and in 59.1% or 266 images the parenchymal marking throughout the lungs were visualised. The proximal bronchi were visible in 78.9% or 355 images while the retrocardiac lung was visualised in 61.3% or 276 images.

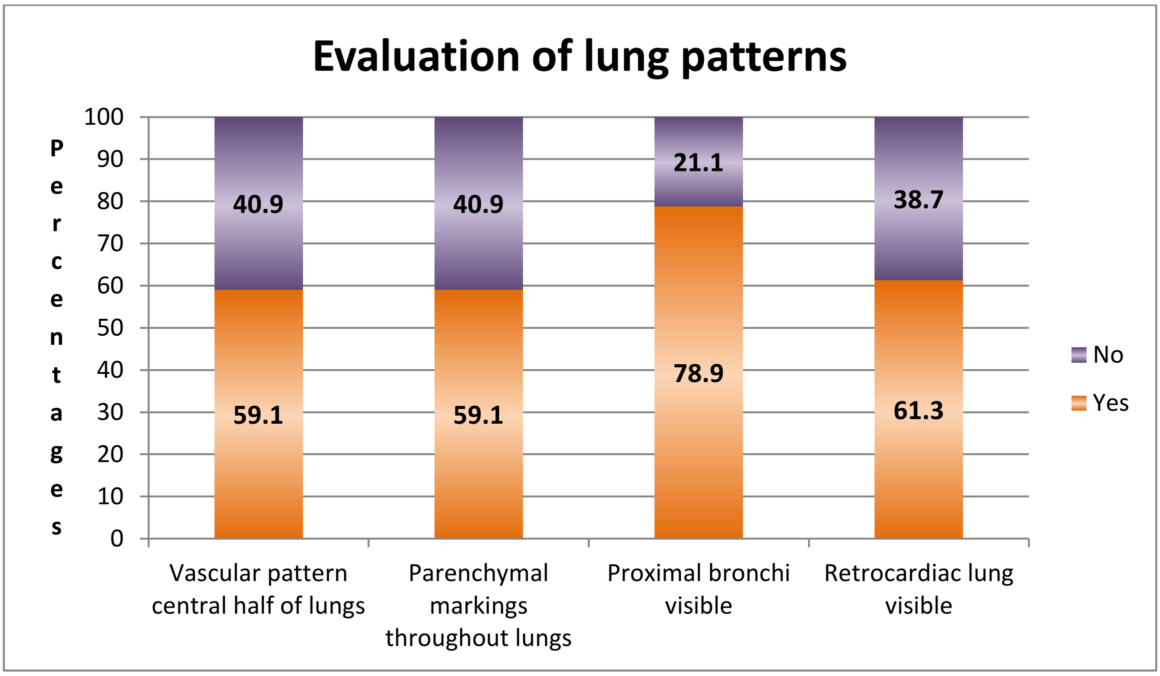


Figure 4.7: Evaluation of lung patterns

Next, the five criteria that evaluated the penetration and visibility of important structures are summarised in Figure 4.8 as percentages. The trachea was visible in 79.8% or 359 images, which correlates with the mediastinum, which was visible in 77.3% or 348 images. The spine and paraspinal structures were visible on 86.2% or 388 images, with the diaphragm and costophrenic angles visualised in 98.4% or 443 images. Furthermore, added catheters were visualised in 97.8% or 440 images.

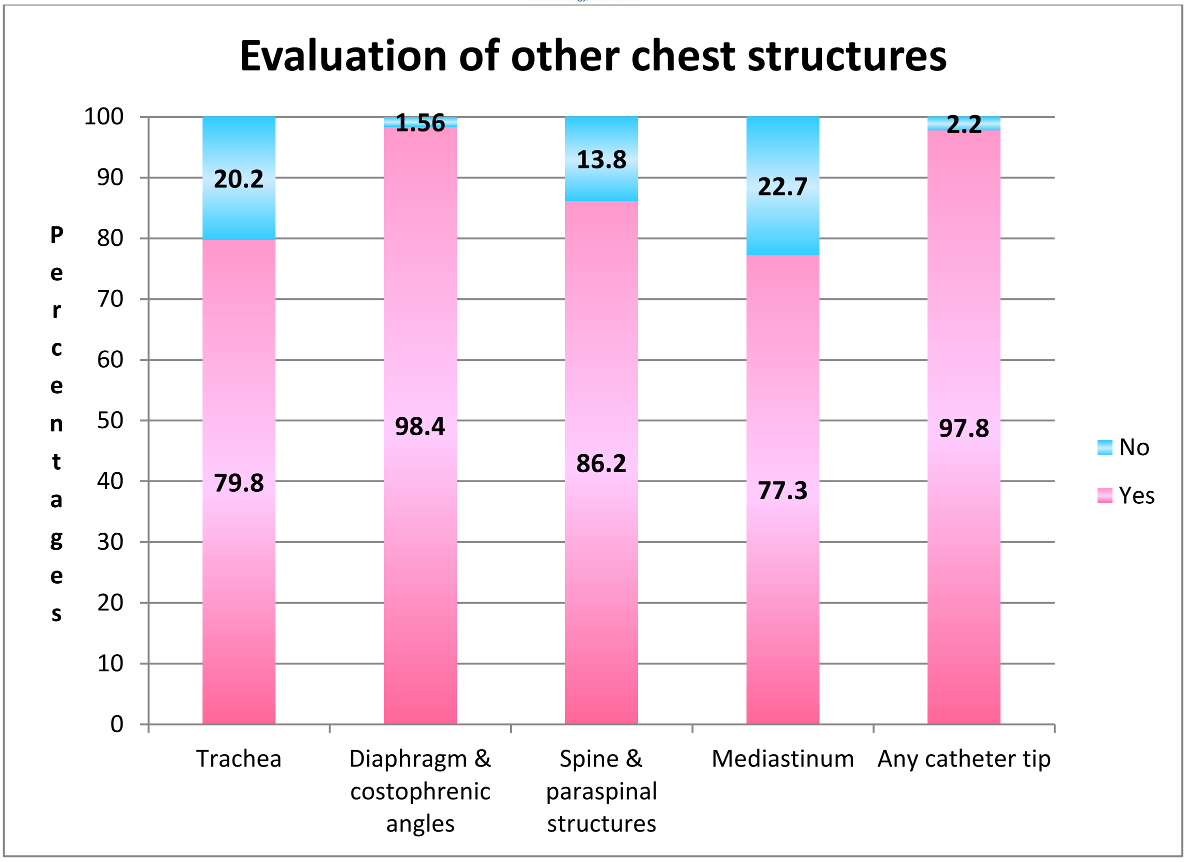


Figure 4.8: Evaluation of other chest structures

The last criteria summarised the overall perception obtained from the image visibility in relation to the selected exposure parameters and captured exposure index on the image. Figure 4.9 summarises the observed data for these two criteria as percentages. When evaluated with the naked eye optimal exposure parameters were seen in 63.6% or 286 images. Furthermore, 41.1% or 185 images the exposure indices observed on the images were in the recommended range, which is discussed shortly.

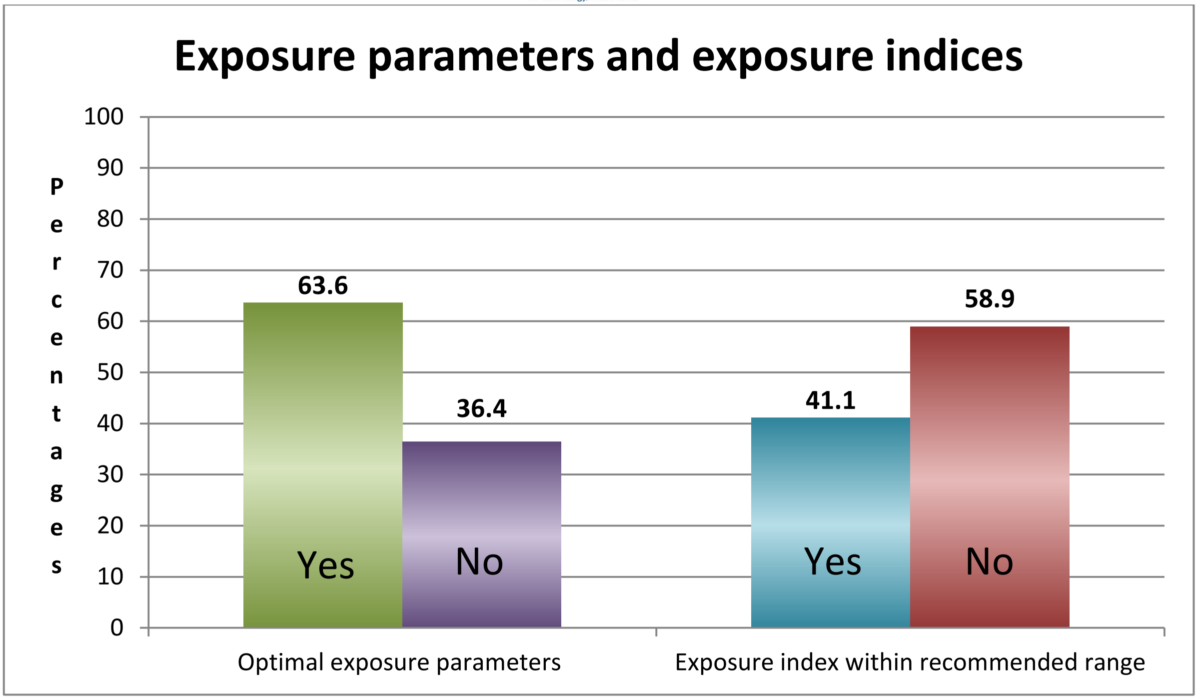


Figure 4.9: Exposure parameters and exposure indices

This finding is in line with the disconnection between acquisition and display recorded in CR systems, as discussed in Chapter 1 (Section 1.2). Willis and Slovis (2004:373) established that mechanical rescaling of the images to provide a relatively consistent appearance ensures that a visual evaluation of the image will be acceptable, as proven by the finding that 63.6% or 286 images could be described as optimal, when evaluated with the naked eye. However this mechanical rescaling means that the traditional feedback mechanism of density, which is familiar to radiographers, is arbitrary and meaningless in CR systems (Willis and Slovis, 2004:373). Evaluating EI values is a more accurate and acceptable way to evaluate the exposure parameters utilised in CR systems (Seibert and Morin, 2011:573-574). Hence the recorded 41.1% or 185 images is the more accurate finding in relation to exposure parameters utilised – it means that 41.1% or 185 images reflected the optimal exposure parameters.

For the 36.4% or 164 images reported as incorrectly exposed in Figure 4.9, 62.8% or 103 of these images were seen as overexposed and 37.2% or 61 images were seen as underexposed, as illustrated in Figure 4.10 as percentages.

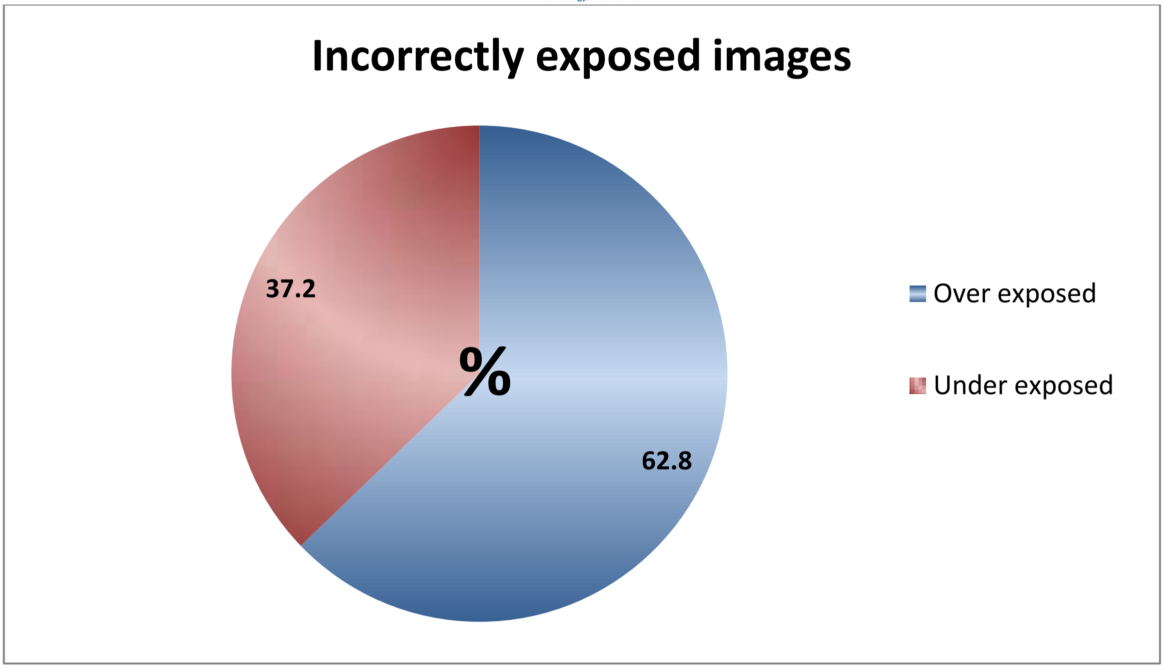


Figure 4.10: Incorrectly exposed images

In relation to exposure indices, the specific value for each image was documented. The three participating hospitals utilised CR systems manufactured by different companies, two institutions used Agfa systems (LGM value) and one institution used a Kodak system (EI value). Each system utilises a different exposure index feedback mechanism, as discussed in Chapter 2, (Section 2.5.6). In this phase of the study 300 images with LGM values were evaluated. The median LGM value for these images was 2, with an inter-quartile range of 1.9 (lower quartile) to 2.6 (upper quartile). The median EI value for the remaining 150 images was 1 690, with an inter-quartile range of 1 490 (lower quartile) to 1 870 (upper quartile).

4.5.7 Collimation

The next part of the checklist evaluated the collimation and the anatomical structures included in the collimation field. Figure 4.11 illustrates the percentile data from this part of the checklist. As can be seen, four-sided collimation was recorded in 34.7% or 156 images. The images evaluated in Phase 3 of the study included most of the required anatomical structures inside the four-sided collimation namely, superior cervical vertebra number seven was seen on 98.4% or 443 images, inferiorly the costophrenic angles were found on 95.3% or 429 images, and bilaterally the shoulders were included on 99.8% or 449 images. In addition, both lung fields were included on 94% or 423 images.

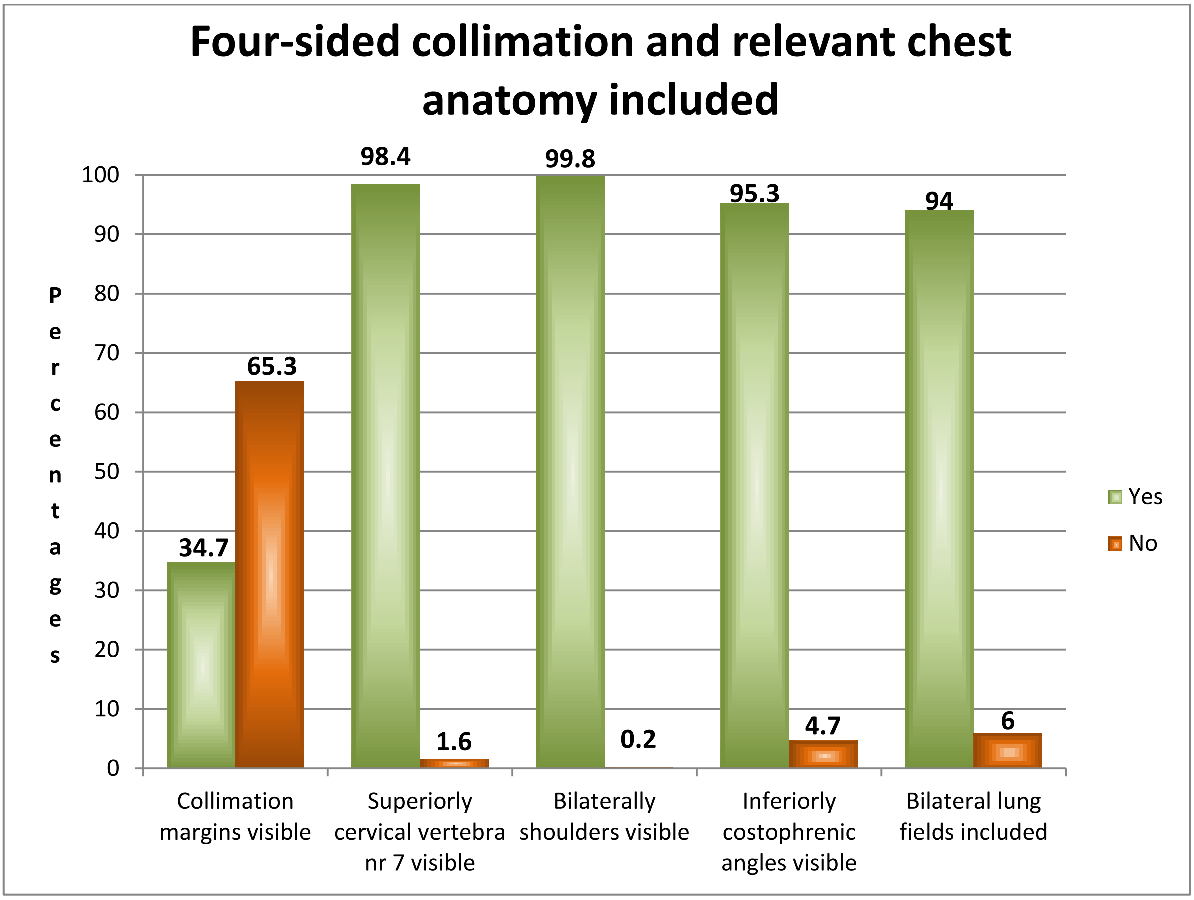


Figure 4.11: Four-sided collimation and relevant chest anatomy included

As shown in Figure 4.11, 1.6% or 7 images did not include cervical vertebra number seven; both the apices of the lung fields were excluded on these images. On the 0.2% or 1 image that did not include the shoulders bilaterally, the left shoulder with underlying lung fields was excluded. The 4.7% or 21 images that did not include costophrenic angles is illustrated in Figure 4.12 as percentages, which shows that 62% or 13 images did not include the left costophrenic angle and 38% or 8 images did not include the right costophrenic angle.

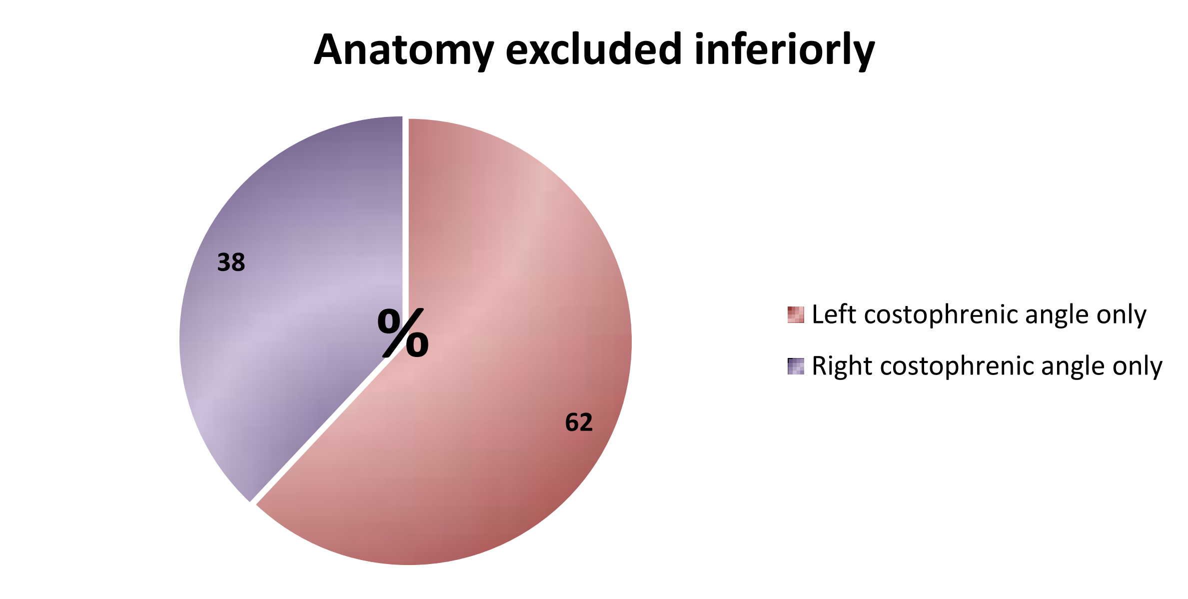


Figure 4.12: Anatomy excluded inferiorly

Figure 4.13 illustrates the percentages of additional anatomical structures included on the images evaluated during Phase 3. Figure 4.13 shows that 64% or 288 images included additional anatomy above cervical vertebra number seven. Figure 4.14 summarises the percentages of anatomical structures that were additionally included on the 288 images (64%) indicated in Figure 4.13.

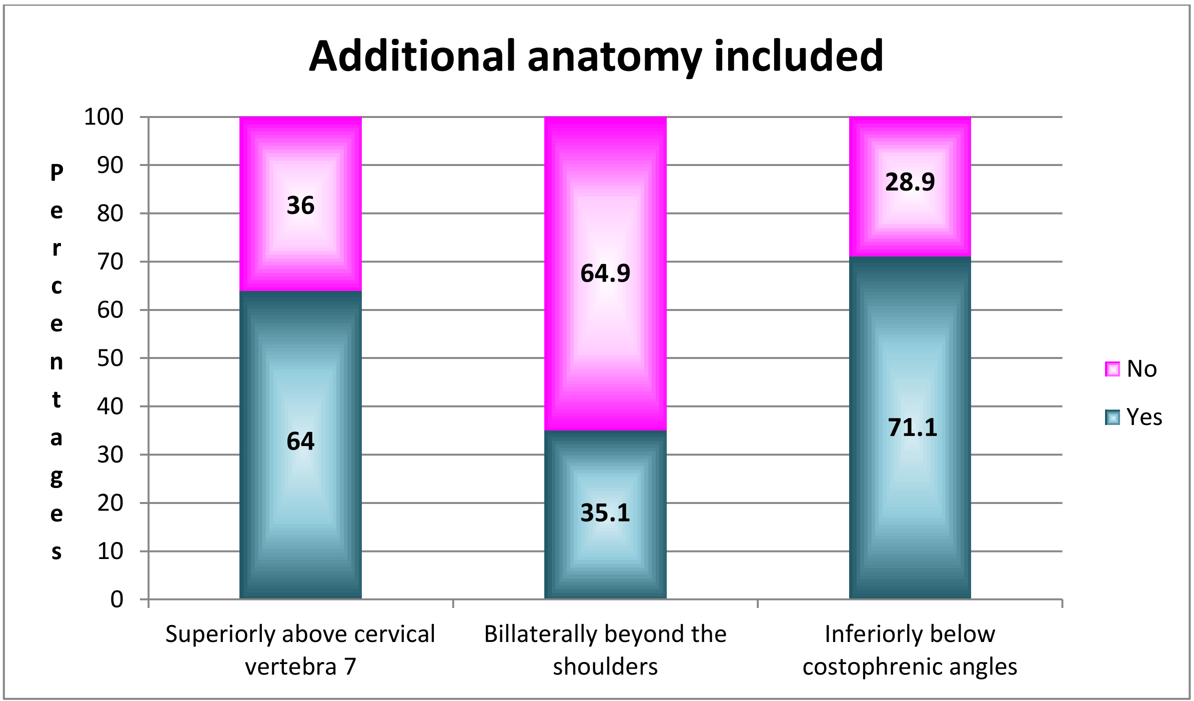


Figure 4.13: Additional anatomy included

Figure 4.14 shows that 266 images (92.3%) involved three additional structures, namely, the cervical spine (33.6% or 97 images), mandible (33.2% or 96 images) and skull (25.5% or 73 images). Cervical vertebra four was additionally included on 7.7% or 22 images.

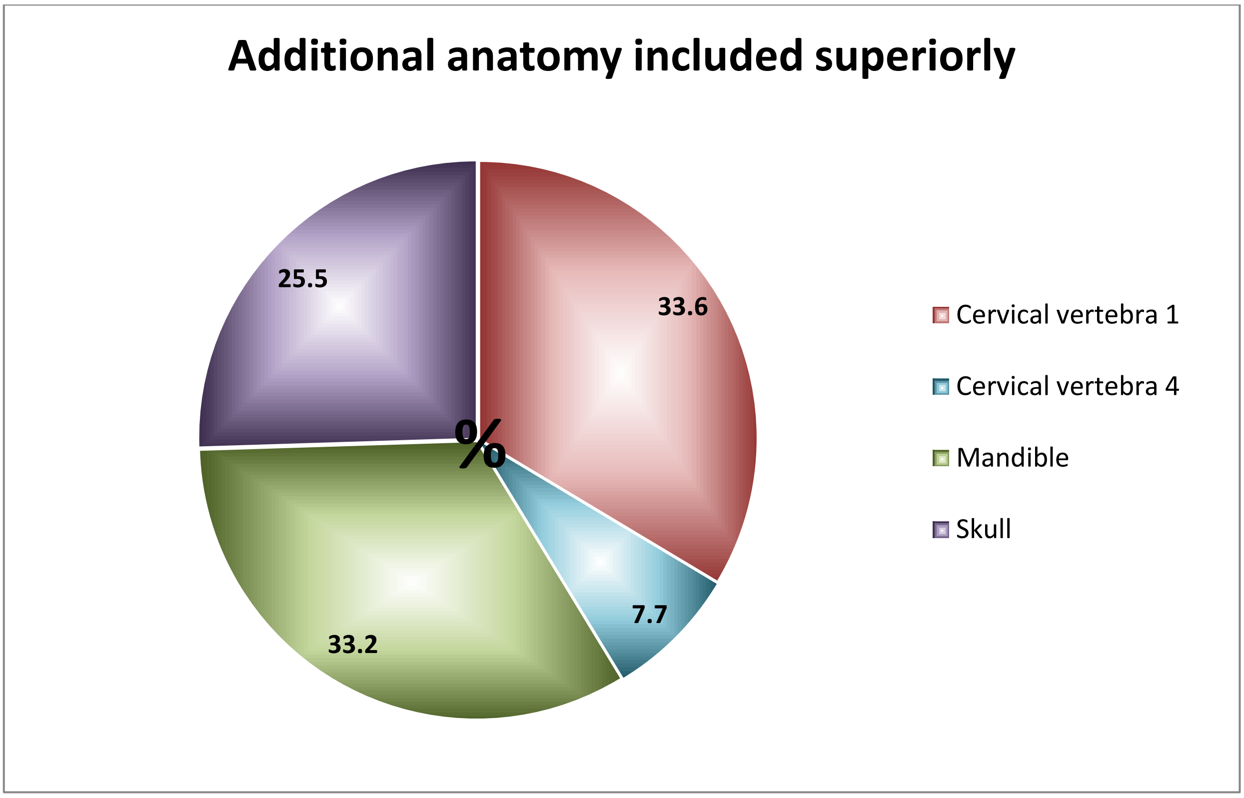


Figure 4.14: Additional anatomy included superiorly

Referring back to Figure 4.13 it shows that 35.1% or 158 images included additional anatomy and/or structures lateral of the shoulders. The specific additional anatomy and/or structures included laterally on the 158 images is summarised in Figure 4.15 as percentages. In 81 images (51.3%) the humeri were included. Both the elbows and humeri were included in 17.1% or 27 images. From the fingers to the humeri was included in 16.5% or 26 images. A staff member's hands were visible on 15% or 24 images. Staff members' hands were visible superimposed on elbows (3.2% or 5 images), entire arms (5.7% or 9 images) and the humeri (6.3% or 10 images).

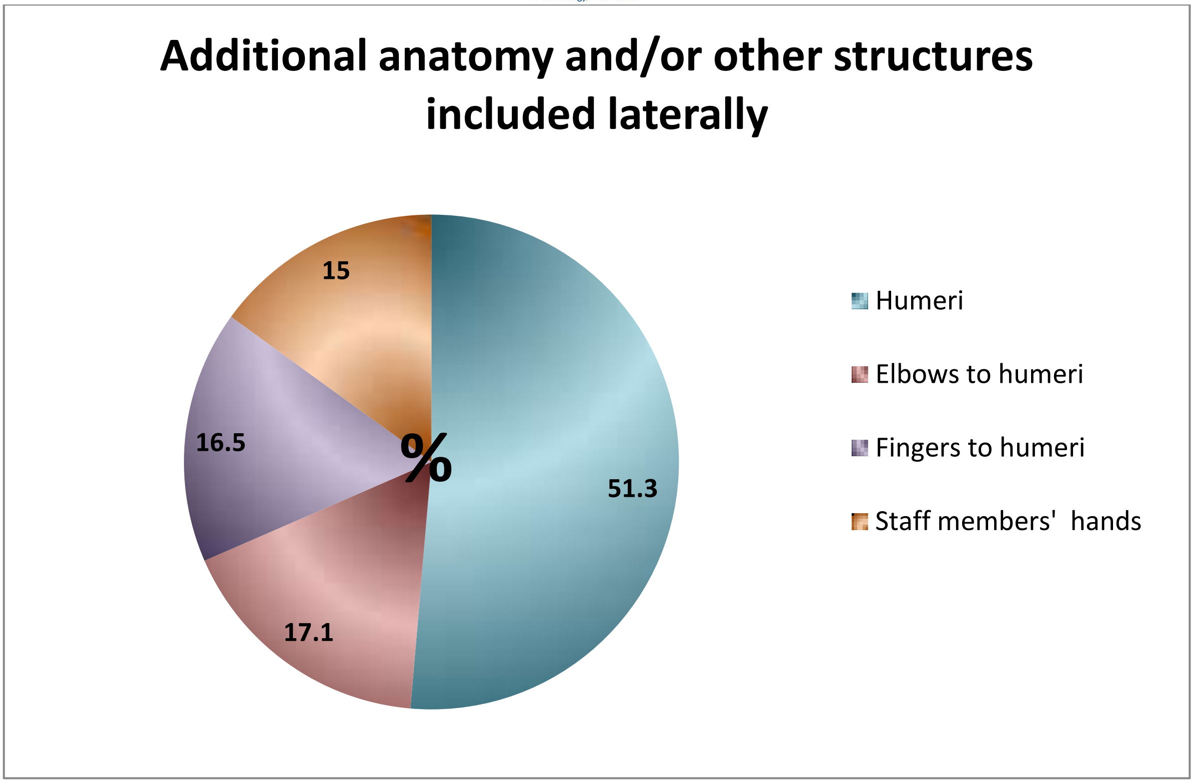


Figure 4.15: Additional anatomy and/or other structures included laterally

Lastly, Figure 4.13 also indicates that 71.1% or 320 images showed additional anatomy included inferior to the costophrenic angles. Figure 4.16 summarises the additional anatomy included inferiorly on these 320 images as percentages. The leading additional anatomy included inferiorly are the iliac crest of the pelvis (28.8% or 92 images), the whole pelvis (20% or 64 images), and femurs from above the knees superiorly (18.1% or 58 images) and from lumber vertebra three superiorly (16.9% or 54 images). The remaining 16.3% (52 images) of additional anatomy included are the lower costal margin (3.8% or 12 images), knees (7.8% or 25 images) and feet (4.7% or 15 images).

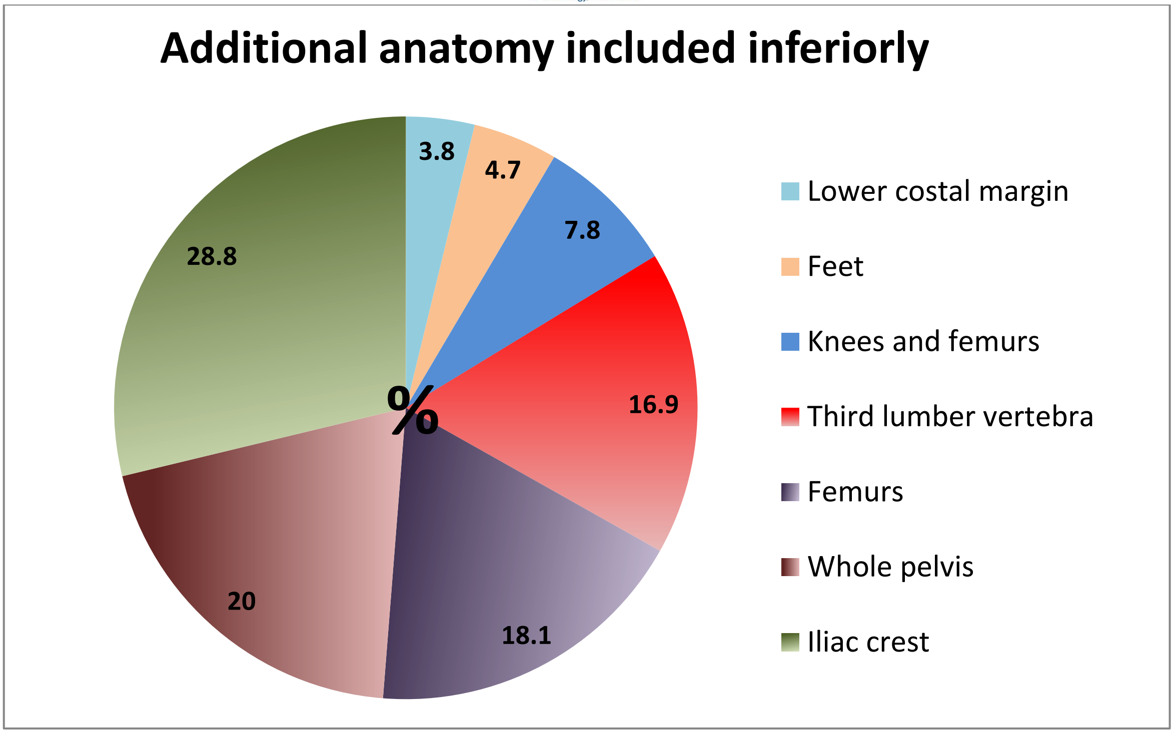


Figure 4.16: Additional anatomy included inferiorly

4.5.8 Final evaluation by the radiographer

Figure 4.17 illustrates the percentages for the final evaluation of images by the radiographers.

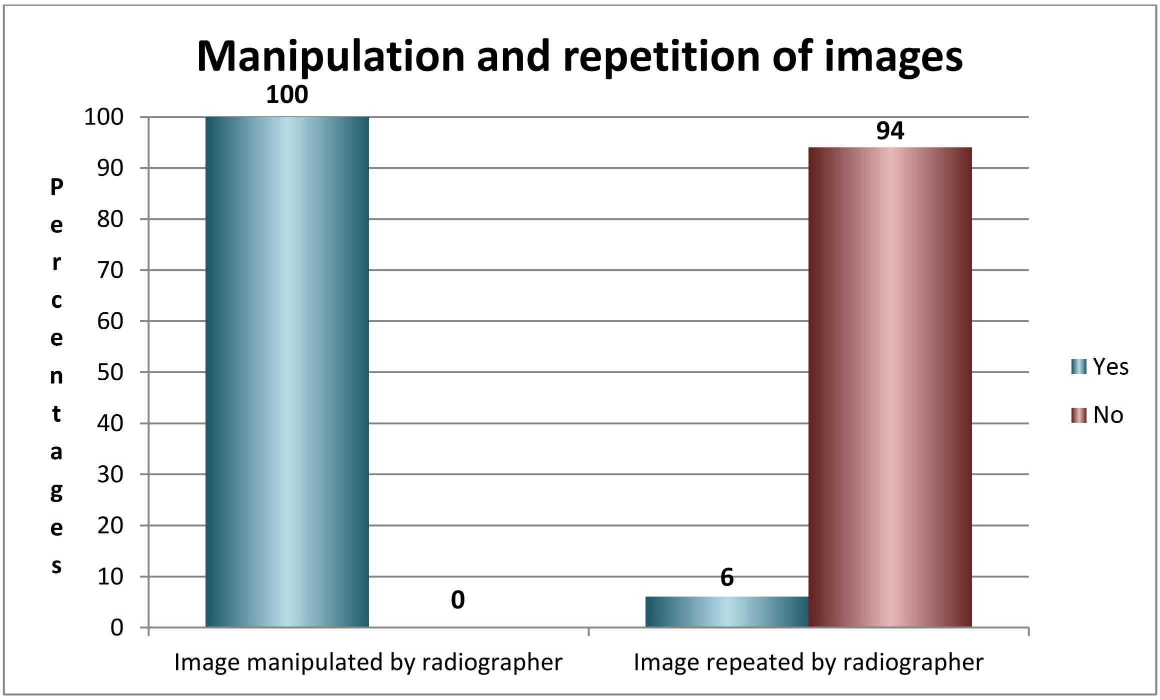


Figure 4.17: Manipulation and repetition of images

In 100% (450) of the images the radiographers manipulated the images. Only 6% or 27 images were repeated – the reasons for repeating the images are summarised in Figure 4.18 as percentages. The 27 images were repeated when a costophrenic angle right (29.6% or 8 images), left (48.1% or 13 images) or apices (22.2% or 6 images) were not included.

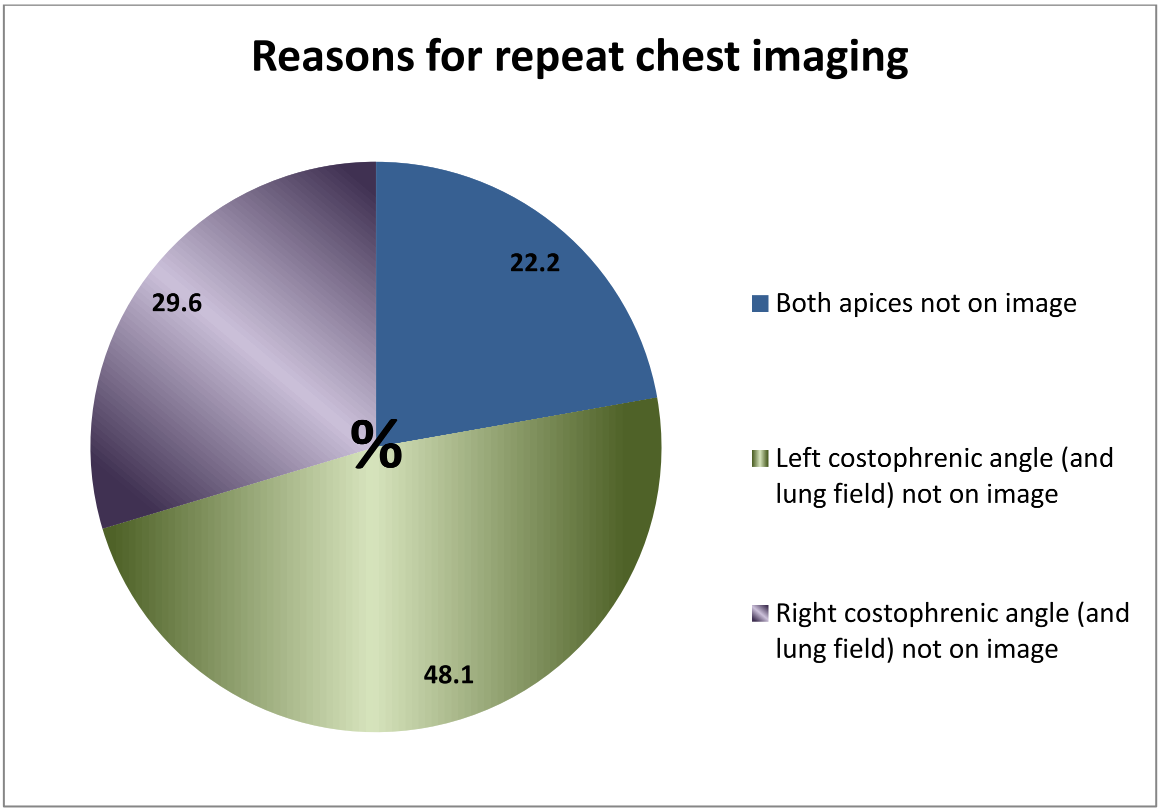


Figure 4.18: Reasons for repeat chest imaging

4.6 DISCUSSION OF THE RESULTS OBTAINED FROM PHASES 1 AND 3

The descriptive statistics were calculated separately for Phase 1 (pre-intervention) and Phase 3 (post-intervention), as explained in Chapter 2 (Section 2.5) and Section 4.5. The comparative data will now be displayed in graphs according to the statistical analysis and the recorded ρ-values discussed. The data will be compared by means of the same sections used for the data of Phases 1 and 3, as explained in Chapter 2 (Section 2.5) and Section 4.5.

4.6.1 Demographic information

In each of Phases 1 and 3 450 chest images were evaluated, the total was achieved by evaluating 150 images per participating institution. Hence the n-value for all the demographical information for both phases was 450.

The average or median age of the neonatal patients whose images were evaluated is shown in Figure 4.19. The median age in Phase 3 (23 days) was higher than that of Phase 1 (8 days). The ρ-value, calculated by means of the Krushal-Wallis test, was less than 0.001, indicating that median ages of the two phases differed significantly. As mentioned in Section 2.2.1; older neonates are much more stable than younger neonates; they can control their body temperature better and are also less susceptible to disease processes (March of Dimes, 2010:online). Hence, neonates subjected to imaging in Phase 3 should have been easier to work with than the neonates of Phase 1. The researcher expectation, based on the median age, is that radiographers would have found the positioning techniques easier to apply because they were working with older neonates, who are less unstable and less at risk than the neonates they worked with in Phase 1.

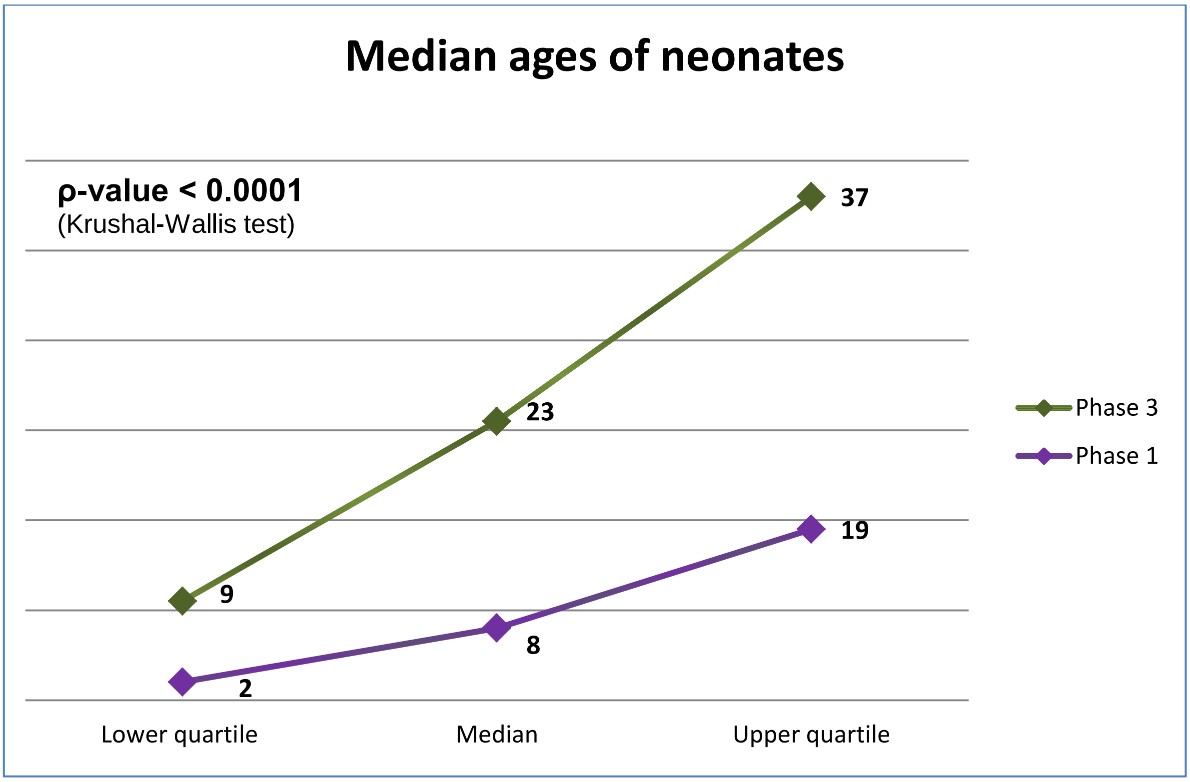


Figure 4.19: Median ages of neonates

Figure 4.20 summarises the gender of neonates involved in the two phases, expressed as percentages. The male female distribution in Phases 1 and 3 is similar: 55.5% versus 56.9% for female neonates and 44.4% versus 43.1% for male neonates). This is confirmed by the ρ–value of 0.69, which indicates no significant difference between the gender distributions of the two phases. The ρ–value was calculated with the Chi-Square test.

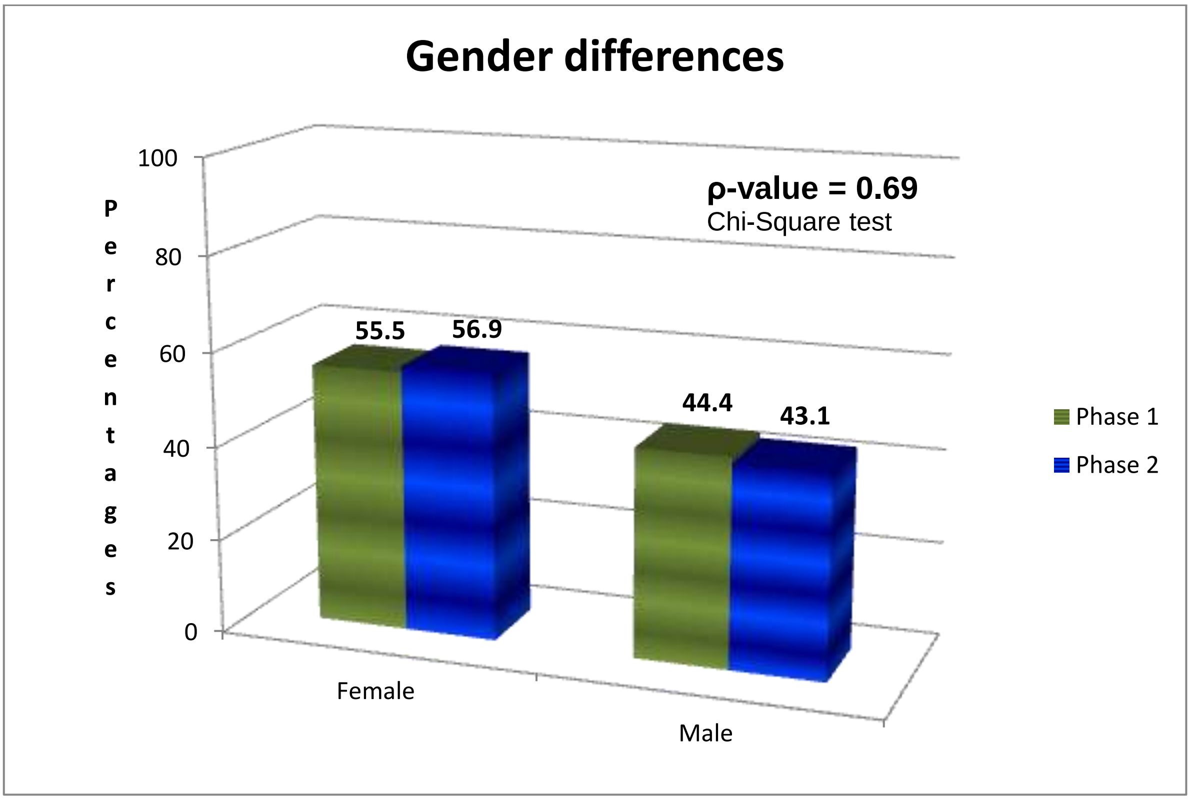
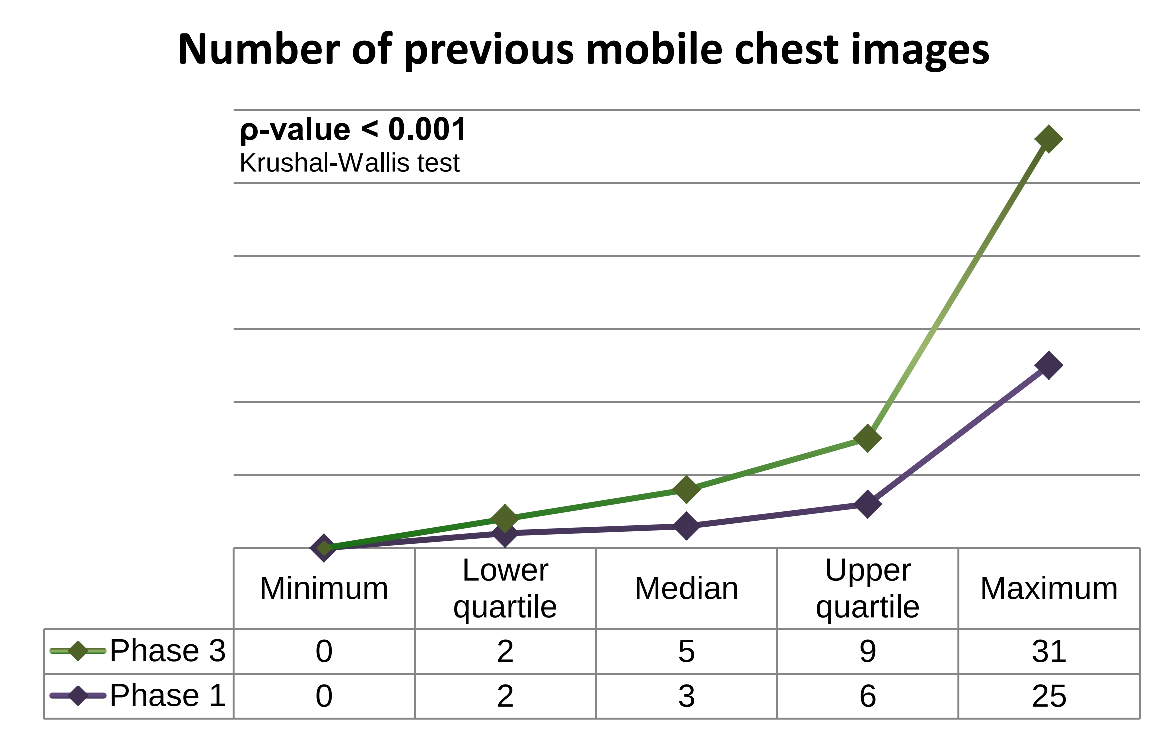


Figure 4.20: Gender differences

The number of previous mobile chest images done on each neonate was also recorded in each phase. This gives the reader a general idea regarding the frequency by which neonates received chest images while they were in the NICU. As stated in the literature review of Chapter 2 (Section 2.2.3), the radiation dose given to neonates during their stay in the NICU should be limited to a minimum, because of the increased possibility of detrimental effect manifestations (Pedrosa de Azevedo *et al.*, 2006:1 637; Dougeni *et al.*, 2007:807; Loovere *et al.*, 2008:198). The median number of previous images that were taken on neonates in the two phases is displayed statistically in Figure 4.21, as is the ρ–value calculated with the Krushal-Wallis test.



	Minimum	Lower quartile	Median	Upper quartile	Maximum
Phase 3	0	2	5	9	31
Phase 1	0	2	3	6	25

Figure 4.21: Number of previous mobile chest images

The average (median) number of images that were taken of neonates during their stays in the NICU was 3 and 5 images, for Phases 1 and 3 respectively. This correlates with findings by Hellwig and Wilson (2013:1), who found a median number of 5 images in their neonatal chest image study. The higher median number for images taken in the third phase of the current study could be due to the fact that the median age of the neonates included in this phase is higher (23 days compared to 3 days for the first phase). This indicates that neonates included in Phase 3 were in the NICU longer than those of Phase 1, and were therefore subjected to a greater number of images than neonates of the first phase. This significant difference in the number of previous images produced during the two phases is confirmed by a ρ-value smaller then 0.001.

The inter-quartile range, which indicates the middle distribution of the data collected, indicates that half of these neonates received at least two, and up to a maximum of nine images while they were in the NICU during Phase 3. This can be considered as a high number of images produced per neonate, if taken into consideration their sensitivity to radiation, as mentioned above. Dougeni *et al.* (2007:807) also recorded a high number of images produced, and the authors explain that the number increases as the severity of the pathological condition increases.

4.6.2 Request letter

According to Bontrager and Lampignano (2014:24), a mobile radiography examination should be justified by a request letter that sets out the clinical history of the patient. A radiographer plans the collimation, centring and exposure parameters according to the clinical history provided (Bontrager and Lampignano, 2014:24). The data gathered during Phases 1 and 3 in relation to the availability of request letters with clinical history completed, is shown in Figure 4.22.

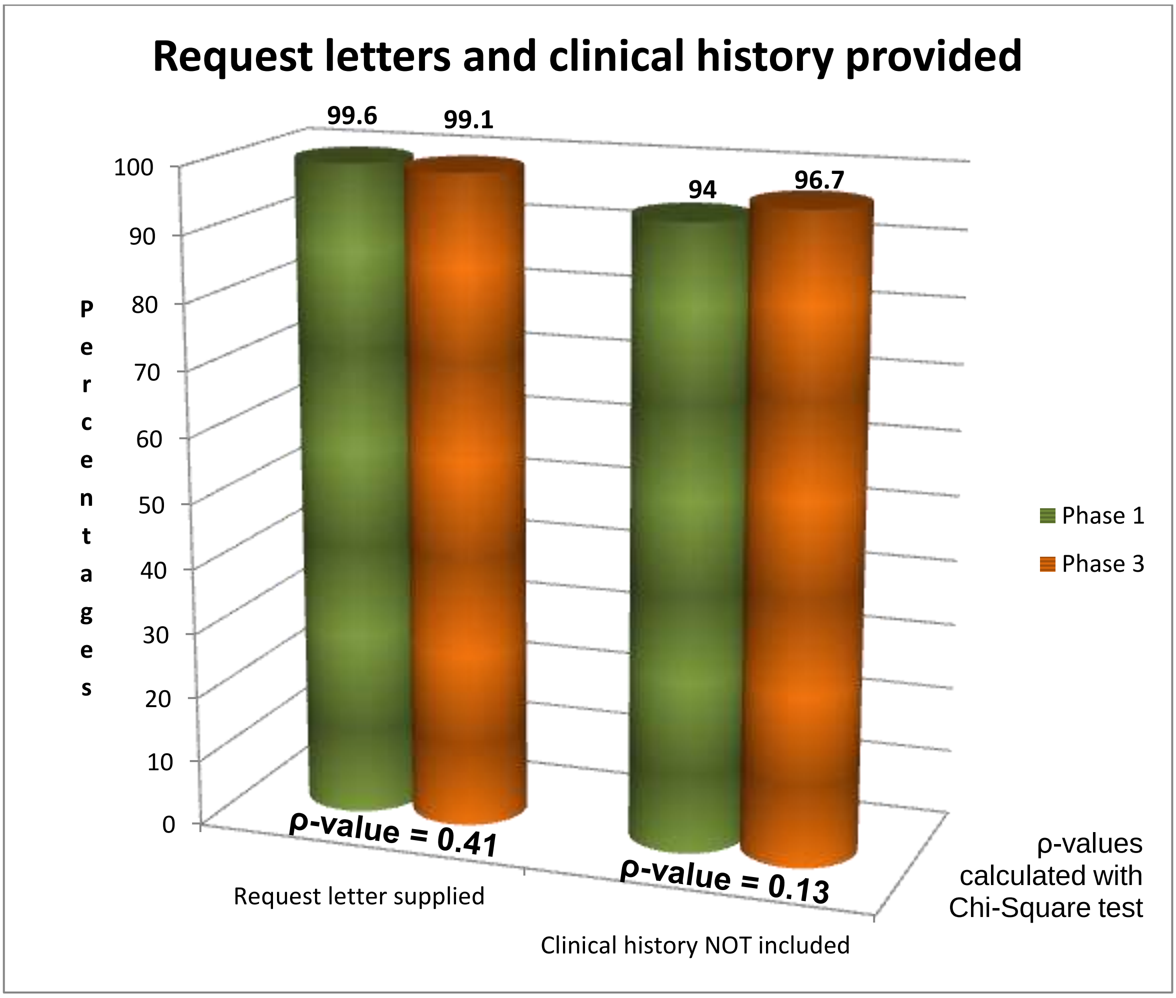


Figure 4.22: Request letters and clinical history provided

Figure 4.22 indicates that request letters were available for most of the chest images produced (99.6% or 448 images for Phase 1 and 99.1% or 446 images for

Phase 3). The ρ–value, calculated with the Chi-Square test, for the availability of request letters was 0.41. This indicates that there was no significant difference between the two phases of the study with regard to the availability of request letters.

In both phases clinical history was not provided with request letters: 94% or 423 images were taken without clinical history in Phase 1 and 96.7% or 435 images in Phase 3. A ρ–value of 0.13 (Chi-Square test) indicates there is no significant difference between the phases. The significance of this data is that the radiographers are producing images without the required justification from the referring physician, and in the absence of information about the expected pathological condition.

4.6.3 Radiographic position

A radiographer should always strive for optimal alignment of the anatomy of the neonate and the image receptor. Furthermore, the image should not exhibit photographic or geometric distortion errors. In order to create an image that is free of these errors, a radiographer must position a neonate optimally (McQuillen Martensen, 2011:121; Carlton and Adler, 2014:451). Figure 4.23 compares the data related to radiographic criteria utilised for positioning in the two phases. No significant difference was found regarding radiographic positioning in Phases 1 and 3, indicated by the ρ–values exceeding 0.05 for all five criteria. These ρ–values were calculated with the Chi-Square test.

Rotation was found more often during the third phase (61.3% or 276 images), after the radiographers had received training in preventing rotation, than in the first phase (56.7% or 255 images), with no noticeable statistical change (ρ-value = 0.20). This indicates that rotation on images did not decrease after the educational programme had been presented. In addition, partial rotation was also present more often in Phase 3 images (9.8% or 44 images) than on Phase 1 images (8.9% or 40 images), with the skull in an oblique position more often in Phase 3 (31.9% or 14 images) than in Phase 1 (10% or 4 images). The number of images with the skull in a lateral position, however, was significantly lower (ρ-value = 0.02) in Phase 3 (68.2% or 28 images) than in Phase 1 (90% or 36 images).

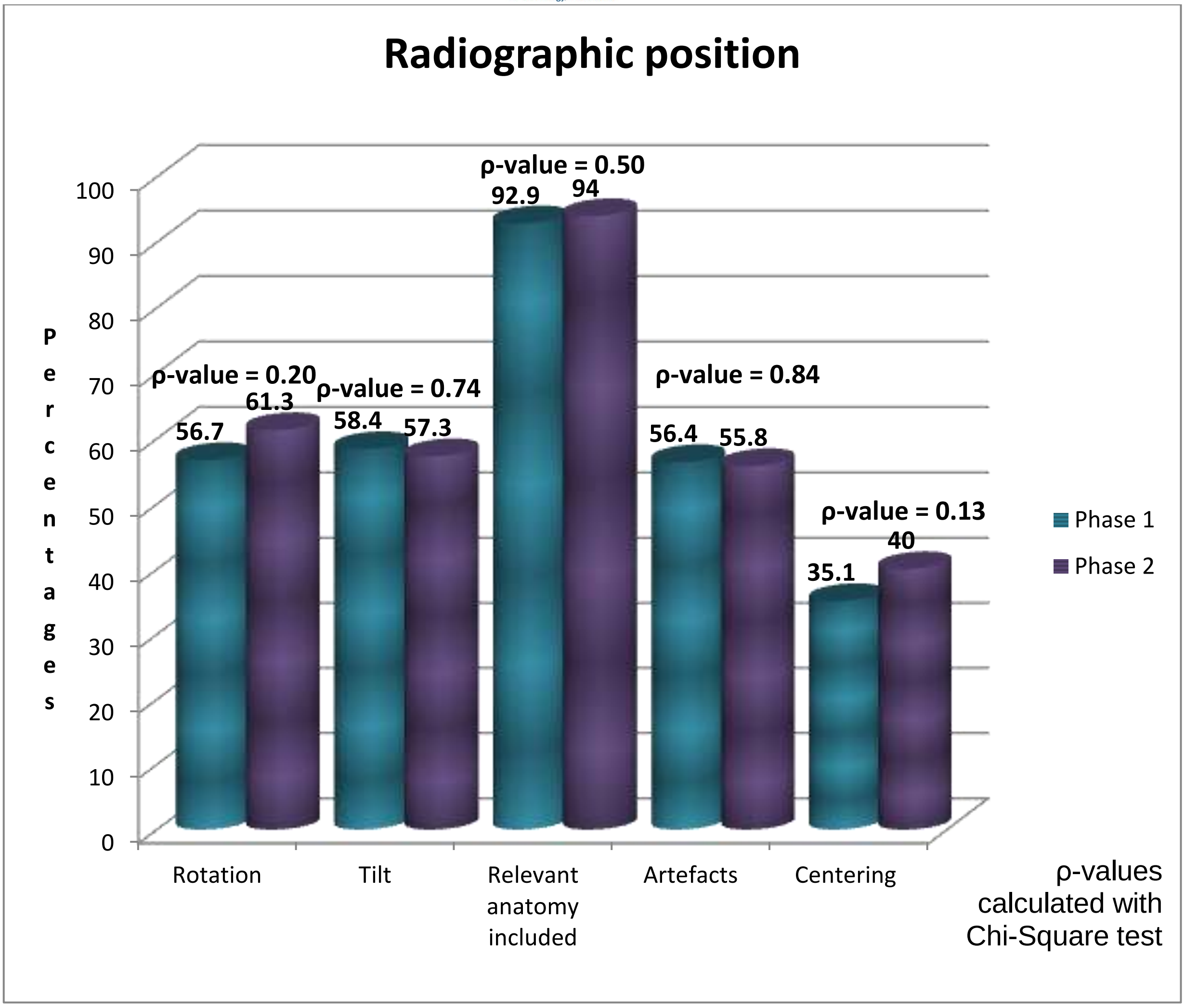


Figure 4.23: Radiographic position

Tilt or angulation of the main radiation beam assist in presenting the lung fields without distortion and free from superimposition by other structures (McQuillen-Martensen, 2011:121). The number of correct angulated images did not increase significantly (ρ-value = 0.74) from Phase 1 (58.4% or 263 images) to Phase 3 (57.3% or 258 images), as shown in Figure 4.23. This indicates that, after the educational programme had been presented, close to 50% of the images produced by the participating radiographers were not appropriately tilted.

All relevant anatomy should be included on an image to ensure optimal visualisation of these structures – only that which is visible can be evaluated (Bontrager and Lampignano, 2014:631). Phase 1 of this study found that most images taken by participating radiographers (92.9% or 418 images) do include all the relevant anatomy. This finding applied to Phase 3 too (94% or 423 images included all relevant anatomy), as illustrated in Figure 4.23. The improvement in Phase 3 was not significant (ρ-value = 0.5). There was a clear correlation between the relevant structures found to be excluded from images (see Figures 2.2 and 4.2).

Artefacts being superimposed on important chest anatomy (Figure 4.23) did not show a significant change (ρ-value = 0.84) from Phase 1 (56.4% or 254 images) to Phase 3 (55.8% or 251 images). This indicates to the researcher that the educational programme did not reduce the number of artefacts found on chest images. However, there was a statistical difference (ρ-value = 0.0001, calculated with Chi-square test) in the percentage of types of artefacts found in Phases 1 and 3. The comparison between the types of artefacts found is illustrated in Figure 4.24.

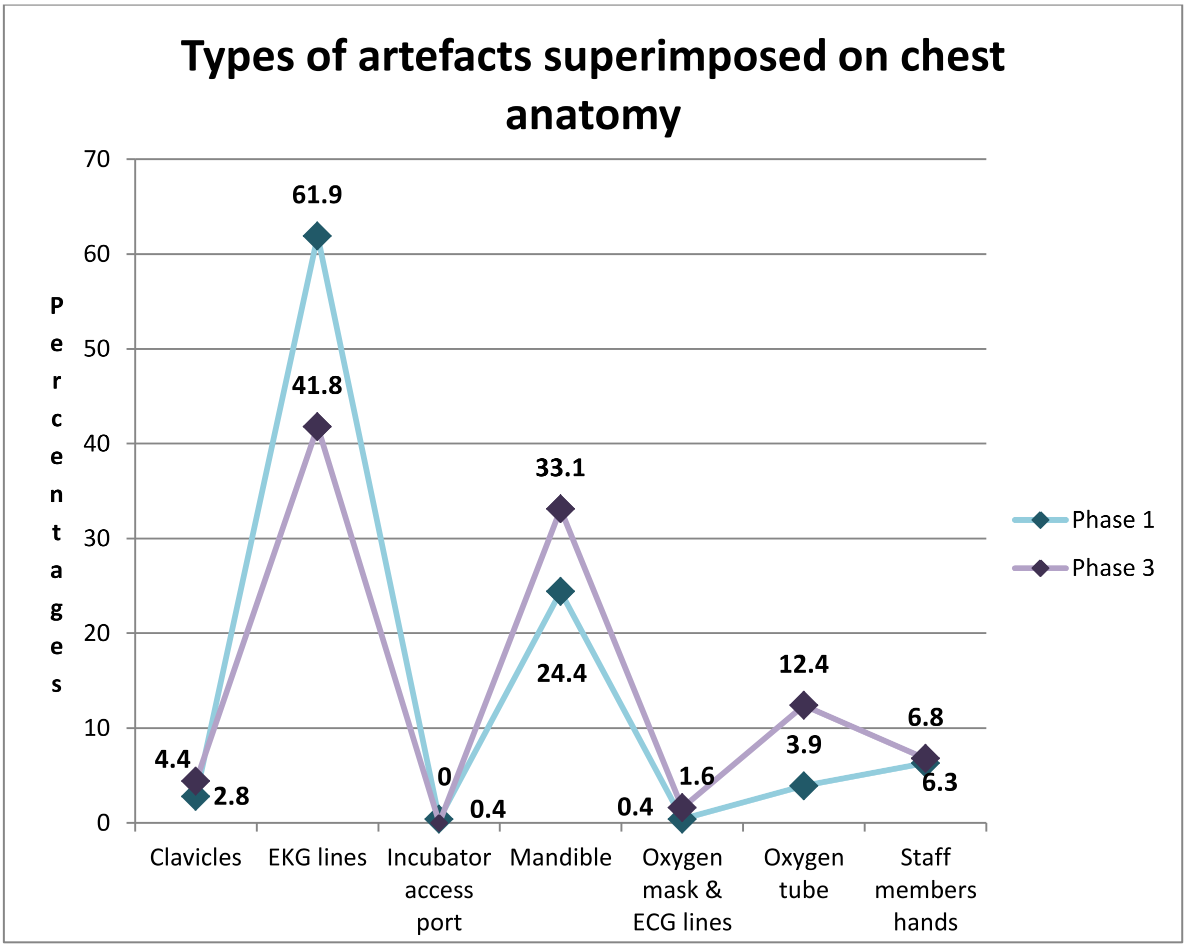


Figure 4.24: Types of artefacts superimposed on chest anatomy

From the figure above it can be seen, that ECG lines, the artefact most often visible in images evaluated during Phase 1 (61.9% or 157 images), shows a decrease in Phase 3 (41.8% or 105 images). This is a clear indication that the radiographers were aware of superimposition of the chest anatomy by ECG lines after the educational programme. However, regarding other artefacts, there was an increase recorded in Phase 3 for the mandible superimposed on the apices of the lungs (24.4% or 62 images increased to 33.1% or 83 images) and of the oxygen tube superimposed on the chest (3.9% or 10 images increased to 12.4% or 31 images).

The chest should be centered in the middle of the image receptor and main radiation beam to prevent distortion and possible exclusion of chest anatomy (McQuillen Martensen, 2011:121; Carlton and Adler, 2014:450). The comparison in Figure 4.23 illustrates that there was no significant improvement (ρ-value = 0.13) in the centring of the chest from Phase 1 (35.1% or 158 images) to Phase 3 (40% or 180 images). Centring therefore did not show improvement after the educational programme. Figure 4.25 compares the specific incorrect centring points noted for Phases 1 and 3.

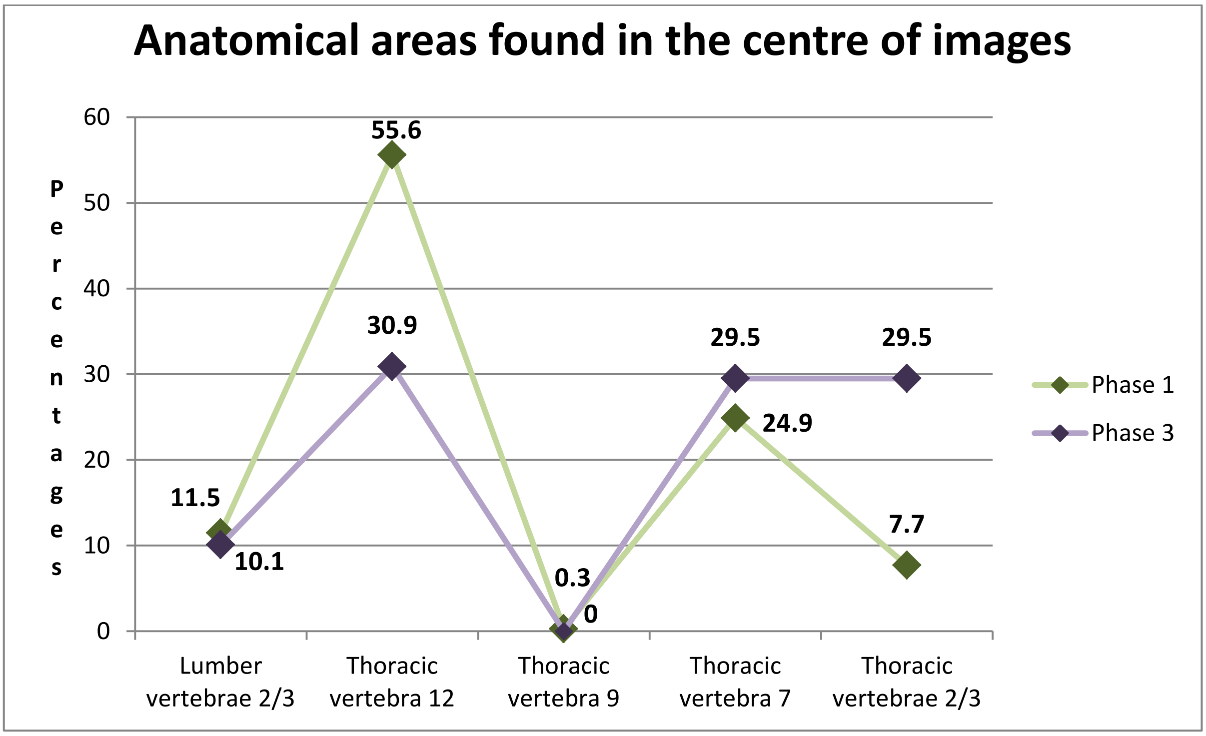


Figure 4.25: Anatomical areas found in the centre of images

From Figure 4.25 it can be deduced that the radiographers were more conscious of their centring because the graph shows a decrease in inferior centring (lumber vertebrae and thoracic vertebra 12) and an increase in superior centring (thoracic vertebrae seven and three). This indicates to the researcher that the educational programme made radiographers more aware of the need to centre on thoracic vertebra four (Loovere *et al,* 2008:201; McQuillen Martensen, 2011:121; Bontrager and Lampignano, 2014:631). The data above show efforts by radiographers to centre closer to thoracic vertebra four.

4.6.4 Breathing techniques, lead marker and radiation protection

In Figure 4.26, the optimal breathing technique was observed in 54.2% or 244 images during Phase 1; this observation reduced significantly (ρ-value = 0.0009, calculated with Chi-square test) in Phase 3, to 43.1% or 194 images. In addition, Phase 3 evaluations found a general 5% increase in both incorrect breathing techniques. This indicates that the educational programme did not enhance the application of the correct breathing technique.

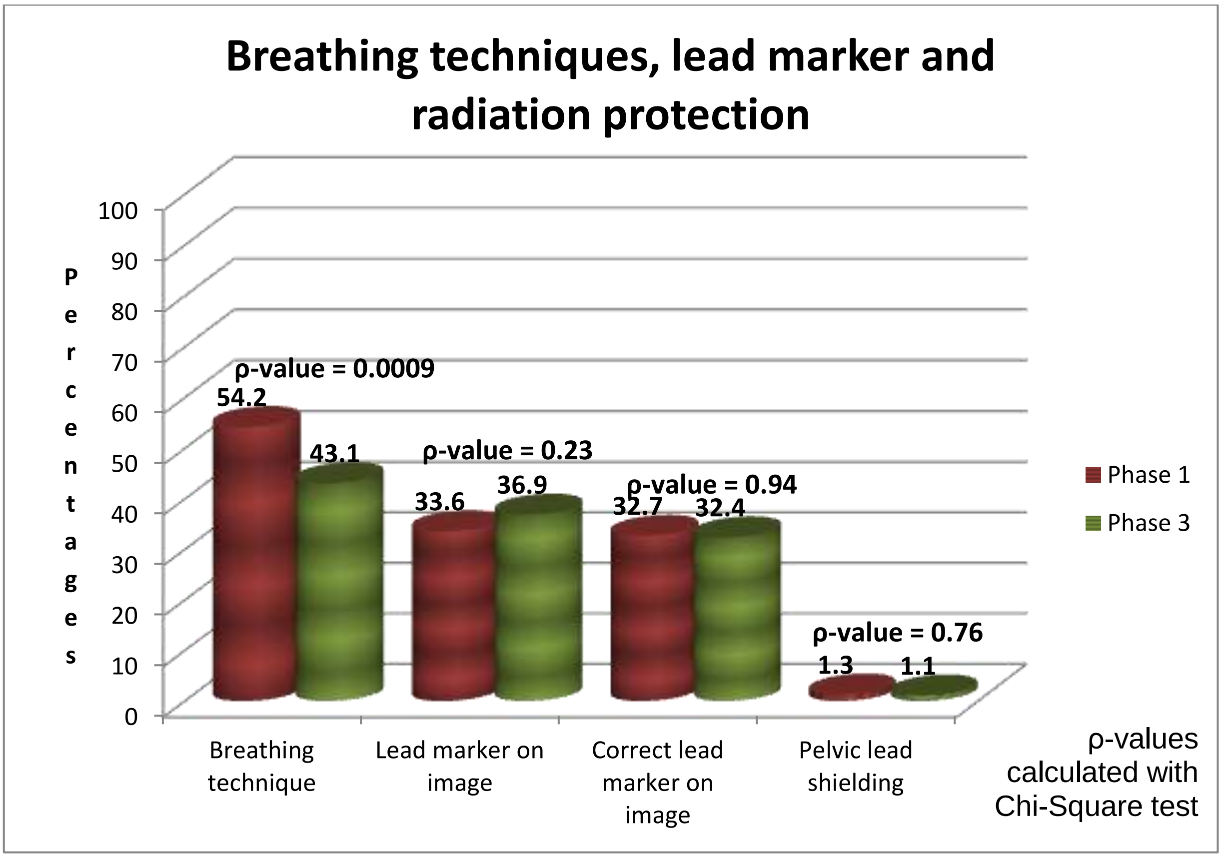


Figure 4.26: Breathing techniques, lead marker and radiation protection

The lead markers found on images and the correct placement of lead markers on images did not show a significant improvement from Phase 1 to Phase 3, as shown in Figure 4.26. Lead markers were found on 33.6% or 151 images evaluated in Phase 1, and this number remains (ρ-value = 0.23, calculated with Chi-square test) low in Phase 3, during which evaluation found lead markers on 36.9% or 166 images. Figure 4.26 also shows that when lead markers were included on images, they were placed correctly, that is, not superimposing important anatomy and on the correct side (McQuillen-Martensen, 2011:121), on 32.7% or 147 images in Phase 1 and 32.4% or 146 images in Phase 3. This indicates that there was no significant improvement regarding lead markers visibility from Phase 1 to Phase 3 (ρ-value = 0.94, calculated with Chi-Square test). In conclusion, the lead marker visible on images did not show any improvement after the educational programme. Radiographers still did not use lead markers as advised and expected by the radiation control body of South Africa (RSA DoH, 1973b:1-2).

Lastly, Figure 4.26 shows that application of radiation protection in the form of lead pelvic shielding, which must be used for neonatal patients (European Commission, 1996:27; Morris, 2003:460-461; Loovere *et al.*, 2008:201), did not show a significant increase (ρ-value of 0.76, calculated with Chi-Square test) after the educational programme. Only 1.3% or 6 images in Phase 1 were found to have a lead shield in place, visible on the image.

This omission contradicts directives of the Department of Radiation Control in SA, which stipulates lead shielding as mandatory (RSA DoH, 1973:8). The researcher included radiation shielding as part of the educational programme, with emphasis on radiation shields that could be utilised by radiographers in the NICU. The programme also included a practical demonstration, and a poster was provided (Appendix N). Nevertheless, the educational programme failed to improve the use of lead shielding by radiographers, with a 1.1% or 5 images seen in Phase 3.

4.6.5 Exposure parameters

Figure 4.27 compares the 11 criteria that were used to evaluate the exposure parameters. The images were furthermore evaluated in their original static setting on the CR-system, before any window width or window level manipulation. The first four criteria relate to the visibility of lung patterns. Reasons for lung patterns not visible could include the selection of inadequate exposure parameters, and/or pathology overshadowing lung patterns. To compensate for the possibility that the lung pattern is invisible due to pathology, four criteria were included. From the figure it can be deduced that the only criterion that showed a significant improvement (ρ-value = 0.02) from Phase 1 to Phase 3 is the visualisation of the proximal bronchi. The other three criteria do not show a significant change after the educational programme had been presented. The ρ-values were calculated with the Chi-Square test.

The next five criteria evaluated the visualisation of support structures in or around the lung fields. Once again, more than one structure was evaluated in order to compensate for possible pathological overshadowing. Three criteria showed a significant improvement from Phase 1 to Phase 3. The trachea (ρ-value = 0.01), diaphragm/costophrenic angles ($\rho < 0.0001$) and any catheter tips inserted in the chest cavity ($\rho < 0.0001$) showed significant improvement after the educational programme had been presented. The remaining two criteria did not show a significant improvement. The Chi-Square test was utilised to calculate these ρ-values.

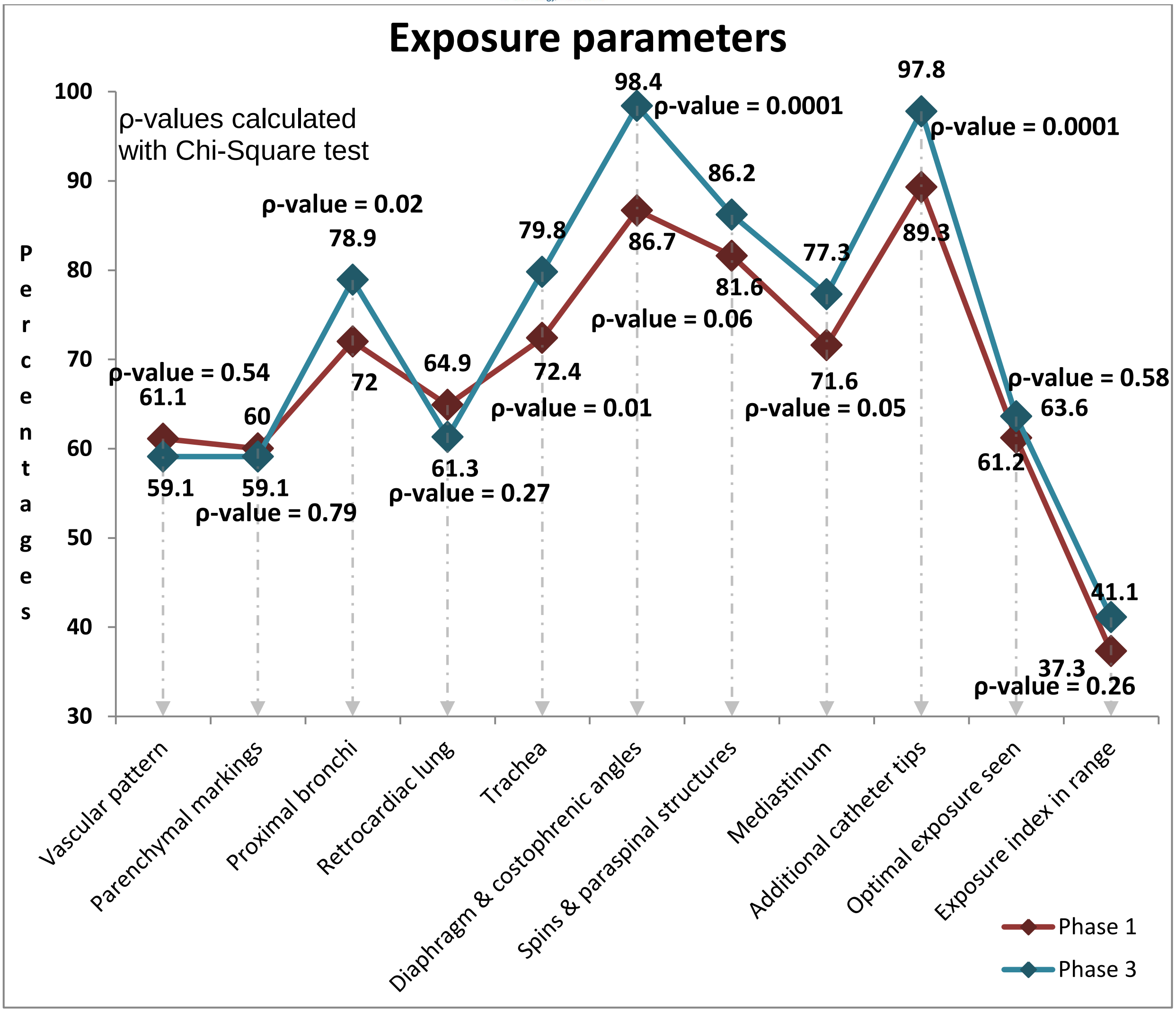
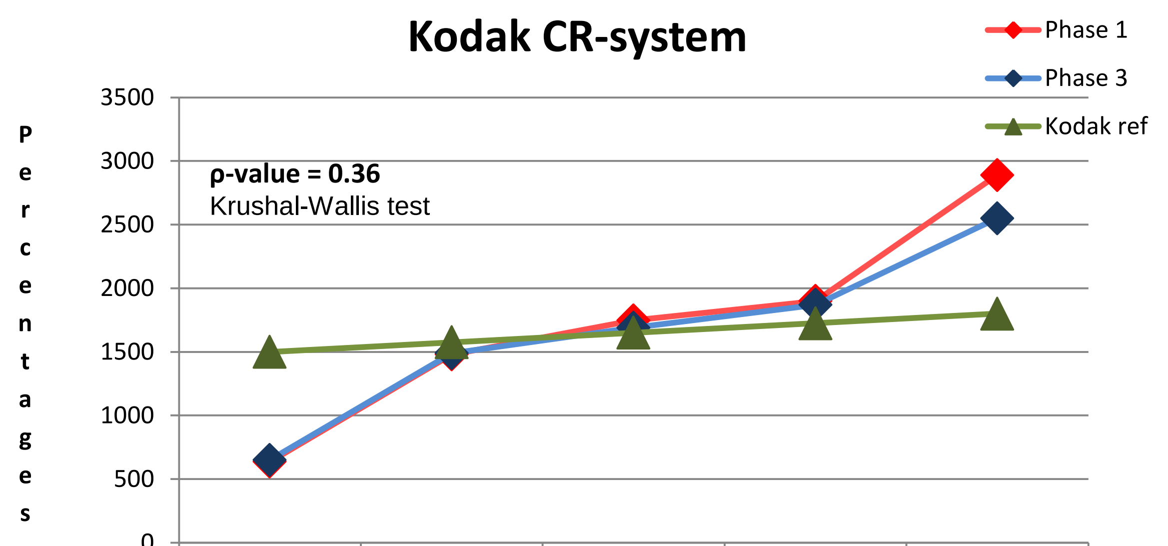


Figure 4.27: Exposure parameters

The final two criteria considered the overall appearance of the exposure parameters utilised, and the corresponding exposure index (Figure 4.27). Neither of these criteria showed a significant change (ρ-value = 0.58 for exposure parameters and ρ = 0.26 for the exposure indices; calculated with the Chi-Square test) from Phase 1 to Phase 3. Even though this topic was one of the focus points of the educational programme the data indicate that the exposure parameters evaluated on the images utilising the criteria in figure 4.27 did not improve after the educational programme.

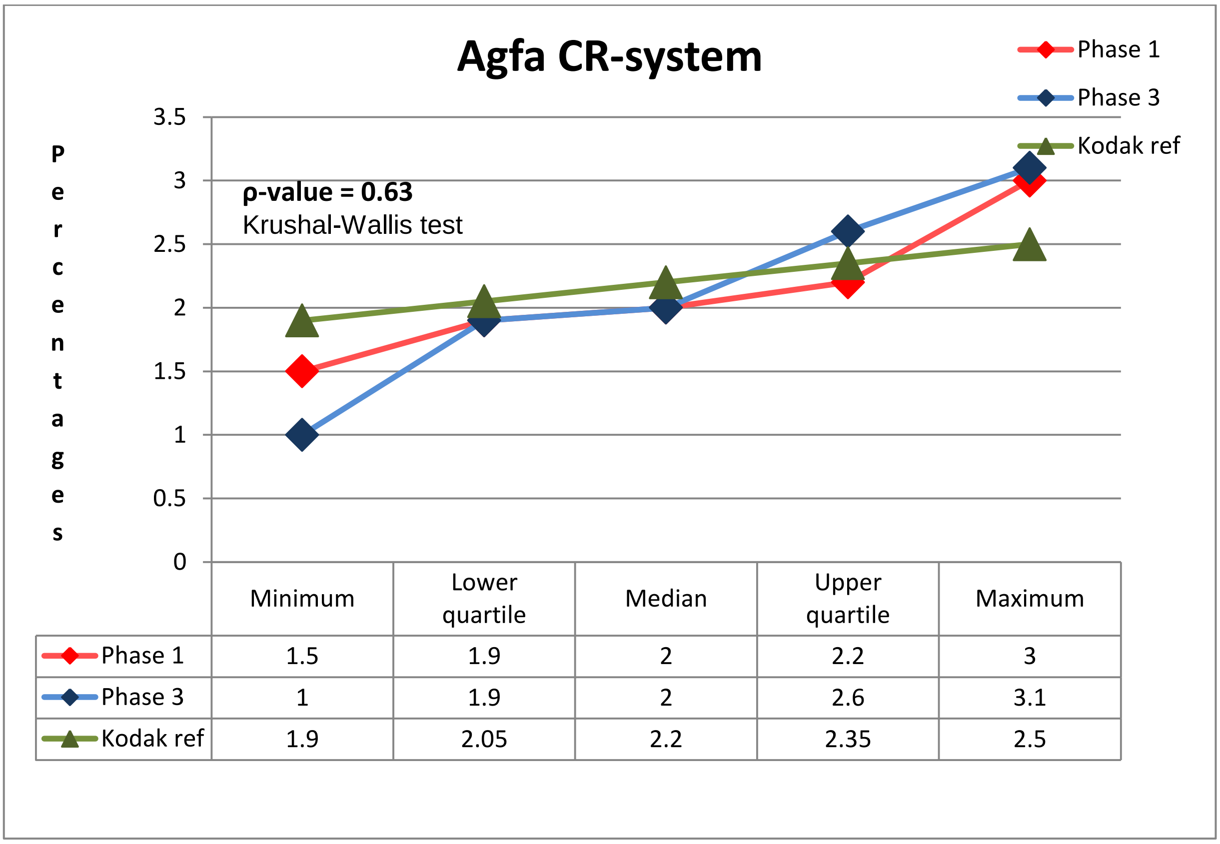
The documented exposure indices for Phases 1 and 3 are compared in Figures 4.28 and 4.29, for the two CR-systems used to produce the images analysed by this study. The Kodak CR-system (Figure 4.28) had an n-value of 150 for both phases separately. As can be seen in Figure 4.28, there was no significant change in the data obtained from Phase 1 and Phase 3, because the ρ-value (calculated with the Krushal-Wallis test) is 0.36. In addition, the recommended exposure range, according to Kodak (CRCPD, 2010:22), is between 1 500 and 1 800. The lower quartile ranges and minimum values are significantly below 1 500. The median for both phases are close to 1 650. This figure indicates that the selected exposure parameters were too low for 25% of the images in Phase 1 and Phase 3. When a radiographer utilises exposure parameters that are too low, it results in a grainy image (inadequate radiation reaches the image receptor, therefore there is less information to display – an effect similar to a TV with poor reception) and higher radiation absorption doses in the neonate (CRCPD, 2010:22).



	Minimum	Lower quartile	Median	Upper quartile	Maximum
Phase 1	637	1480	1748	1900	2890
Phase 3	650	1490	1690	1870	2550
Kodak ref	1500	1575	1650	1725	1800

Figure 4.28: Kodak CR-system

Figure 4.29 illustrates the Agfa system's exposure index, which is referred to as the LGM value (CRCPD, 2010:22). The Agfa CR system had an n-value of 300 for each of the two phases. As can be seen in Figure 4.29, there is no significant difference in the data obtained in Phases 1 and 3, because the ρ-value (calculated with the Krushal-Wallis test) is 0.63. In addition, the recommended exposure range, according to Agfa (CRCPD, 2010:22), should be between 1.9 and 2.5. The lower quartile ranges were below 1.9. The median for both phases are close to the prescribed Agfa range (2.2). This indicates that the selected exposure parameters for the Agfa CR-systems were considered low compared to the prescribed exposure parameters. The grainy appearance will be visible, with a greater dose absorbed for the neonate (CRCPD, 2010:22).



	Minimum	Lower quartile	Median	Upper quartile	Maximum
Phase 1	1.5	1.9	2	2.2	3
Phase 3	1	1.9	2	2.6	3.1
Kodak ref	1.9	2.05	2.2	2.35	2.5

Figure 4.29: Agfa CR-system

The educational programme did not affect either of these two applications by radiographers, as neither of the two ρ-values were considered to be significant.

4.6.6 Collimation

Figure 4.30 shows the amount of collimation observed and the inclusion of superior, inferior, bilateral anatomical structures and lung fields required for chest images. All indicated ρ-values for collimation were calculated with the Chi-Square test. The only significant change observed from Phase 1 to Phase 3 was in the collimation visible (ρ-value = 0.002). More collimation was visible during Phase 3 (34.7% or 156 images) than in Phase 1 (25.1% or 113 images). This indicated that the educational programme did make radiographers more aware about providing collimation. The other four criteria did not show a significant change from Phase 1 to Phase 3. This indicates that the educational programme did not enhance the practices relating to these four criteria. However, it is important to note that all four criteria were already very well applied by radiographers, with percentages above 90% for both phases.

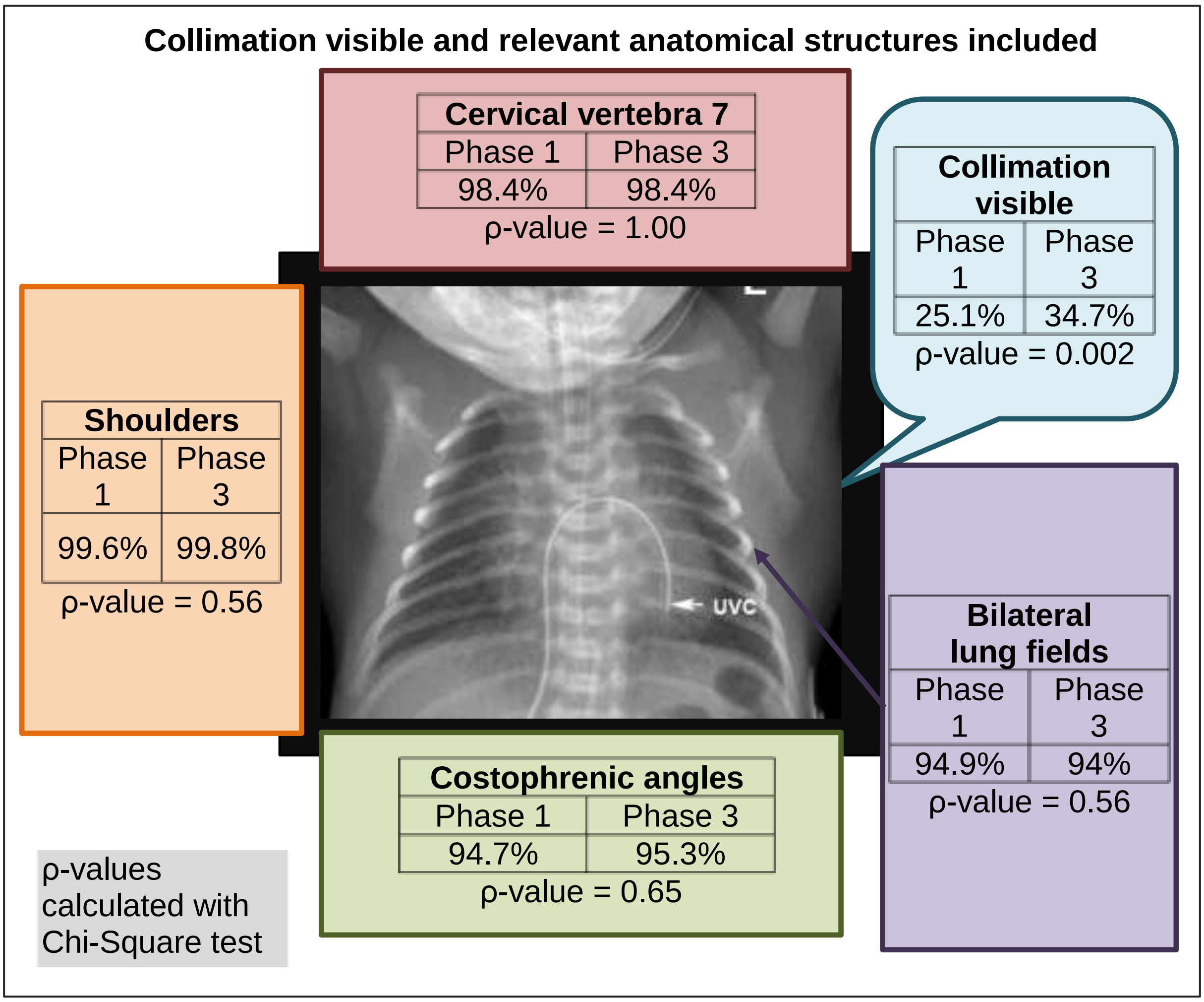


Figure 4.30: Collimation visible and relevant anatomical structures included

Collimation enables a radiographer to restrict the anatomical area exposed to radiation. For chest imaging a radiographer would prefer to include only up to the areas indicated in Figure 4.30, superiorly the seventh cervical vertebra, inferiorly the costophrenic angles and bilaterally the shoulders. Including any additional anatomy leads to an increase in the radiation dose to the patient with no significant contribution to the diagnostic process (Carlton and Adler, 2014:162). Figure 4.31 compares the percentages of additional anatomy included in Phases 1 and 3. Regarding additional anatomy included laterally (ρ-value = 0.02) and inferiorly (ρ-value = 0.01) there is a significant reduction in Phase 3 compared to Phase 1. The overall superior inclusion of additional anatomy (ρ-value = 0.06) did not show a significant decrease in Phase 3 compared to Phase 1. This indicates that the educational programme did promote the exclusion of anatomical structures inferiorly and laterally, but failed to promote the exclusion of anatomical structures superiorly. The ρ-values were calculated with the Chi-Square test.

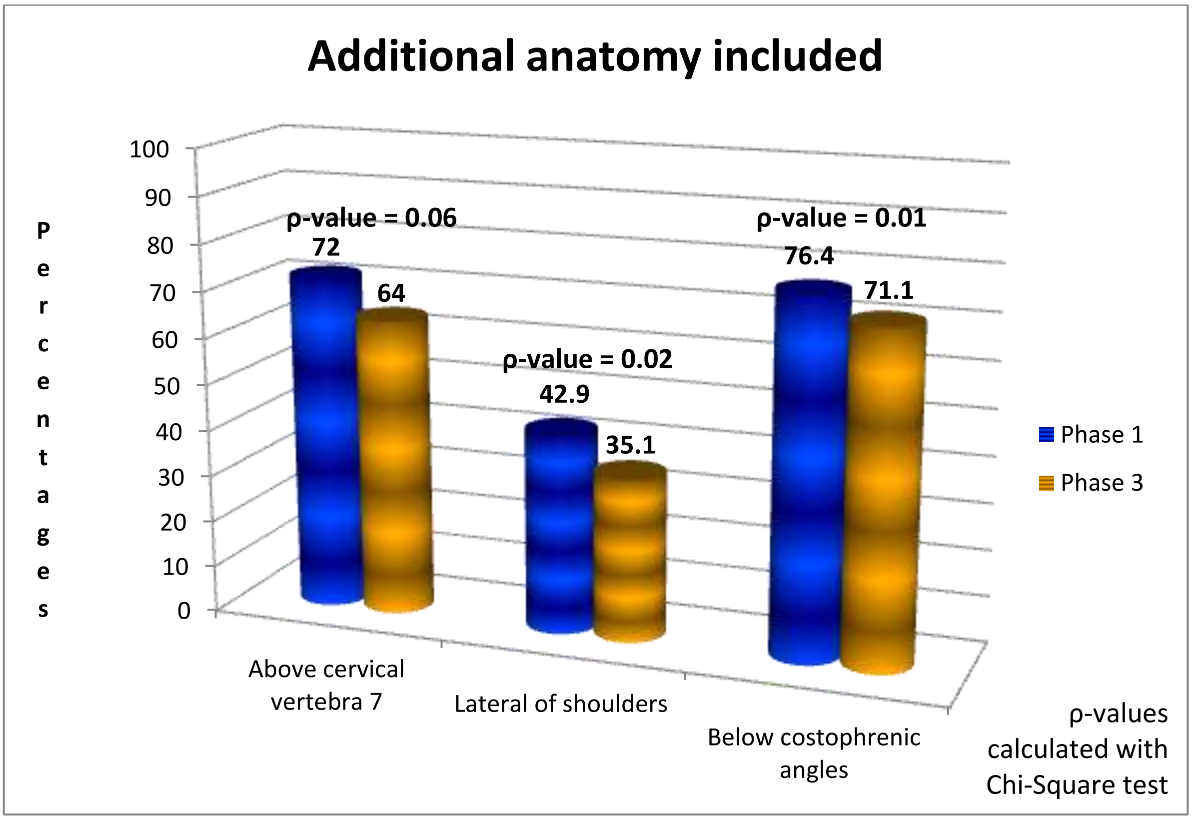


Figure 4.31: Additional anatomy included

Regarding the specific anatomical structures included superiorly, there was a significant difference observed between the structures included during Phase 1 and those included in Phase 3. Figure 4.32 compares the additional anatomy included superiorly during the two phases. As can be seen on this graph, the inclusion of the mandible, which was the anatomy most often included during Phase 1 (43.7% or 141 images), reduced significantly (ρ-value = 0.003) in Phase 3

(33.2% or 95 images). On the other hand, the inclusion of the skull increased significantly (ρ-value = 0.003) from Phase 1 (17.9% or 58 images) to Phase 3 (25.5% or 73 images). A percentage of 25.5% means that one quarter of these evaluated images included the entire skull, indicating that the educational programme did not promote the exclusion of superior anatomy not relevant for chest imaging. The ρ-values were calculated with the Chi-Square test.

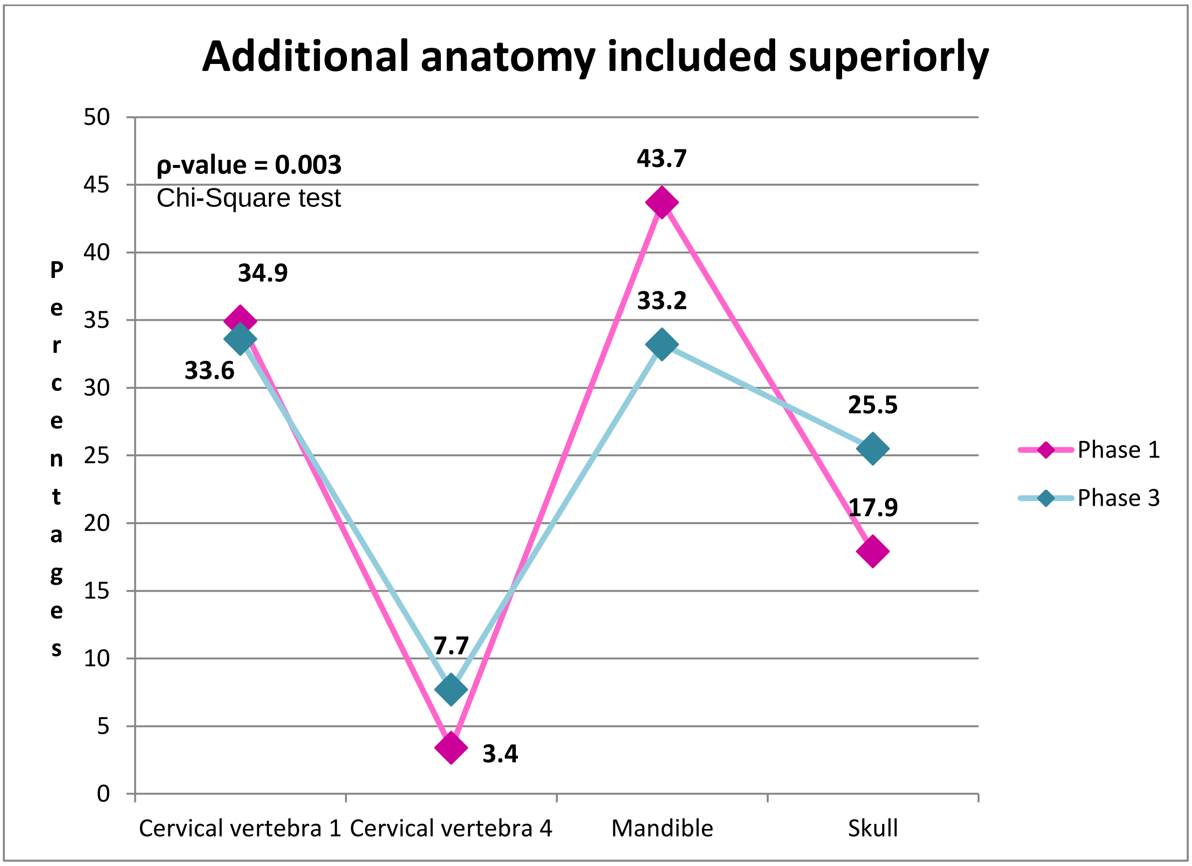


Figure 4.32: Additional anatomy included superiorly

The additional structures included lateral to the shoulder joints did show an overall reduction, as illustrated in Figure 4.31. In addition, the specific structures found included laterally for Phase 1 and Phase 3 differed significantly. The comparison for additional anatomy and/or structures included to the lateral aspect of the shoulder joints is shown in Figure 4.33. This figure clearly shows a decrease in the inclusion of the humeri (from 63.4% or 123 images in Phase 1 to 51.3% or 81 images in Phase 3) and the area from the wrists to humeri (3.1% or 6 images in Phase 1 to no such inclusions in Phase 3).

However the inclusion of the area from the elbows to the humeri, from the fingers to the humeri and radiographers' hands showed an increase from Phase 1 to Phase 3. The increase for the first two inclusions is very slight, but the presence of the staff members' hands increased from 6.7% or 13 images during Phase 1 to 15% or 24 images during Phase 3. The significant increase in the inclusion of staff members' hands can be ascribed to the radiographers' determined attempts to immobilise the neonate more effectively after the radiographers had been exposed to immobilisation techniques in the educational programme, but they still struggled to ensure their or other staff members' personal safety while immobilising optimally.

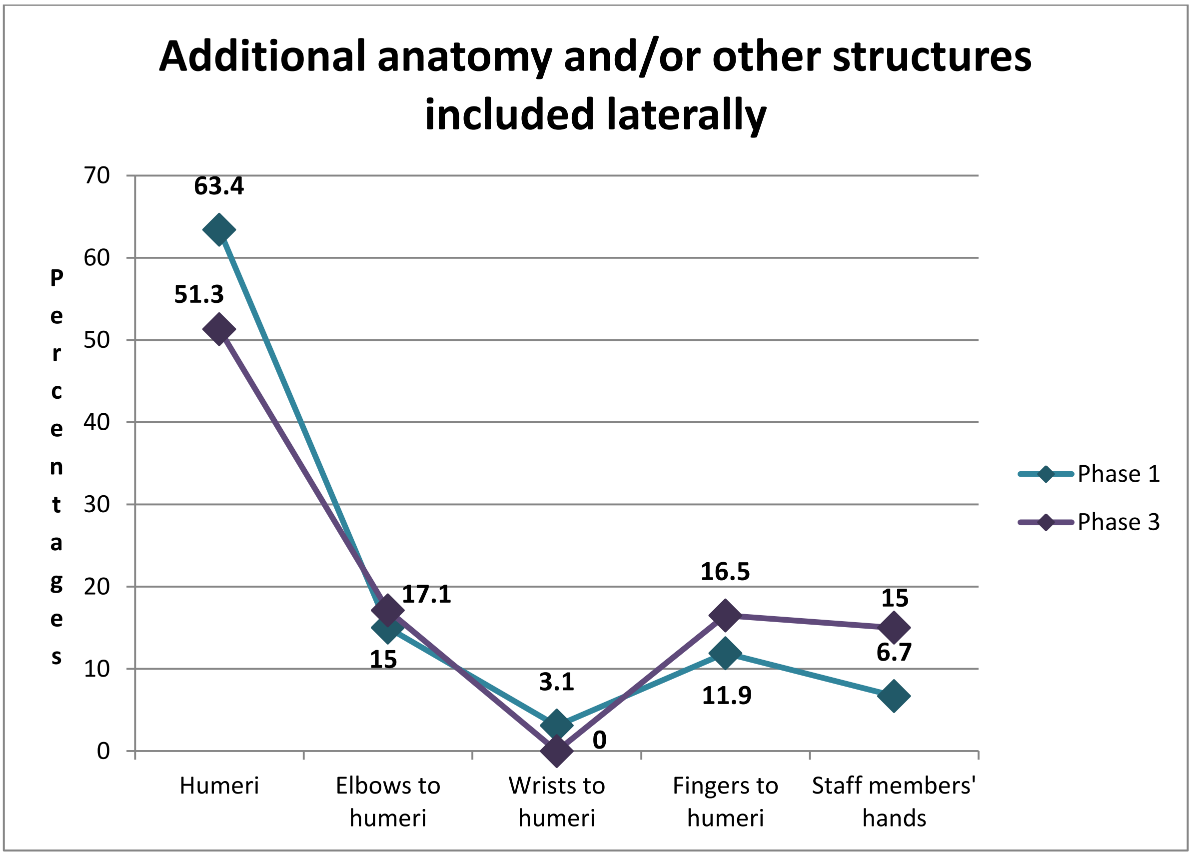


Figure 4.33: Additional anatomy and/or other structures included laterally

Lastly, the unnecessary anatomy that was included inferior of the costophrenic angles for Phase 1 and Phase 3 is compared in Figure 4.34. The figure illustrates that radiographers excluded the pelvic area more frequently in Phase 3 than in Phase 1. In addition, exclusion of the third lumber vertebra upwards increased significantly, which indicates that radiographers were excluding the pelvic area inferior of lumber vertebra three.

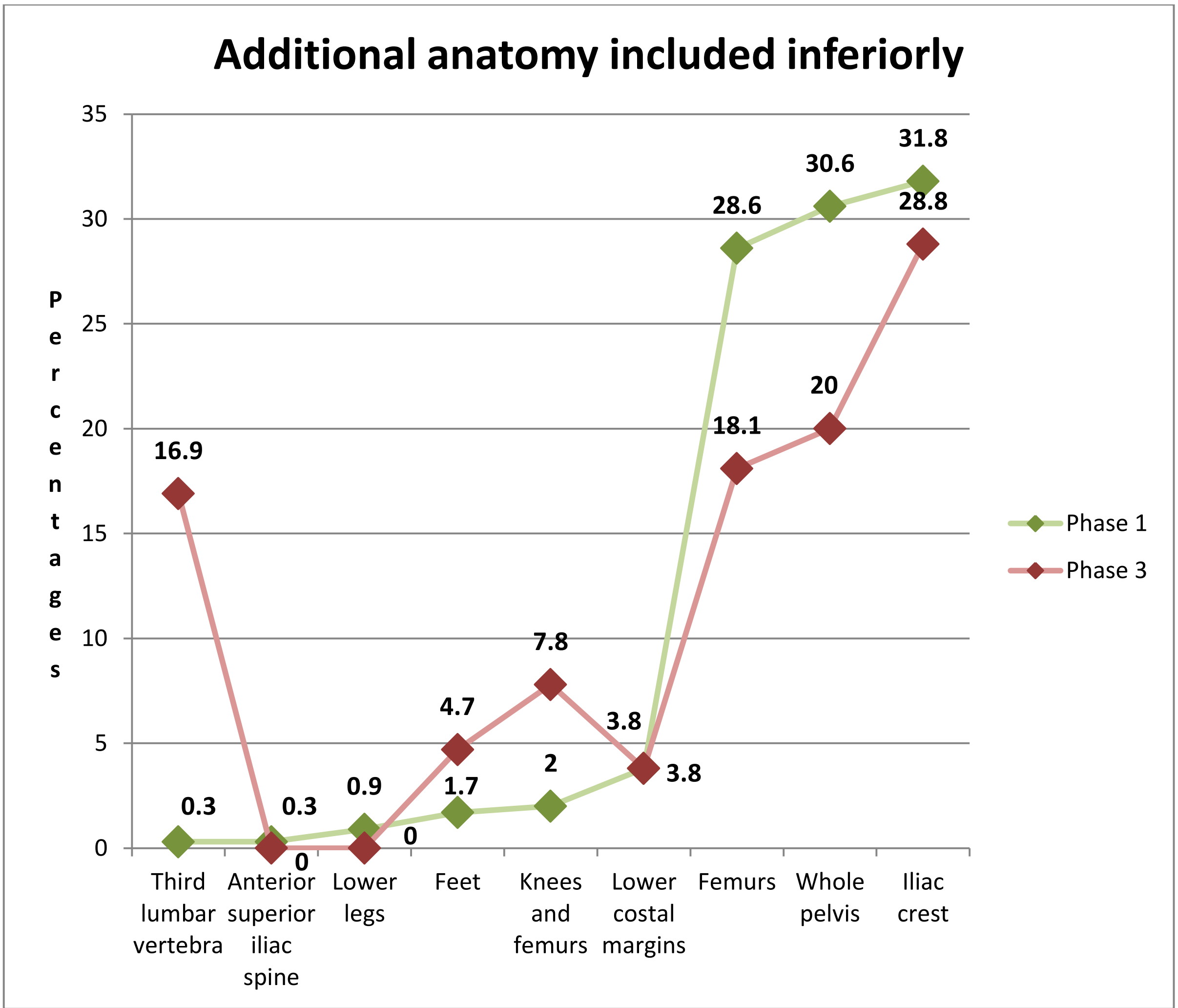


Figure 4.34: Additional anatomy included inferiorly

4.6.7 Final evaluation by the radiographer

Finally, a radiographer had to decide whether to manipulate the image or to leave it unchanged. In both Phases 1 and 3 it was found that 100% (450) of the images had been manipulated by the radiographers, suggesting that none of the images incorporated in this study had 0% error on the image (optimal image quality) since manipulation of the static image was required. However, images that were of adequate quality could have been utilised for diagnostic purposes. This conclusion is confirmed by a statement by Morris (2003:460-461), that imaging of neonates is very challenging and requires attention to detail.

The last criterion included in the checklist asked whether radiographers needed to repeat an image, due to inadequate image quality. In Phase 1, 4.7% or 22 images were repeated and, in Phase 3, 6% or 27 images, hence there was no significant difference between the two phases (ρ-value = 0.37; calculated with the Chi-Square test). The reasons for repeating images were very similar for the two phases with only a significant increase in the observation of lung apices not visible more often during Phase 3 than in Phase 1. Figure 4.35 provides an illustrative comparison of the motivations for repeating images.

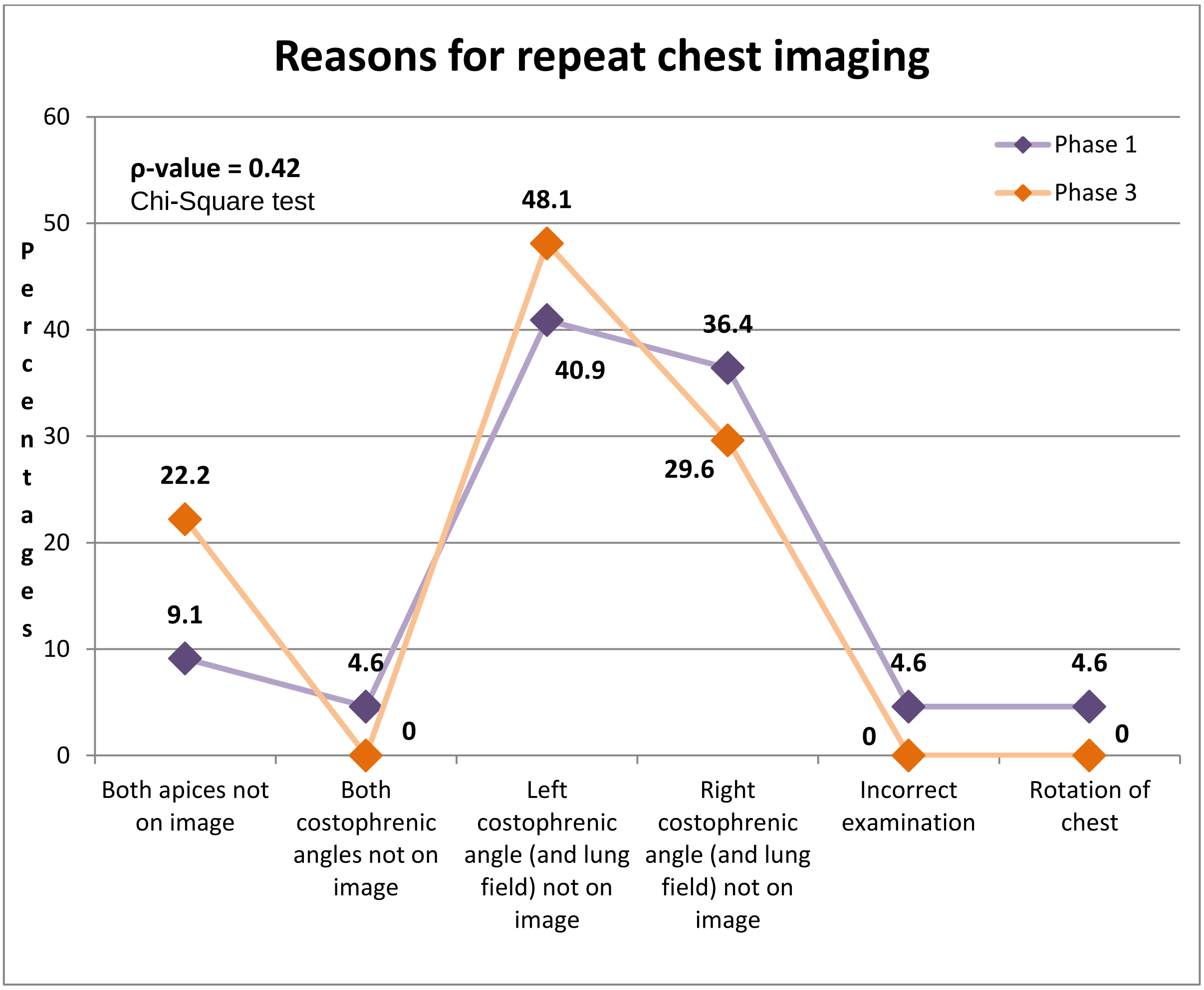


Figure 4.35: Reasons for repeat chest imaging

4.7 CONCLUSION

In this chapter the data obtained from the final phase of the study was discussed and compared to the first, similar phase. The data from Phase 3 showed strong similarities to the data obtained from the Phase 1, with some areas of significant improvement. These areas of significant improvement in image quality included a reduction of images with ECG lines superimposed on chest anatomy, thoracic vertebra four more often closer to the centre of the image and four-sided collimation more often visible on images.

Image quality criteria that showed no significant improvement after the presentation of the educational programme are the presence of lead markers and the use of radiation shielding. The next chapter, Chapter 5 will conclude this dissertation with the limitations, recommendations as well as identification of topics for future studies investigating the enhancement of mobile neonatal chest image quality.

CHAPTER 5

CONCLUSIONS, RECOMMENDATIONS AND LIMITATIONS

5.1 INTRODUCTION

The ARSPI of the Image Gently campaign (Image Gently, 2014:online), promote additional training for radiographers. This additional training is essential for achieving the goal of the Alliance, namely, that each neonate receives "the right optimal imaging examination, at the correct time, with the minimum radiation dose" (Goske *et al.*, 2010:618).

The goal of this chapter is to provide an overview of the study and to present concluding remarks. The chapter starts with an overview of the study findings, followed by recommendations. Limitations experienced during the study will be discussed, followed by an analysis of the significance of the study and suggestions for topics of possible future studies. The chapter concludes with final conclusive remarks.

5.2 OVERVIEW OF THE STUDY FINDINGS

The main aim of this study was to address the image quality of mobile neonatal chest examinations executed in NICUs by the application of an educational programme and, thereby, to deliver optimal radiation protection measures to neonates. To achieve this aim three objectives had to be achieved. The findings for each objective will be discussed independently.

5.2.1 Objective 1

The first objective was to determine the quality of images produced in the NICU prior to the delivery of the educational programme. The quality of images was assessed by means of a checklist based on and compiled from guidelines in available image quality literature (Appendix E). This objective was discussed in Chapter 2.

Chapter 2 summarised the checklist results and main findings (Section 2.5) obtained from 450 neonatal chest images produced with mobile units in the NICUs. The data showed various areas in which the image quality could have been addressed. Radiographic positioning observed as incorrect were rotation (56.7%), inadequate angulation or tilt of the main radiation beam (41.6%), inappropriate centring (64.9%), and artefacts superimposing chest anatomy (56.4%). An incorrect breathing technique was observed in 45.8% of the images. Other observations involved the lead marker being absent (66.4%) and the absence of lead shielding that should be applied over the pelvis (98.7%). Inadequate exposure indices were recorded in 62.7% of the images produced. Lastly, a lack of collimation (74.9%) was recorded; this led to the inclusion of anatomical structures not required for diagnosis.

5.2.2 Objective 2

The second objective was to design and present an educational programme. The design of the programme was based on the checklist used for the assessment of the images. The programme included information on current radiographic positioning techniques and guidelines for ensuring optimal image quality, obtained from literature consulted.

In Chapter 3 the researcher reported on the delivery of the educational programme, which took the form of training sessions. The educational programme was divided into the following sessions: three theoretical, two optional practical and two group discussions. Attendance of the compulsory theory sessions was 100%.

The educational programme included six specific areas, namely, patient positioning, breathing technique, lead marker, radiation protection, exposure parameters and collimation. Patient positioning made specific reference to preventing rotation, optimising angulation of the main radiation beam, correct centring of the main radiation beam, anatomical structures that should be included, and the removal of artefacts superimposed over relevant anatomical structures. The educational programme explained the negative impact incorrect application of any of the above in relation to patient positioning would have on the diagnosis of pathological conditions (Appendix J).

The educational programme also paid attention to application of the correct breathing technique. The consequences to pathology diagnosis of images that were produced with the incorrect technique were explained. The importance and relevance of utilising lead markers during neonatal radiography was discussed. In addition, the reasons for using radiation protection in the form of lead shielding was also included (save the gonads, Section 3.2.5.5). The consequences of producing an image without a lead marker or lead shielding were included in the educational programme (Appendices J and K).

The optimal application of exposure parameters to ensure clear demonstration of all applicable anatomical areas were included in the educational programme, along with their relevant exposure indices for the specific CR-system utilised in each institution. Collimation as a form of radiation protection and enhancement of image quality was also included. The different measures that can be taken to ensure optimal collimation (Baker cones and shadow shielding, Section 3.2.5.4) were included in the educational programme (Appendix K).

During the discussion sessions the researcher documented research notes to record specific challenges experienced by the radiographers and perceived solutions to these challenges. Discussion sessions were facilitated after the theoretical sessions. Challenges experienced by participating radiographers were centered on positioning techniques which radiographers were struggling with and which the participating radiographers indicated may be solved by means of the educational programme. Other challenges experienced by the radiographers were inadequate resources and funds for obtaining specialised radiation protection equipment, a problem that can only be addressed by institutional management. Communication with and assistance by nursing staff in the NICU was also identified as a problem by the radiographers.

The radiographers completed an evaluation form to determine the participants' perceptions in relation to the educational properties of the programme. The results of the evaluation form showed that the perception of the radiographers who attended the sessions was that the educational programme benefited them (96.4% given for the usefulness of content, 89.2% for presenter effectiveness and 91.1% for the opportunity to interact during theoretical sessions). Participants indicated that pathology in relation to exposure indices (Figure 3.8) should have been included in the programme, and this can be incorporated in future presentations without difficulty.

In addition, CPD accreditation was obtained for the programme (Appendix O), to enhance its benefit to the participating radiographers. Posters were designed and posted on bulletin boards (Appendices M and N) to remind radiographers of the importance of optimal image quality when working with neonates. The posters highlighted anatomical catheters and lines that should be included on images, inside the collimation, as well as different forms of shielding for radiation protection.

5.2.3 Objective 3

The final objective was to re-evaluate the quality of the images produced in the NICUs to establish whether image quality had been addressed after delivery of the educational programme. The same checklist used for the initial assessment of the images was utilised. The researcher evaluated 450 neonatal chest images produced in the same NICUs as during the first phase. Only images produced by radiographers who had completed the educational programme were included in the re-evaluation.

In Chapter 4 the researcher discussed areas that did not show improvement after the presentation of the educational programme. The results were obtained by comparing the results obtained before and after educational programme delivery (Chapter 2, Objective 1). Of particular interest in this study was the fact that the clinical history was absent from referral letters in more than 90% of cases (94% Phase 1 and 96.7% Phase 3). Clinical history is important, because radiographers determine anatomical structures to be included, radiographic techniques and radiation parameters according to the clinical history provided (Morris, 2003:460-461). Without a clinical history the justification of the neonatal examination is lacking; radiation regulations (RSA DoH, 1973:8) require this history, and it should therefore be included.

The radiographic positioning techniques visible on images did not show a significant improvement (ρ-values did not show a significant change, Figure 4.23). After the educational programme incorrect rotation was still observed in 61.3% of images (compared to 56.7% of the first phase); a lack of tilt or angulation of the main radiation beam was still present in 42.7% of images (versus 41.6% of Phase 1) and artefacts were superimposed on chest anatomy in 55.8% of images (compared to 56.4% of Phase 1).

However, the ECG line artifact did show a significant decrease (ρ-value = 0.001) from Phase 1 (61.9%) to Phase 3 (41.8%). This artefact was observed at the highest frequency of all the artefacts recorded, therefore a reduction in the observation of this artefact implies a significant enhancement of image quality.

The centring point did not show a significant change (64.9% of images were incorrectly centered in Phase 1 and 60% in Phase 3), but the overall trend is closer to the prescribed thoracic vertebrae four (Loovere *et al.*, 2008:201; McQuillen Martensen, 2011:121; Bontrager and Lampignano, 2014:631) from Phase 1 to Phase 3 (Figure 2.4 compared to Figure 4.4). Correct centring is essential, because it limits geometric unsharpness and image distortion (McQuillen Martensen, 2011:18-22; Carlton and Adler, 2014:460).

The breathing technique visible on images was optimal more often during Phase 1 (54.2%) than Phase 3 (43.1%). More images with motion unsharpness due to normal breathing during production of the image, as well as images with poor demonstration of lung fields due to unsatisfactory inspiration, presented in Phase 3 than in Phase 1. The breathing technique was discussed during the educational programme, and specific strategies to ensure the correct respiration moment were discussed during theoretical sessions and demonstrated in the NICU. The decrease in the observed application of the correct breathing technique cannot be explained or justified by the researcher.

Of most concern to the researcher is the lack of lead marker placement and absence of lead shielding evident on images before and after the educational programme. During Phase 1 only 33.6% of images contained markers and 1.33% indicated that lead shielding had been used. After the educational programme, only 36.9% of images presented with lead markers and only 1.11% of images showed lead shielding. In total for the two phases, lead markers were only visible on an average of 35% of images and lead shielding on 1.22% of images. Both these aspects are addressed by the RSA DoH, (1973:8 and 1974b:1-2) in the Act of 1971 and 1974 respectively, regulations concerning the control of electronic products and the scope of radiography profession. These factors cannot be considered as optional, but are imperative.

The educational programme included information on various techniques for ensuring inclusion of lead markers and application of lead shielding. Most of the discussions were focused on matters relating to quality assurance, to ensure that these become common practice (Table 3.3). Challenges in relation to lead shielding devices and NICU protocols in relation to cross infection were taken into consideration during these discussion sessions. Almost half the radiographers (48.2%) indicated that radiation protection is something that they can implement in their daily work (Figure 3.7). A poster dedicated to information about lead shielding and lead marker placement was distributed in the participating institutions (Appendix N). Nevertheless, the third phase of the study recorded no significant change in the visibility of radiation shielding and lead marker placement.

The exposure parameters did not show a significant change from Phase 1 to Phase 3. Specific anatomical structures did visualise more consistently during Phase 3, but that could be due to the fact that older neonates were imaged in the third phase (median age 23 days in Phase 3, Figure 4.19), or due to a decrease in pathological manifestation superimposed on these areas. In relation to exposure indices the study found that the range of exposure indices closely resembled the range specified by manufacturers, and it did not change significantly from Phase 1 (62.7%) to Phase 3 (58.9%).

The amount of collimation found on images increased significantly (ρ-value = 0.002) from Phase 1 (25.1%) to Phase 3 (34.7%). In addition, most images included the relevant anatomy and during Phase 3, a decrease in the inclusion of additional anatomy laterally (ρ-value = 0.02) and inferiorly (ρ-value = 0.01) was noted. This indicates that sensitive structures, like the humerus (included in 63.4% of images during Phase 1 versus 51.3% of images in Phase 3) and pelvis, were more frequently excluded after the educational programme because of improved levels of collimation (pelvis included on 30.6% of images before the programme versus 20% of images showing the pelvis after the programme). In addition, radiographers were centring closer to thoracic vertebra four, which also led to the exclusion of irrelevant anatomy.

In the end, a similar percentage of images were repeated during the two phases, namely 4.7 % in Phase 1 and 6% in Phase 3. Radiographers manipulated 100% of their images in Phase 1, and continued to do so in Phase 3. Radiographers are only human, and neonates are small and difficult to image. There will always be a small percentage of inadequate images. The focus should be on limiting these images to a bare minimum while optimising radiation protection techniques such as optimal collimation and radiation shielding.

5.3 RECOMMENDATIONS FROM THE STUDY

A recommendation based on this study's results is that institutional management should implement the radiation regulations obligated by the DoH in relation to lead marker placement and lead shielding. On the evaluated mobile neonatal chest images of this study, radiographers seem unable to adhere to this important regulation and managerial support could assist in ensuring compliance to this regulation. This was also recommended by Hellwig and Wilson (2013:2) as part of their radiation safety quality improvement process. Radiology management should, first, purchase dedicated neonatal radiation protection equipment and, second, include radiation protection and anatomical lead marker placement in radiographer performance appraisals. This study has shown that the traditional route of CPD through educational sessions and posters alone, is not addressing professional behavior significantly. Offering an additional incentive to radiographers for optimal radiation protection measures applied, determined through spot checks, could possibly change this potentially hazardous practice.

A recommendation regarding radiographic positioning techniques, breathing techniques, lead marker placement, lead shielding and collimation could be that training should become part of a neonatal quality control audit programme enforced by each institution's radiology management structure. Such an audit programme should include a comprehensive, ongoing training element that should involve educational content, discussion sessions focused on problem solving, compulsory practical sessions and interdepartmental meetings. This can be achieved as an online radiation safety course, as called for by the Bonn Call-for-Action (2013:online), and could include participation by other interested healthcare members, such as nursing staff, referring physicians and radiographers. The educational content should also include a portfolio of evidence as part of assessment. The practical aspect of such a programme can involve a practical assessment, done in the NICU.

The above mentioned quality control audit programme can be implemented by utilising the checklist that was designed (Appendix E). The checklist evaluation should be done by at least two radiologists and two radiographers at the end of the audit programme time frame, to determine if the programme was successful. This type of auditing will determine the effectiveness of the training and will also identify new areas that require attention. Hlabangana (2012:14) agrees with this recommendation, as her study showed a decline in image quality after an initial improvement upon completion of an educational programme. Hellwig and Wilson (2013:2-4) implemented a similar radiation safety quality improvement plan and their results showed an improvement in radiation safety over a period of two years, although with no remarkable improvement in positioning. They are however convinced that this plan will lead to an improvement in positioning over a longer period.

Recommendations based on the problems raised during discussion sessions include the design and presentation of an educational programme that focuses on educating NICU nursing staff about the importance of limiting x-ray requests for neonates; providing radiation protection to the neonate; and being aware of the important aspects of an optimal radiographic positioning technique. These three areas were identified as problems by radiographers (Table 3.3). An educational programme of this nature will ensure that NICU staff will be able to assist radiographers in producing images of the highest quality. NICU staff would also be able to assist radiology management in implementing a neonatal image quality audit programme. NICU staff and referring physicians can also be offered and information session on the importance of providing a clinical history in the planning of neonatal chest imaging, as less than 10% of referral letters contained a clinical history in this study.

Specifically, in relation to ECG lines visible on images, the researcher recommends that radiology departments and NICU managerial staff investigate techniques to prevent or limit the superimposition of these lines on images, because a referring physician cannot evaluate lung fields superimposed by ECG lines.

A further recommendation in relation to breathing techniques is that senior radiographers who have more NICU imaging experience and general practice experience should become mentors for junior radiographers, thereby working to optimise the visualisation of the correct suspended inspiratory breathing technique. Even though the data from this study did not compare images by senior and junior personnel, the researcher encourages junior radiographers to produce images in the NICU with the presence and support of a senior radiographer if possible. In addition, breathing technique simulations can be performed utilising a neonatal phantom and a mobile x-ray machine – this will assist junior staff to acquire this skill.

Even though the educational programme that was designed for this study cannot, in its current format, be considered for a credit-bearing qualification registered with the National Qualifications Framework, this programme can be incorporated into an existing credit-bearing qualification or can be used for training as part of a neonatal quality control audit programme, as mentioned previously. This educational programme can be included in the curriculum in the third and fourth years of the Bachelor degree in Diagnostic Radiography. In addition, this educational programme can be further developed for CPD activities. Should practical sessions form part of the such a programme, these sessions should be compulsory and not optional.

5.4 LIMITATIONS OF THE STUDY

A number of limitations were identified in this study. Evaluation of image quality by a single observer is considered to be a limitation. An additional observer could have ensured that the evaluation process was more trustworthy. On the other hand, a single observer ensured that quantitative data was evaluated consistently. The checklist can be adjusted to include specific evaluation criteria relating to the superimposition of the mandible over lung apices and scapulae superimposed over lateral lung fields. Furthermore, when an image is optimally collimated, abdominal/pelvic shielding will not always be visible and is therefore a limitation on the current checklist.

The educational programme content was designed by a single reviewer. The content of the educational programme was contextualized by all the evaluation criteria and positioning techniques. A second reviewer could have ensured that the content was moderated and this would have improved the trustworthiness of the study.

The second reviewer could also have attended a presentation session to moderate the presentation skills of the researcher. Even though the majority of participating radiographers were satisfied with regard to the presentation of the educational programme (above 80% indicated excellent), a formal moderation of the presenters skills would have enhanced the trustworthiness of the presentation.

Practical session attendance was not optionally attended and therefore a limitation to the study. Future studies should make these sessions compulsory, and should involve follow-up sessions to enhance practical skills. The researcher did not distinguish between the images of radiographers that attended these sessions from those that did not and could therefore not compare the data. A single educational activity with no planned continuation does not facilitate deep learning processes in professionals. To ensure deep learning there should be a form of assessment included in the educational programme, as described by Biggs and Tang (2007:24), in the form of a portfolio of evidence and follow-up sessions to enhance application of educational content. This study lacked any form of assessment of the radiographers for the theoretical component of the programme. The re-evaluation of the image quality was the only form of assessment in the study.

The posters incorporated in this study (Appendices M and N) were placed on notice boards in radiography departments to enhance the awareness of radiographers in relation to this study. The posters served as reminders of the educational programme content. The specific location of posters is considered a limitation because a poster in the department will be forgotten by radiographers who work in the distant NICU.

The educational programme did not effectively intervene in some image quality areas identified during Phase 1 because the researcher did not allow sufficient time for the design of the educational programme after the completion of the first phase. Furthermore, the educational programme was modeled according to traditional CPD activities, namely a presentation. It fell outside the scope of this programme to provide lead shielding devices or exposure charts. The researcher assumed that such radiographic aids are a given in radiographic practices. The lack in this regard is echoed by three participating radiographers that indicated in their comments a need for more time allocated to troubleshooting of identified challenges (Table 3.3 and Figure 3.8). The researcher considered the educational programme more as creating awareness than intervening in practice. This focus led to areas in the image quality that could not have shown improvement.

5.5 FUTURE RESEARCH

Possibilities for future research include investigating methods that will enhance image quality beyond the application of CPD educational activities as a single form of intervention. CPD as required by HPCSA do not necessarily lead to changes in practice, as shown by this study. Future studies should focus on determining techniques that will change practice and by changing practice, lead to justifiable application of these techniques as CPD training events. Studies should be undertaken about CPD events that require the submission of a portfolio of evidence, to determine if these CPD events will lead to a permanent change in practice (Labissiere, s.a.: online).

Future studies can also involve the design and implementation of a specific radiation shield, custom designed to the needs of a radiology department. Such a study can determine if a radiation shield is handily available, whether it will be utilised by radiographers or left to gather dust. A readily available shield may ensure consistent optimal application of radiation protection by radiographers in the NICU, which was found lacking the results of this study (average of 1% application).

5.6 SIGNIFICANCE OF THE STUDY

The significance of this study lies in the checklist that was designed and the educational programme that can be utilised as part of a neonatal image quality audit programme, referred to in Section 5.4. The checklist can be converted into an electronic format and can assist in evaluating radiographer positioning techniques visible on images, as part of performance appraisals, in addition to being utilised for self-evaluation.

The educational programme can assist undergraduate and postgraduate students to obtain the outcomes required for optimal imaging practices in an NICU. The educational programme contributed significantly to radiation protection through collimation and correct centring of the neonatal patients in the participating NICUs. The programme also raised awareness among radiographers and is aligned to the main goal of the Image Gently campaign (2014:online) and Bonn Call-for-Action (2013:online)

This study has also identified aspects of image quality that require improvement; even if the study could not address these aspects, they are now known and future studies can focus on creating the change required.

5.7 CONCLUSIVE REMARKS

This study asked the question whether the chest image quality produced by radiographers during mobile radiography in the NICU can be addressed through additional training provided by means of an educational programme. The findings of this study showed that an educational programme can improve image quality (improved centring and collimation was noted after the programme). However to make a significant difference such a programme needs to be applied consistently over an extended period and be supported by the departmental management and NICU staff. Studies done by Hlabangana (2012:14) and Hellwig and Wilson (2013:2-4) can confirm these findings.

Aspects of neonatal chest image quality that were improved after the educational programme are collimation – this lowers radiation dose to the neonate. In addition, after the programme, images were centered closer to the fourth thoracic vertebra which excludes anatomical areas not of interest. ECG line artefacts, which were a common phenomenon before the educational programme, were reduced significantly. However, image quality areas that were not improved by the educational programme included the absence of lead shielding and lead marker.

The most notable limitation in this study was that the design and presentation of the educational programme was a single-person effort. The trustworthiness of the content and presentation of the educational programme can therefore be questionable, even though the design was based on relevant literature.

The implementation of a neonatal image quality audit programme by imaging departments that service NICUs is recommended. Such an audit programme will align with the goal of the Image Gently (2014:online) campaign, namely, to change practice, as well as the Bonn Call-for-Action (2013:online) to enhance optimisation and to enhance educational opportunities in relation to radiation protection.

The checklist that addressed the gap in literature has also proven to be an instrument to discern areas of improvement in terms of image quality. The areas of image quality that caused concern could be identified with this instrument. The educational programme improved collimation, and centring and therefore contributed to the main purpose of the Image Gently (2013:online) campaign, which is to change general practice.

It was noted that mobile neonatal imaging is challenging. The patient is very small, cannot respond to breathing instructions and is usually in an incubator. But it is the right of this neonate, who is unable to talk, to have optimal images for an accurate diagnosis with the lowest justifiable radiation dose. It is the ethical duty of all involved, specifically the radiographer, to respond to this right by ensuring an optimised diagnostic examination as called for in the Bonn Call-for-Action (2014:online).

REFERENCES

ANNEY, V.N. 2014. Ensuring the quality of the findings of qualitative research: Looking at trustworthiness criteria. *Journal of Emerging Trends in Educational Research and Policy Studies,* 5(2): 272-281.

ARTHUR, R. 2001. The neonatal chest X-ray. *Paediatric Respiratory Reviews* 2(4): 311-323.

ARPANSA (Australian Radiation Protection and Nuclear Safety Agency). 2002. Recommendations for limiting exposure to ionising radiation and national standard for limiting occupational exposure to ionising radiation. National occupational health and safety commission: Radiation Protection Series 1. [online]. Available from: http://www.arpansa.gov.au/pubs/rps/rps1.pdf. Accessed on: 1 October 2014.

BADER, D., DATZ, H., BARTAL, G., JUSTER, A.A., MARKS, K., SMOLKIN, T., ZANGEN, S., KUGELMAN, A., HOFFMANN, C., SHANI, G., BEN-SHLOMO, A., MARGALIOT, M. & SADETZKI S. 2007. Unintentional exposure of neonates to conventional radiography in the neonatal intensive care units. . *Journal of Perinatology,* 27: 579-585.

BALL, J. & PRICE, T. 1995. Chesney's radiographic imaging. 6th edition. London: Blackwell Sciences.

BALLINGER, P.W. & FRANK, E.D. 1999. Merrill's atlas of radiographic positions and radiologic procedures. Volume 3: 9th edition. Missouri: Mosby.

BANSAL, G.J. 2006. Digital radiography: A comparison with modern conventional imaging. *Postgraduate Medical Journal,* 82(969): 425-428.

BICKMAN, L. & ROG, D. 1998. Handbook of applied social research methods: designing a qualitative study. SAGE Publications.

BIGGS, J. & TANG, C. 2007. Teaching for quality learning at university. 3rd edition. Berkshire: Open University Press.

Bonn Call-for-Action. 2013. Ten actions to improve radiation protection in medicine in the next decade. [online]. Available from: http://www.who.int/ionizing_radiation/medical_exposure/Bonn_call_action.pdf. Accessed on: 10 March 2015.

BONTRAGER, K.L. & LAMPIGNANO, J.P. 2014. Textbook of radiographic positioning and related anatomy. 8th edition. Missouri: Elsevier Mosby.

BOWLING, A. 2002. Research methods in health: Investigating health and health services. 2nd edition. United Kingdom: Open University Press.

BUSHBERG, J.T., SEIBERT, J.A., LEIDHOLDT, E.M. & BOONE, J.M. 2012. The essential physics of medical imaging. 3rd edition. Philadelphia: Lippincott Williams & Wilkins.

CARLTON, R.R. & ADLER, A.M. 2014. Principles of radiographic imaging: An art and a science. 5th edition. Canada: Thomson Delmar Learning.

CHE (Council on Higher Education). 2002. A new academic policy for policy for programmes and qualifications in higher education. [online]. Available from: http://www.dhet.gov.za/LinkClick.aspx?fileticket=TW72PFor6Wg%3D&tabid=92&mid=495. Accessed on: 16 December 2013.

COHEN, M.D., COOPER, M.L., PIERSALL, K. & APGAR, B.K. 2010. Quality assurance: Using the exposure index and the deviation index to monitor radiation exposure for portable chest radiographs in neonates. . *Pediatric Radiology,* 41: 592-601.

CRCPD (Conference of Radiation Control Program Directors). 2010. Computed radiography (CR) and digital radiography (DR) state x-ray inspection protocol. [online]. Available from: http://www.crcpd.org/Pubs/CR&DR_Protocol.pdf. Accessed on: 17 March 2015.

CUT (Central University of Technology). 2015. Bachelor for Radiography in Diagnostics: Unpublished organisational guide. Bloemfontein: CUT.

DELPORT, C.S.L. & FOUCHé, C.B. 2011. Mixed methods research. *In*: De Vos A.S., Strydom H., Fouché C.B. and Delport C.S.L. eds. Research as grass roots: For the social sciences and human service professions. 4th edition. Pretoria: Van Schaik Publishers. pp. 433-448.

DELPORT, C.S.L. & ROESTENBURG, W.J.H. 2011. Quantitative data-collection methods: Questionnaires, checklists, structured observation and structured interview schedules. *In*: De Vos, A.S., Strydom, H., Fouché, C.B. & Delport, C.S.L. eds. Research as grass roots: For the social sciences and human service professions. 4th edition. Pretoria: Van Schaik Publishers. pp. 171-205.

DENSCOMBE, M. 2007. The good research guide for small-scale social research projects. 3rd edition. Berkshire: McGraw-Hill.

Digital Radiology and Teleradiology Solutions. 2014. Kodak/Siemens ITX 560 digital mobile x-ray. [online]. Available from: http://www.mobile-cr.com/digital-radiology-system/used-refurbished-pre-owned-x-ray-radiology-equipment-sales. Accessed on: 10 January 2014.

DOUGENI, E.D., DELIS, H.B., KARATZA, A.A., KALOGEROPOULOU, C.P., SKIADOPOULOS, S.G., MANTAGOS, S.P. & PANAYOITAKIS, G.S. 2007. Dose and image quality optimization in neonatal radiography. *The British Journal of Radiology,* 80(958): 807-815.

DUGGAN, L., WARREN-FORWARD, H., SMITH, T. & KRON, T. 2003. Investigation of dose reduction in neonatal radiography using specially designed phantoms and LiF:Mg, Cu,P TLDs. *The British Journal of Radiology,* 76(904): 232-237.

ECS McREL. 2004. A policymaker's primer on educational research: How to understand, evaluate and use it. [online]. Available from: http://www.ecs.org/html/educationIssues/Research/primer/appendixA.asp. Accessed on: 1 November 2010.

Entrepreneur. 1997. Gonadal protection methods in neonatal chest radiography (Radiation Protection). [online]. Available from: http://www.entrepreneur.com/tradejournals/article/print/20176493.html. Accessed on: 6 June 2010.

European Commission (EC). 1996. European guidelines on quality criteria for diagnostic radiographic images in pediatrics. Luxembourg: Office for Official Publications of the European Communities.

FOUCHé, C.B. 2011. Evaluation research. *In*: De Vos, A.S., Strydom, H., Fouché, C.B. & Delport, C.S.L. eds. Research as grass roots: For the social sciences and human service professions. 4th edition. Pretoria: Van Schaik. pp. 449-472.

FOUCHé, C.B. & SCHURINK W. 2011. Qualitative research design. *In*: De Vos, A.S., Strydom, H., Fouché, C.B. & Delport, C.S.L. eds. Research as grass roots: For the social sciences and human service professions. 4th edition. Pretoria: Van Schaik. pp. 307-327.

FULLER, M.J. 2009a. Neonatal chest radiography. [online]. Available from: http://www.wikiradiography.com/page/Neonatal+Chest+Radiography. Accessed on: 28 March 2011.

FULLER, M.J. 2009b. Using Baker Cones in the neonatal intensive care unit. [online]. Available from: http://www.wikiradiography.com/page/Using+Baker+Cones+in+the+Neonatal+Intensive+Care+Unit. Accessed on: 28 March 2011.

FULLER, M.J. 2009c. Neonatal lines, tubes and catheters. [online]. Available from: http://www.wikiradiography.com/page/Neonatal+Lines%2C+Tubes+and+Catheters. Accessed on: 28 March 2011.

GIBSON, D.J. & DAVIDSON, R.A. 2012. Exposure creep in Computed Radiography: A longitudinal study. *Academic Radiology* 19(4): 458-462.

GODDARD, W. & MELVILLE, S. 2001. Research methodology: An introduction. Lansdowne: Juta.

GOLDWIRE, M. 2013.Clinical considerations in premature infants. *US Pharmacist*. [online]. Available from: www.medscape.com/viewarticle/805512_print. Accessed on: 7 November 2014.

GOODWIN, J.C. 1995. Research in psychology: Methods and design. New York: John Wiley & Sons.

GOSKE, M.J., CHARKOT, E., HERRMAN, T., JOHN, S.D., MILLS, T.T., MORRISON, G. & SMITH, S.N. 2010. Image Gently: Challenges for radiologic technologists when performing digital radiography in children. *Pediatric Radiology,* 41*:* 611-619.

HARDY, M. & BOYNES, S. 2003. Paediatric radiography. Oxford: Blackwell Science.

HASSON, F., KEENEY, S. & MCKENNA, H. 2000. Research guidelines for the Delphi survey technique. *Journal of Advanced Nursing*, 32(4): 1008-1015.

HAY, J. 2005. HOS711: Programme planning and development/Design of study material. Reader 1, Units 1 & 2. University of the Free State: Bloemfontein.

HELLWIG, B.J. & WILSON, B. 2013. Quality improvement related to radiation safety of chest radiography in the NICU. *Radiology Management*, 35(2):18-23.

HINDS, D. 2000. Research instruments. *In*: Wilkinson, D. ed. The researcher's toolkit: The complete guide to practitioner research. London: Routledge Falmar. Page: 20-42.

HLABANGANA, L.T. 2012. Introduction of a pictorial poster and a 'crash course' of radiographic errors for improving the quality of paediatric chest radiographs in an unsupervised unit. Dissertation (Masters of Medicine). Johannesburg: Faculty of Health Sciences, University of the Witwatersrand. [online]. Available from: http://wiredspace.wits.ac.za/bitstream/handle/10539/13712/Final%20Thesis%20Submission-Graduation%2011%20Dec.pdf?sequence=1. Accessed on: 15 November 2013.

HOLE, G. 2011. Research skills: The Kruskal-Wallis test. [online]. Available from: http://www.sussex.ac.uk/Users/grahamh/RM1web/Kruskal-Wallis%2520Handout2011.pdf. Accessed on: 27 September 2014.

HOPKINS W.G. 2008. Quantitative research design. *Sportscience*, 4(1). [online]. Available from: http://www.sportsci.org/jour/0001/wghdesign.html. Accessed on: 12 July 2011.

HPCSA (Health Professional Council of South Africa). 2008a. General ethical guidelines for the health care professions: *Booklet 1.* [online]. Available from:

http://www.hpcsa.co.za/conduct_generic_ethical_rules.php. Accessed on: 13 April 2010.

HPCSA (Health Professions Council of South Africa). 2008b. Guidelines for health care professionals: Continuing professional development. *Booklet 4*. [online]. Available from: http://www.hpcsa.co.za/booklet_4_cpd_guidelines_final.pdf. Accessed on: 15 January 2012.

HULL, D. & WHELDON, A. 1986. Open or closed incubators. *Archives of Disease in Childhood,* 61(2): 108-109.

IAEA (International Atomic Energy Agency). 2002. Board of governors general conference: International action plan for radiological protection of patients. [online]. Available from: http://www.iaea.org/About/Policy/GC/GC46/GC46Documents/English/gc46-12_en.pdf. Accessed on: 10 January 2014.

IAEA (International Atomic Energy Agency). 2015. Launching of AFROSAFE. [online]. Available from: https://rpop.iaea.org/RPOP/RPOP/Content/News/launching-afrosafe.htm. Accessed on: 10 March 2015.

ICRP (International System of Radiological Protection). 2013. Radiological protection in paediatric diagnostic and interventional radiology. *ICRP Publication 121. Ann. I CRP,* 42(2). [online]. Available from: http://www.icrp.org/publication.asp?id=ICRPPublication121. Accessed on: 19 November 2014.

Image Gently. 2014. The alliance. [online]. Available from: http://imagegently.dnnstaging.com/FAQsMore/TheAlliance.aspx. Accessed on: 6 January 2014.

JONES, N.F., PALARM, T.W. & NEGUS, I.S. 2001. Neonatal chest and abdominal dosimetry: A comparison of two radiographic techniques. *The British Journal of Radiology,* 74(886): 920-925.

KETTUNEN, A. 2004. Radiation dose and radiation risk to foetuses and newborns during x- ray examinations. Academic dissertation, Department of Radiology, University of Oulu. STUK- A204.

LABISSIERE, Y. [s.a.]. Using reflective electronic portfolios to enhance student learning: Theory and practice. [online]. Available from: http://www.frinq-workshop.michael-flower.com/resources/Wednesday-the-17th/ReflectiveEP.pdf. Accessed on: 19 January 2015.

LAI, T.T. & BEARER, C.F. 2008. Iatrogenic environmental hazards in the neonatal intensive care unit. *Clinics in Perinatology*, 35(1): 163-181.

LANCA, L. & SILVA, A. 2014. Evaluation of exposure index (lgm) in orthopedic radiography. Portugal: Aveiro.

LEEDY, P.D. & ORMROD, J.E. 2002. Practical research: Planning and design. 7th edition. New Jersey: Merrill Prentice Hall.

LINN, P.L., HOROWITZ, F.D. & FOX, H.A. 1985. Stimulation in the NICU: Is more necessarily better? *Clinics in Perinatology*, 12(2): 407-422.

LOOVERE, L., BOYLE, E.M., BLATZ, S., BOWSLAUGH, M., KERELIUK, M. & PAES, B. 2008. Quality improvement in radiography in a neonatal intensive care unit. *Canadian Association of Radiologists Journal,* 59(4) 197-202.

LOWE, A., FINCH, A., BONIFACE, D., CHAUDHURI, R. & SHEKHDAR, J. 1999. Diagnostic image quality of mobile neonatal chest x-rays and the radiation exposure incurred. *The British Journal of Radiography,* 72(853) : 55-61.

MABEN, A.F. 2014. Chi-square test. [online]. Available from: http://enviroliteracy.org/pdf/materials/1210.pdf. Accessed on: 27 September 2014.

MACK, N., WOODSONG, C., MacQUEEN, K.M., GUEST, G. & NAMEY, E. 2005. Qualitative research methods: A data collector's field guide. [online]. Available from: http://www.fhi360.org/sites/default/files/media/documents/Qualitative%20Research%20Methods%20-%20A%20Data%20Collector%27s%20Field%20Guide.pdf. Accessed on: 10 November 2014.

March of Dimes. 2010. Your premature baby. [online]. Available from: http://www.marchofdimes.com/baby/premature_indepth.html. Accessed on: 17 August 2011.

MASSYN, L. 2005. HOS711: Programme planning and development/Design of study material. Reader 2, Units3 & 4. University of the Free State: Bloemfontein.

MAYS, N. & POPE, C. 1995. Qualitative research: Rigour and qualitative research. *British Medical Journal,* 311(6997): 109-112.

McMILLAN, J.H. & SCHUMACHER, S. 2006. Research in education: Evidence-based inquiry. 6th edition. Boston: Pearson.

MCQUILLEN MARTENSEN, K. 2011. Radiographic image analysis. 3rd edition. Missouri: Saunders Elsevier.

MORRIS, S.J. 2003. Radiology of the chest in neonates. *Pediatric and Child Health,* 13(6): 460-468.

MUTCH, S.J. & WENTWORTH, S.D.P. 2007. Imaging the neonate in the incubator: An investigation of the technical, radiological and nursing issues. *The British Journal of Radiolog*y, 80(959): 902-910.

NANNAN, N., DORRINGTON, R., LAUBSER, R., ZINYAKATIRA, N., PRINSLOO, M., DARIKWE, T., MATZOPOULOS, R. & BRADSHAW, D. 2012. Under-5 mortality statistics in South Africa: Shedding some light on the trend and causes 1997-2007. *South African Medical Research Council*: Burden of Disease Research Unit. Available from: www.mrs.ac.za/bod/MortalityStatisticsSA.pdf. Accessed on: 7 November 2014. Page 4.

Natus. 2005. Save the gonads x-ray shield. [online].
Available from: http://www.natus.com/index.cfm?page=products_1&crid=197. Accessed on: 28 March 2011.

NCRP (National Council on Radiation Protection and Measurements). 2013. The Application of ALARA for Occupational Exposures. *Reports No. 116 & No. 127, Statement No. 8.* [online]. Available from: http://www.ncrponline.org/Publications/Statements/Statement_8.pdf.
Accessed on: 16 December 2013.

OLGAR, T., ONAL, E., BOR, D., OKUMUS, N., ATALAY, Y., TURKYILMAZ, C., ERGENEKON, E. & KOC, E. 2008. Radiation exposure to premature infants in a neonatal intensive care unit in Turkey. *Korean Journal of Radiology,* 9(5): 416-419.

Pan American Health Organization. 2012. 28th Pan American sanitary conference; 64th Session of the regional committee: Radiation protection and safety of radiation sources – International basic safety standards. USA: Washington. [online]. Available from:
http://www.google.co.za/url?sa=t&rct=j&q=&esrc=s&frm=1&source=web&cd=8&cad=rja&uact=8&ved=0CFAQFjAH&url=http%3A%2F%2Fwww.paho.org%2Fhq%2Findex.

php%3Foption%3Dcom_docman%26task%3Ddoc_download%26gid%3D21189%26Itemid%3D&ei=i6QpVOfwIszB7AbTr4CQBg&usg=AFQjCNH-Zh56zLJkshRGP4kiAt6Tpy0B4g. Accessed on: 10 November 2014.

PEDROSA DE AZEVEDO, A.C., OSIBOTE, A.O. & BOECHAT, M.C.B. 2006. Survey of doses and frequency of x-ray examinations on children at the intensive care unit of a large reference pediatric hospital. *Applied Radiation and Isotopes,* 64(12): 1637-1642.

PUCH-KAPST, K., JURAN, R., STOEVER, B. & WAUER, R.R. 2009. Radiation exposure in 212 very low and extremely low birth weight infants. *Pediatrics,* 124(6): 1556-1564.

RAMACHANDRAPPA, A. & JAIN, L. 2008. Iatrogenic disorders in modern neonatology: A focus on safety and quality of care. *Clinics in Perinatology,* 35(1): 1-34.

RSA DoH (Republic of South Africa. Department of Health). 1973. Public Health Amendment Act, 1971: Regulations concerning the control of electronic products. GN R1332 in *Government Gazette* 1822 of 3 August 1973. Pretoria: Government Printers.

RSA DoH (Republic of South Africa. Department of Health). 1974a. Government. Act 56. Health Professions Act: Training and registration. GN R2326 in *Government Gazette* 5349 of 31 December 1976. Pretoria: Government Printers.

RSA DoH (Republic of South Africa. Department of Health). 1974b. Government. Act 56. Health Professions Act: Regulations defining the scope of the profession of radiography. GN R1018 in *Government Gazette* 18170 of 1 August 1997. Pretoria: Government Printers.

SAQA (South African Qualification Authority). 2004. Criteria and guidelines for short courses and skills programmes: Guideline document. [online]. Available from: http://www.saqa.org.za/docs/guide/2004/s-courses.pdf. Accessed on: 26 January 2013.

SAQA (South African Qualification Authority). 2013a. Publication of the general and further educational and training qualifications sub-framework and higher education qualifications sub-framework of the national qualifications framework. *Government Gazette*: No. 36721 Vol. 578. [online]. Available from: http://www.che.ac.za/sites/default/files/publications/GG-%20Publication%20of%20the%20GFETQSF%20and%20HEQSF%20of%20the%20NQF%202%20August%202013_0.pdf. Accessed on: 16 December 2013. Pages 55.

SAQA (South African Qualification Authority). 2013b. South African Qualifications Authority registered qualification: Bachelor of diagnostic radiography. [online]. Available from: http://www.hpcsa.co.za/Uploads/editor/UserFiles/downloads/rct/reg_qual_bach_diag_rad_20_02_2013.pdf. Accessed on: 10 January 2014.

SCHURINK W., FOUCHé, C.B. & DE VOS, A.S. 2011. Qualitative data analysis and interpretation. *In*: De Vos, A.S., Strydom, H., Fouché, C.B. and Delport, C.S.L. eds. Research as grass roots: For the social sciences and human service professions. 4th edition. Pretoria: Van Schaik. pp. 397-423.

SEIBERT, J.A. & MORIN, R.L. 2011. The standardized exposure index for digital radiography: an opportunity for optimization of radiation dose to the pediatric population. *Pediatric Radiology,* 41(5): 573-576.

SHANK, G.D. 2002. Qualitative research: a personal skills approach. New Jersey; Merrill Prentice Hall.

SHERBINI, S. 2000. Policy, guidelines and regulations – ALARA. [online]. Available from: http://www.hps.org/publicinformation/ate/q435.html. Accessed on: 15 August 2011.

SLADE, D., HARRISON, S., MORRIS, S., ALFAHAM, M., DAVIS, P., GUILDEA, Z. & TUTHILL, D. 2005. Neonates do not need to be handled for radiographs. *Pediatric Radiology,* 35(6): 608-611.

SMANS, K., STRUELENS, L., SMET, M., BOSMANS, H. & VANHAVERE, F. 2008. Patient dose in neonatal units. *Radiation Protection Dosimetry*, 131(1): 143-147.

STRYDOM, H. 2011. Mixed methods research. *In*: De Vos A.S., Strydom H., Fouché C.B. and Delport C.S.L. eds. Research as grass roots: For the social sciences and human service professions. 4th edition. Pretoria: Van Schaik Publishers. pp. 222-235.

SWALLOW, R.A., NAYLOR, E., ROEBUCK, E.J. & WHITLEY, A.S. 1986. Clark's positioning in radiography. Volume 1: 10th edition. London: William Heinemann Medical Books.

VILJOEN, M. 2014. Discussion on the statistical analysis of recorded data with bio-statistician. 18 August 2014. Bloemfontein.

VYBORNY, C.J. 1997. The AAPM/RSNA physics tutorial for residents. *Imaging and Therapeutic Technology,* 17(2): 479-480.

WILLIAMS, A. 2003. How to … write and analyse a questionnaire. *Journal of Orthodontics*, 3: 245-252.

WILLIS, C.E. 2009. Optimizing digital radiography of children. *European Journal of Radiology,* 72(2): 266-273.

WILLIS, C.E. & SLOVIS, T.L. 2004. The ALARA concept in pediatric CR and DR: dose reduction in pediatric radiographic exams – A white paper conference executive summary. *American Journal of Radiology*, 184:373-374.

WHO (World Health Organisation). 2014. Health topics: Infants/Newborn. [online]. Available from: http://www.who.int/topics/infant_newborn/en/. Accessed on: 20 November 2014.

WMA (World Medical Association). 2008. Declaration of Helsinki: Ethical principles for medical research involving human subjects. [online]. Available from: http://www.wma.net/en/30publications/10policies/b3/17c.pdf. Accessed on: 10 January 2015.

YATES, D.S., MOORE, D.S. & STARNES, D.S. 2008. The practice of statistics. 3rd edition. New York: WH Freeman.

APPENDICES

APPENDIX A:

Permission from institutions

Radiology Department
Universitas Hospital
Bloemfontein
9330

Work Number: 051 403 9601
Email: duplessisms@ufs.ac.za

23 August 2011

Po Box 26373
Langenhovenpark
Bloemfontein
9330

Dear Reader

<u>Consent for research study: Addressing mobile neonatal image quality through an educational programme</u>

Hereby I give permission for this research to be done. Staff will be allowed to partake in the study. All participation is voluntary. The privacy and confidentiality of both patient and radiography staff will be protected by the researcher. I would like to see the results of the study.

Thank you.

Best regards.

Prof CS de Vries
Head of Department Diagnostic Radiology

Radiography • Private Bag X20539 • Bloemfontein • SOUTH AFRICA • 9300 •
Tel: +27 51 507 38 53• **Fax:** +27 51 507 3354 • **E-mail:** bevdmerwe@cut.ac.za • **Website:** www.cut.ac.za

Central University of Technology, Free State

health

Department of Health
FREE STATE PROVINCE

20 September 2011

Beatrix Kotze
Junior Lecturer
Central University of Technology
Free State

Dear Me Kotze

RESEARCH PROJECT: ADDRESSING MOBILE NEONATAL IMAGE QUALITY THROUGH AN EDUCATIONAL PROGRAMME

Herewith permission for the mentioned project to be done at Universitas Academic Hospital on condition that approval is obtained from the Ethics Committee

The Chief Executive Officer must be notified if the findings of the project will be published.

Yours sincerely

DR NRJ VAN ZYL
2011 -09- 2 0
HEAD: CLINICAL SERVICES
UNIVERSITAS ACADEMIC HOSPITAL

DR NIC R J VAN ZYL
HEAD: CLINICALSERVICES
UNIVERSITAS ACADEMIC HOSPITAL

HEAD: CLINICAL SERVICES: DR NRJ VAN ZYL
Private Bag X20660, Bloemfontein, 9300. Tel. No.: 051-4052866,
Fax: 051-4053500, Room 1077, First Floor, Universitas Academic Hospital
E-mail: vanzylnr@fshealth.gov.za

www.fs.gov.za

DrsVanDyk&Vennote/Partners In
REG. NO. 1995/003519/21 PR. NO. 38
DIAGNOSTIESE RADIOLOË • DIAGNOSTIC RADIOLOGI
A VAN DYK ▪ JH LAMPRECHT ▪ DJ GOUWS ▪ CT VERSTE
JHA VENTER ▪ WG PIEK ▪ HB LOUW

20 September 2011

CENTRAL UNIVERSITY OF TECHNOLOGY
FREE STATE
PRIVATE BAG X20539
BLOEMFONTEIN
9300

Re: **REQUEST FOR RESEARCH STUDY - BEA KOTZE**

We hereby give Bea Kotze permission to conduct her research at the Practice.

Regards

JS TAUTE
PRACTICE MANAGER

BLOEMFONTEIN MEDI-CLINIC
ACCOUNTS Tel 051 444 2868 | 444 2869 • Fax 051 444 1622

Central University of Technology, Free State
Radiography

Central University of Technology, Free State

Celebrating 30 Years of Technological Innovation

Po Box 26373
Langenhovenpark
Bloemfontein
9330

Cell: 083 270 4663
Work Number: 051 507 3266
Email: bekotze@cut.ac.za

20 September 2011

Pelonomi Regional Hospital
Bloemfontein
9300

Dear Dr Africa

Request for consent of research study: Addressing mobile neonatal image quality through an educational programme

This is a letter to the management of the radiology department of Pelonomi Regional hospital asking for consent on a proposed research study. The study will be done by a post graduate student of the Central University of Technology with the aim of obtaining her master degree in radiography. This student is employed by the Central University of Technology as a junior lecturer.

The proposed study is based on the image quality of neonatal chest images taken in the neonatal intensive care wards by radiographers. The study aims to address the image quality and develop areas of image quality as needed to ensure optimal service delivery to the neonate in general.

The study will consist out of three phases. All three phases will be implemented in the radiology department of the institution. In phase one mobile chest images will be evaluated by the researcher as they are processed in the radiology department, based on a pre- defined checklist. This checklist will be the instrument by which short comings in the current image technique will be identified.

These short comings will be ad[illegible]hase two when all radiography staff (radiographers) working in the neonatal intensive care ward will receive training. The educational programme will be scheduled with the radiology departmental management as not to impinge on productivity or workflow. The training will be accredited by the HPCSA as to allow staff to receive a compensation for training in the form of CEU's.

The third phase will then be a repetition of the first phase. This last phase will determine whether the image quality has improved after training. The same instrumental checklist will be utilised.

The study if consented will be done in one private institution and two government institutions. The name of the institutions and those of the personnel will be kept confidential. All checklists will be anonymous. Participation will be voluntary. .

The researcher needs written consent from the department to perform the proposed research study. This letter of consent will be part of a proposal that must be handed in at the ethical committee of the University of the Free State. This committee will decide on the value of such a study and weather such a study is ethically correct.

With this letter I am asking for consent to perform this study in the radiology department governmental institution of Pelonomi regional hospital. I believe this study will be of great benefit to the service provided to neonatal patients and will lead to better health care for these patients.

Thank you for reading and considering this study proposal.

Best regards.

Beatrix Kotzé
Junior Lecturer

Yes, I approve this research study to be implemented in the radiology department of Pelonomi regional hospital

Dr Africa 22/09/2011
Date

Dr MK Africa MMed FCRAD (SA)
Specialist (Radiology)
MP 0451371 Cell 082-5777705

Central University of Technology, Free State

pelonomi hospital

Department of Health
Pelonomi Regional Hospital
FREE STATE PROVINCE

DATE:	16 April 2012		
TO:	**Ms Kotze B** **PO Box 26373** **Langehovenpark** **Bloemfontein**	**FROM:**	**Dr Matshediso G.P** **Acting: CEO** **Tel: 051 405 1660** **MatshediGP@fshealth.gov.za**

SUBJECT: PROJECT ON ADDRESSING MOBILE NEONATAL IMAGE QUALITY THROUGH AN EDUCATIONAL PROGRAMME

Pelonomi Regional Hospital **grants you permission** and the following criteria must be met.

- [X] The Hospital incurs no cost in the course of your research.
- [X] Access to the staff and patients at the Pelonomi Hospital will not interrupt the daily provision of services.
- [X] Prior to conducting the research you will liaise with the supervisors of the relevant sections and introduce yourself with permission letter and to make arrangements with them in a manner that is convenient to the sections.

Your Sincerely

PELONOMI HOSPITAL
Dr. Matshediso GP
Chief Medical Officer
16 -04- 2012
DEPARTMENT OF HEALTH

Dr Matshediso G.P
Acting: CEO

APPENDIX B:

Approval from the Ethics Committee of the Faculty of Health Sciences at the University of the Free State

UNIVERSITEIT VAN DIE VRYSTAAT
UNIVERSITY OF THE FREE STATE
YUNIVESITHI YA FREISTATA

Direkteur: Fakulteitsadministrasie / Director: Faculty Administration
Fakulteit Gesondheidswetenskappe / Faculty of Health Sciences

Research Division
Internal Post Box G40
☎(051) 4052812
Fax (051) 4444359

E-mail address: StraussHS@ufs.ac.za

Ms H Strauss

2011-11-11

REC Reference nr 230408-011
IRB nr 00006240

MS B KOTZÉ
PO BOX 28373
LANGENHOVENPARK
9330

Dear Ms Kotzé

ECUFS NR 163/2011
PROJECT TITLE: ADDRESSING MOBILE NEONATAL IMAGE QUALITY THROUGH AN EDUCATIONAL PROGRAMME.

- You are hereby kindly informed that the Ethics Committee approved the above project at the meeting held on 08 November 2011.
- Committee guidance documents: Declaration of Helsinki, ICH, GCP and MRC Guidelines on Bio Medical Research. Clinical Trial Guidelines 2000 Department of Health RSA; Ethics in Health Research: Principles Structure and Processes Department of Health RSA 2004; Guidelines for Good Practice in the Conduct of Clinical Trials with Human Participants in South Africa, Second Edition (2006); the Constitution of the Ethics Committee of the Faculty of Health Sciences and the Guidelines of the SA Medicines Control Council as well as Laws and Regulations with regard to the Control of Medicines.
- Any amendment, extension or other modifications to the protocol must be submitted to the Ethics Committee for approval.
- The Committee must be informed of any serious adverse event and/or termination of the study.
- A progress report should be submitted within one year of approval of long term studies and a final report at completion of both short term and long term studies.
- Kindly refer to the ECUFS reference number in correspondence to the Ethics Committee secretariat.

Yours faithfully

CHAIR: ETHICS COMMITTEE

Cc Prof HS Friedrich-Nel

339, Bloomfontein 9300,RSA ☎ (051) 405 2812 StraussHS@ufs.ac.za
Republiek van Suid-Afrika / Republic of South Africa

APPENDIX C:

Informed consent from participating radiographers

CONSENT TO PARTICIPATE IN RESEARCH

Optimal image quality for neonatal chest radiography

You have been asked to partake in a research study. You have been informed about the study by Ms B Kotzé. You may contact Ms B Kotzé (083 270 4663) at any time if you have questions about the research.

You may contact the Secretariat of the Ethics Committee of the Faculty of Health Sciences, UFS (051 4052812) if you have questions about the rights as a research subject.

The participation in this research is voluntary, and you will not be penalized or lose benefits if you refuse participation or decide to terminate participation. If you agree to participation, you will be given a signed copy of this document as well as the participant information document, which is a written summary of the research.

The research study, including the above information has been verbally described to me. I understand what my involvement in the study means and I voluntarily agree to participation.

____________________ __________________

Signature of Participant Date

____________________ __________________

Signature of Witness Date

INFORMATION DOCUMENT

Optimal image quality for neonatal chest radiography

Dear Participant

I, Bea Kotzé from the Central University of Technology in the Free State am doing research on the quality of the neonatal chest images delivered by the radiological department. Research is just the process to learn the answer to a question. In this study I want to address areas in which we can improve the quality of the chest images performed on neonates.

This study is being done to improve the service delivered to neonates in hospitals. It is important to note that no additional images will be taken for the purpose of this study. Only images requested by referral physicians for the diagnosis or treatment of a neonate's condition will be examined in this study.

I am asking you to participate in this research study.

This study will involve the evaluation of chest images taken by you on a daily basis. You will also commit to a training program on image quality. This training program will consist out of short education sessions as well as practical demonstrations. If you sign this consent form you agree to complete the *WHOLE* training program as part of your participation in this study.

There are no risks involved in this study as the researcher will only witness the normal diagnostic radiography process. The long term benefits for this study are improved service delivery to neonates in hospitals. The results from this study will be made available to you, through email or the postal service at your request. There is no financial gain for you or the researcher in the study.

Participation is voluntary, and refusal to participate will involve no penalty or loss of benefits to which you are otherwise entitled; you may discontinue participation at any time without penalty or loss of benefits to you.

Efforts will be made to keep personal information confidential. Absolute confidentiality cannot be guaranteed. Personal information may be disclosed if required by law. All personal information found on the images of neonates, will be removed if an image is going to be included in any research report, materials or publication.

Please feel free to contact me, for more information:
Bea Kotzé
Cell: 083 270 4663
Po Box 26373
Langenhovenpark
9330

Central University of Technology, Free State

TOESTEMMING TOT DEELNAME AAN NAVORSING

Optimale beeld kwaliteit vir neonaat borskas radiografie

U is versoek u om deel te neem aan 'n navorsingstudie. U is oor die studie ingelig deur Mej. B Kotzé. U kan Mej. B Kotzé (083 270 4663) enige tyd kontak indien u vrae oor die navorsing het.

U kan die Sekretariaat van die Etiekkomitee van die Fakulteit Gesondheidsweteskappe, UV (051 4052812) kontak indien u enige vrae het oor u regte van 'n proefpersoon.

Deelname aan hierdie navorsing is vrywillig, en u sal nie gepenaliseer word of voordele verbeur as u weier om deel te neem of besluit om deelname te staak nie. As u instem tot deelname, sal 'n ondertekende kopie van hierdie dokument sowel as die deelnemerinligtings dokument, wat 'n geskrewe opsomming van die navorsing is, aan u gegee word .

Die navorsingstudie, insluitend die bogenoemde inligting is verbaal aan my beskryf. Ek begryp wat my betrokkenheid by die studie beteken en ek stem vrywillig in tot deelname.

________________________ __________________

Handtekening van Deelnemer Datum

_____________________ __________________

Handtekening van Getuie Datum

INLIGTINGSDOKUMENT

Optimale beeld kwaliteit vir neonaat borskas radiografie

Geagte Deelnemer

Ek, Bea Kotzé van die Sentrale Universiteit van Tegnologie in die Vrystaat is besig om navorsing te doen oor die kwaliteit van die borskas plate van neonate deur radiografiste. Navorsing is slegs die proses waardeur die antwoord op 'n vraagstuk verkry word. In hierdie studie wil ek enige gedeeltes waar radiografiste die beeld kwaliteit van hulle borskas plate kan verbeter, aanspreek.

Hierdie studie word gedoen om die diens wat neonate in die hospitaal ontvang te verbeter. Dit is belangrik om kennis daarvan te neem dat geen addisionele beelde geneem sal word nie. Net ondersoeke wat deur die verwysende dokter aangevra word om te help met diagnosering of behandeling, sal deel maak van die studie.

Ek versoek u om deel te neem aan die navorsings studie.

Die studie behels die evaluering van die kwaliteit van die neonatale borskas plate wat deur u geneem is op 'n daaglikse basis. Hiermee stem u ook in om 'n opleidings kurses the voltooi. Die opleidings kurses handel oor beeld kwaliteit en sal bestaan uit kort inligting en demonstrasie sessies. Daar sal van u vereis word om die ***HELE*** kurses te voltooi as deel name aan die studie.

Daar is geen risiko's verbonde aan hierdie studie nie. Die navorser gaan net die normale radiografiese proses evalueer. Die lang termyn voordeel van die studie is verbeterde diens verskaffing aan neonate in die hospitaal. Die resultate van die studie sal aan u gepos word. Daar is geen finansiele vergoeding vir u of die navorser nie.

Deelname is vrywillig en weiering om deel te neem sal geen boete of verlies van voordele waarop u andersins geregtig is behels nie; u kan te eniger tyd deelname onttrek sonder boete of verlies van voordele waarop u andersins geregtig sou wees.

Daar sal gepoog word om persoonlike inligting vertroulik te hou. Volkome vertroulikheid kan nie gewaarborg word nie. Persoonlike inligting kan bekend gemaak word as die wet dit vereis. Alle persoonlike inligting wat op beelde aangedui is, sal verwyder word as dit deel gaan maak van 'n navorsings verslag, materiaal of publikasie.

U is welkom om my te kontak vir verdere inligting:
Bea Kotzé
Sel: 083 270 4663
Posbus 26373
Langenhovenpark
9330

Central University of Technology, Free State

Tumello ya ho nka karolo

Ponahalo e phethahetseng ya setshwantsho sa x-ray ya sefuba

O kopuwe hore o fane ka tumelo ha hore ditshwantsho tsa x-ray tsa ngwana hao di sebediswe dipatlisisong. Mofumatsana B. Kotzè o otsebisitse ka dipatlisiso tsena. O ka ikopanya le Mofumatsana B. Kotzè neng kapa neng dinomorong tsena (083 270 4663) ebang o na le dipotso mabapi le dipatlisiso tsena.

O ka ikopanya le kantoro ya Komiti ya Melao ya Boitshwaro ya Lekala la Mahlale a Bophelo bo Botle, Yunivesithing ya Freistata (051 405 2818) ebang o batla ho tseba ka ditokelo tsa hao jwalo ka motho eo ho etswang dipatlisiso ho yena.

Motho o kenela dipatlisiso tsena ka boithaopo, mme o ke ke wa fumana kotlo kapa ho nkelwa menyetla ebang o hana ho nka karolo kapa o ikgula dipatlisisong tsena. Ebang o dumela ho nka karolo, o tla fuwa kgatiso e saennweng ya tokomane ena mmoho le tokomane ya bankakarolo ya tlhahisoleseding, e leng dintlha tse ngotsweng ka bokgutshwane tsa tlhahisoleseding.

Ke hlaloseditswe ka molomo ka ha dipatlisiso tsena mmoho le tlhahisoleseding e boletsweng ka hodimo. Ke utlwisisa hore seabo sa ngwana wa ka e tla ba e feng mme ke ithaopa ho nka karolo.

_________________________ _________________________

Motekeno wa Motswadi Letsatsi

_________________________ _________________________

Motekeno wa Paki Letsatsi

Tokomane ya Tlhahisoleseding

Ponahalo e phethahetseng ya setshwantsho sa x-ray ya sefuba

Monkakarolo ya ratehang

Nna, Bea Kotzè ho tswa Central University of Technology, Free State ke etsa dipatlisiso tse mabapi le boleng ba ditshwantsho tsa sefuba tse nkuwang ho ngwana wa hao ke lekala la radioloji. Dipatlisiso ke motjha wa ho fumana dikarabo dipotsong tse teng. Dipatlisisong tsena ke batla ho fumana ditsela tseo ka tsona re ka ntlafatsang ponahalo ya ditshwantsho tsa x-ray tse nkuwang ngwaneng wa hao.

Dipatlisiso tsena di etswa ho ntlafatsa phano ya ditshebeletso ho bana ba dipetlele. Ho bohlokwa ho ela hlooko hore ha hona ditshwantsho tse ding tse tla nkuwa tsa ngwana wa hao bakeng sa dipatlisiso tsena. Ho tla hlahlojwa ditshwantsho tseo ngaka e ileng ya dikopa bakeng sa ho phekola bohloko bo itseng. o ntse o tla fumana ditshwantsho tsena kaofela ha ngwana wa hao a lokollwa sepetlele.

Ke kopa o ntumelle ho hlahloba ditshwantsho tsa ngwana wa hao bakeng sa diphuputso tsena. Dipatlisitso tsena di tla etswa ka mokgwa wa hore mofuputsi a hlahlobe ditshwantsho tsa ngwana hao letsatsi ka leng. Mofuputsi o tla hlahloba feela ponahalo ya ditshwantsho mme a ke ke a hlahloba maemo a sefuba sa ngwana hao. Ditshwantsho tsohle tsa nkuweng ha ngwana wa hao a le sepetlele di tla ba karolo ya dipatlisiso tsena.

Dipatlisiso tsena di ke ke tsa beha maemo a ngwana hao kotsing kaha ho tla sebediswa feela ditshwantsho tse kopuweng ke ngaka bakeng sa kalafo. Molemo wa dipatlisiso tsena ke ho ntlafatsa maemo a ditshebeletso dipetlele. O tla romellwa sephetho sa dipatlisiso tsena ka poso kapa e-mail ho latela kopo ya hao. Ha hona tjhelete eo wena kapa mofuputsi a tlang ho e fumana dipatlisisong tsena.

Motho o nka karolo dipatlisisong tsena ka boithaopo, mme o ke ke wa fumana kotlo kapa ngwana hao a nkelwa menyetla eo a nang le tokelo ya ona ebang o hana ho ba le seabo dipatlisisong tsena; o ka ikgula neng kapa neng dipatlisisong tsena mme o keke wa fuwa kotlo kapa hona ho hulwa ha menyetla e itseng ya ngwana hao.

Ho tla etswa mekutu yohle ho netefatsa hore ho se ke ha fanwa ka tlhahisoleseding ya sephiri. Ho ke ke ha netefatswa hore tlhahisoleseding e tla ba ya sephiri ka dinako tsohle. Tlhahisoleseding ya sephiri e kanna ya hlahiswa ebang molao o re laela ho etsa jwalo. Tlhahisoleseding yohle a mabapi le ngwana wa hao e tla tloswa ebang setshwantsho se fe kapa se fe se tlo kenyeletswa raporotong kapa kgatisong ya dipatlisiso.

Eba e bolokollohi ba ho ikopanya lenna bakeng la tlhahisoleseding e fetang ena:

Bea Kotzé
Cell: 083 270 4663
Po Box 26373
Langenhovenpark
9330

APPENDIX D:

Checklist for pilot study

PILOT Checklist							Nr:	
Hospital:	Univ		Pelo		Van Dyk			
Date:			Time:					
Gender of neonate:	Male		Female					
Date of Birth:								
Birth weight: (g)								
Exposure factors: kVp mAs								
Diagnosis (if available):								
Number of previous chest examinations:								

On the image:	Yes	No	Partially	Partially explained/Notes/ List
Request letter available				
Clinical history indicated on request letter				
Radiographic position				
Rotation, evaluated by the equal distance of the lung borders to the vertebral column				
Tilt, evaluated by the trapezoid shaped chest and horisontal rib appearance				
All relevant anatomy free from superimposition by other anatomical structures				
Artifacts superimposing chest anatomy, list artefacts (tubes & radiographer hands)				
Chest centered in the collimated field (area of thoracic vertebrae 7)				
Breathing technique				
Suspended inspiration (demonstrated by 8-9 posterior ribs visible above the diaphragm)				
Normal breathing visible (suggested by blurred diagraphms, heart border or lung markings)				
Expiration (demonstrated by 5-6 posterior ribs visible above the diagraphms)				
Lead marker				
Lead marker visible on image				
Lead marker anatomical correctly placed				
Radiation Protection				
Lead shielding visible, over the pelvic area				
Exposure parameters				
Exposure is optimal, list under/ over exposure				
Visualise vascular pattern in central half of lungs				
Visualise parenchymal markings throughout the lungs				
Penetration of trachea visible				
Penetration proximal bronchi visible				
Sharp reproduction of diaphragm and costophrenic angles				
Visualise spine and paraspinal structures				
Visualise retrocardiac lung				
Visualise mediastinum				
Visualise any catheter tip in relevant anatomy area clearly				
Exposure index within recommended range (List EI value)				
Collimation				
Collimation is visible				
Superiorly, cervical vertebra 7 is included				
Is anything above cervical vertebra 7 included, list additional anatomy				
Bilateral, is the shoulders included				
Is anything lateral from the shoulders included, list additional anatomy				
Inferiorly, costophrenic angles are included				

Is anything below the costophrenic angles included, list additional anatomy				
Bilateral lungfields is included				
End result				
Was the image be manipulated by the radiographer				
Did the radiographer repeat the examination, list grounds for repeat				

APPENDIX E:

Final checklist

Checklist	Nr:					
Hospital:	Univ		Pelo		Van Dyk	
Date:						
Time:						
Gender of neonate:	Male		Female			
Date of Birth:						
Number of previous chest examinations:						

On the image:	Yes	No	Partially	Partially explained/Notes/ List
Request letter available				
Clinical history indicated on request letter				
Radiographic position				
Rotation, evaluated by the equal distance of the lung borders to the vertebral column				
Tilt, evaluated by the trapezoid shaped chest and horisontal rib appearance				
All relevant anatomy included on the film (detail – collimation area)				
Artifacts superimposing chest anatomy, list artefacts (tubes & radiographer hands)				
Chest centered in the collimated field (area of thoracic vertebrae 4)				
Breathing technique				
Suspended inspiration (demonstrated by 8-9 posterior ribs visible above the diaphragm)				
Normal breathing visible (suggested by blurred diagraphms, heart border or lung markings)				
Expiration (demonstrated by 5-6 posterior ribs visible above the diagraphms)				
Lead marker				
Lead marker visible on image				
Lead marker anatomical correctly placed				
Radiation Protection				
Lead shielding visible, over the pelvic area				
Exposure parameters				
Exposure is optimal, list under/ over exposure				
Visualise vascular pattern in central half of lungs				
Visualise parenchymal markings throughout the lungs				
Penetration of trachea visible				
Penetration proximal bronchi visible				
Sharp reproduction of diaphragm and costophrenic angles				
Visualise spine and paraspinal structures				
Visualise retrocardiac lung				
Visualise mediastinum				
Visualise any catheter tip in relevant anatomy area clearly				
Exposure index within recommended range (List EI value)				
Collimation				
Collimation is visible				
Superiorly, cervical vertebra 7 is included				
Is anything above cervical vertebra 7 included, list additional anatomy				
Bilateral, is the shoulders included				
Is anything lateral from the shoulders included, list additional anatomy				
Inferiorly, costophrenic angles are included				
Is anything below the costophrenic angles included, list additional anatomy				
Bilateral lungfields is included				
End result				
Will the image be manipulated by the radiographer				
Will the radiographer repeat the examination, list grounds for repeat				

APPENDIX F:

Statistical analysis (coding system) visible on checklist

	Checklist Nr:				
A	Hospital:	Univ		Pelo	Van Dyk
B	Date:				
C	Time:				
D	Gender of neonate:	Male		Female	
E	Date of Birth: / /				
F	Number of previous chest examinations:				
	On the image:	**Yes**	**No**	**Partially**	**Partially explained**
G	Request letter available				
H	Clinical history indicated on request letter				
	Radiographic position				
I	Rotation, evaluated by the equal distance of the lung borders to the vertebral column				
J	Tilt, evaluated by the trapezoid shaped chest and horisontal rib appearance				
K	All relevant anatomy included on the film (detail – collimation area)				
L	Artifacts superimposing chest anatomy, list artefacts (tubes & radiographer hands)				
M	Chest centered in the collimated field (area of thoracic vertebrae 7)				
	Breathing technique				
N	Suspended inspiration (demonstrated by 8-9 posterior ribs visible above the diaphragm)				
O	Normal breathing visible (suggested by blurred diagraphms, heart border or lung markings)				
P	Expiration (demonstrated by 5-6 posterior ribs visible above the diagraphms)				
	Lead marker				
Q	Lead marker visible on image				
R	Lead marker anatomical correctly placed				
	Radiation Protection				
S	Lead shielding visible, over the pelvic area				
	Exposure parameters				
T	Exposure is optimal, list under/ over exposure				
U	Visualise vascular pattern in central half of lungs				
V	Visualise parenchymal markings throughout the lungs				
W	Penetration of trachea visible				
X	Penetration proximal bronchi visible				
Y	Sharp reproduction of diaphragm and costophrenic angles				
Z	Visualise spine and paraspinal structures				
AA	Visualise retrocardiac lung				
BB	Visualise mediastinum				
CC	Visualise any catheter tip in relevant anatomy area clearly				
DD	Exposure index within recommended range (List EI value)				
	Collimation				
EE	Collimation is visible				
FF	Superiorly, cervical vertebra 7 is included				
GG	Is anything above cervical vertebra 7 included, list additional anatomy				
HH	Bilateral, is the shoulders included				
II	Is anything lateral from the shoulders included, list additional anatomy				
JJ	Inferiorly, costophrenic angles are included				
KK	Is anything below the costophrenic angles included, list additional anatomy				
LL	Bilateral lungfields is included				
	End result				
MM	Will the image be manipulated by the radiographer				
NN	Will the radiographer repeat the examination, list grounds for repeat				

APPENDIX G:

Presentation of the educational programme

Presentation of educational programme			
Institution	**Session**	**Date**	**Radiographers**
Private institution	Introduction	02.07.12/04.07.12	16
	1st theoretical	09.07.12/11.07.12	
	Discussion	09.07.12/11.07.12	
	Practical	09.07.12/11.07.12	
	2nd theoretical	16.07.12/23.07.12	
	Discussion	16.07.12/23.07.12	
	Practical	16.07.12/23.07.12	
Governmental institution	Introduction	19.06.12	22
	1st theoretical	22.06.12	
	Discussion	22.06.12	
	Practical	22.06.12	
	2nd theoretical	29.06.12	
	Discussion	29.06.12	
	Practical	29.06.12	
2nd Governmental institution	Introduction	06.07.12	18
	1st theoretical	13.07.12	
	Discussion	13.07.12	
	Practical	13.07.12	
	2nd theoretical	20.07.12	
	Discussion	20.07.12	
	Practical	20.07.12	

APPENDIX H:

Radiographer evaluation form of the educational programme

FACULTY OF HEALTH AND ENVIRONMENTAL SCIENCES
PROGRAM: RADIOGRAPHY

Celebrating 30 Years of Technological Innovation
Soaring to 2020

EVALUATION

To evaluate the effectiveness of this qualified "Neonatal Chest Image Quality" activity, we would appreciate your completing this questionnaire. You need not indicate your name.

Feedback form

Please rate the session by checking the appropriate box for each item below

	5	4	3	2	1
	Excellent		Acceptable		Poor
Usefulness of content					
Effectiveness of presenter					
Opportunities for interaction					
Overall effectiveness of the activity					

1. <u>What did you learn that you can use in your daily work in the NICU?</u>

2. <u>Presentation of the activity could be improved by:</u>

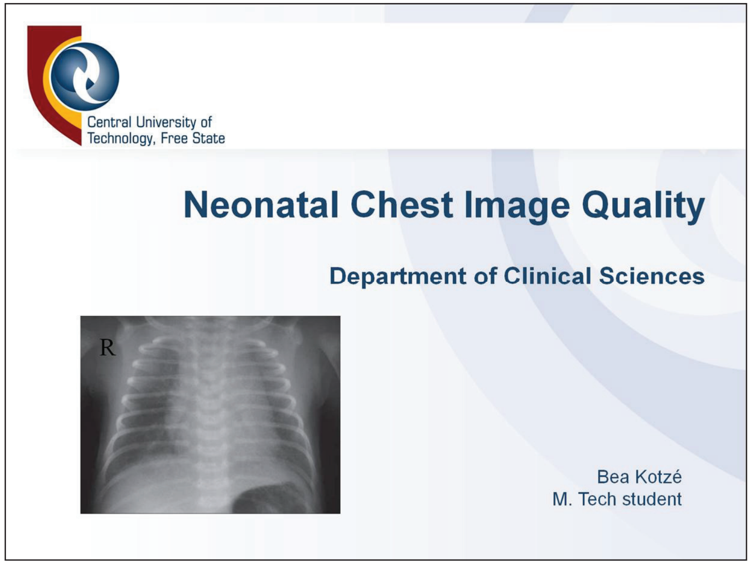
3. <u>Is there any additional information you would like to receive on this specific topic?</u>

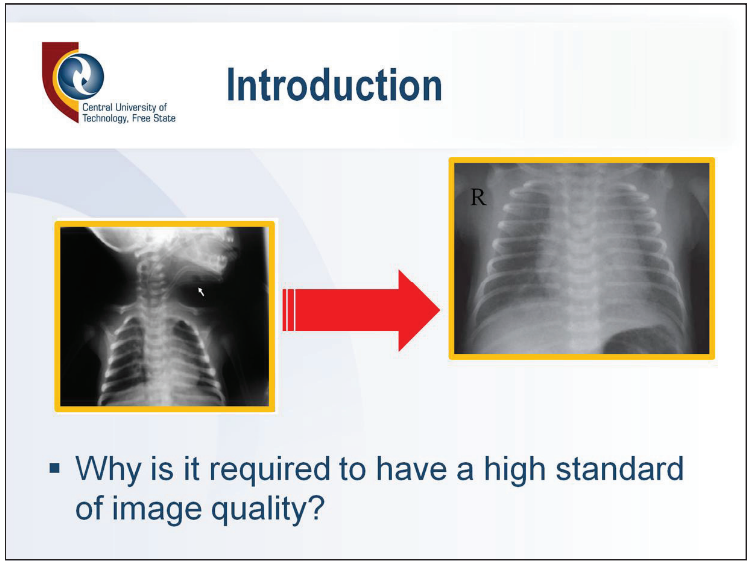
Thank you for your cooperation
Please return this form to the presenter before you leave

Radiography • Private Bag X20539 • Bloemfontein • SOUTH AFRICA • 9300 •
Tel: +27 51-507 3853 • **Fax:** +27 51-507 3354 • **E-mail:** bevdmerwe@cut.ac.za • **Website:** www.cut.ac.za

APPENDIX I:

Educational programme introduction (PowerPoint and footnotes)





The neonate is the smallest patient group we work with.

Because of their small size and fragile state, excellence and innovation is expected from radiographers when working with these patients.

By delivering an optimal image the first time with the application of ALARA, we will keep the accumulative radiation dose to the individual patient low and there by keep possible radiation manifestations in later life to a minimum.

Why is it required to have a high standard of image quality?

Image plays an important role in the assessment and treatment of the neonate.

First quality image will reduce the number of repeat images and so the dose to the neonate.

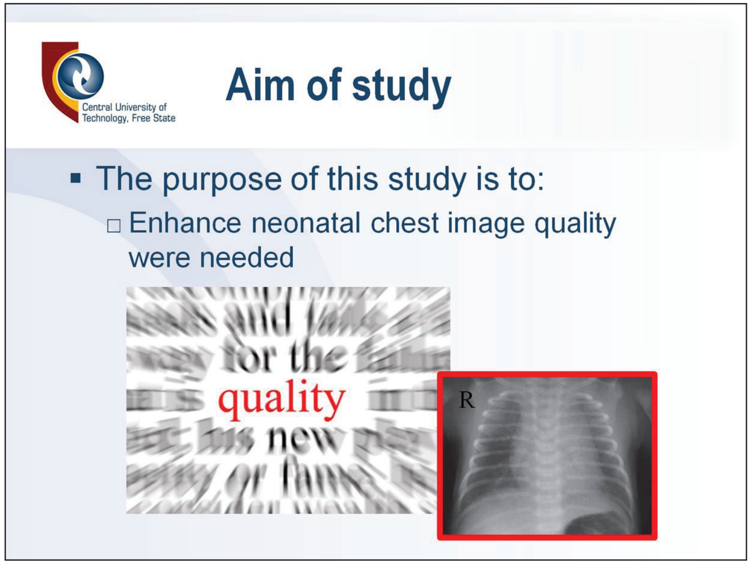
Radiologists at a private institution were not satisfied with the quality of neonatal images.

They were dissatisfied with the amount of collimation, lack of radiation shielding and rotation visible on the daily images produced by their radiography staff.

In other words they were not satisfied with the quality of these images.

This triggered questions about the quality of images at other institutions, do they also have problems with image quality specifically for neonates.

How can the image quality be improved on?



The purpose of this study is to:

Enhance neonatal chest image quality where needed.

Objectives of study

- Determine current neonatal chest image quality
- Identify areas which can be enhanced
- Address these areas through training
- Evaluate the effectiveness of the training

Determine the current neonatal chest image quality produced.

Identify areas which can be enhanced.

Address these areas through training, be it practical or theory.

Evaluate the effectiveness of the training by re- evaluating neonatal chest image quality.

Layout of study

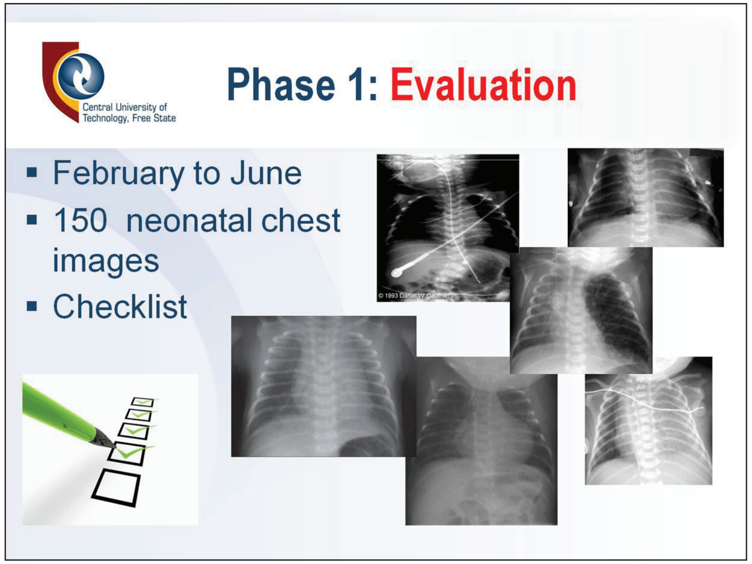
- Phase 1: Evaluate current neonatal chest image quality
- Phase 2: Training focused on enhancement
- Phase 3: Re-evaluation of neonatal chest image quality

To reach the planned aim and objective the study is divided into 3 phases:

Phase 1: Evaluate current neonatal chest image quality.

Phase 2: Training focused on enhancement.

Phase 3: Re- evaluation of neonatal chest image quality.



Was done from February to June.

150 neonatal chest images were evaluated.

These images were evaluated by means of a checklist.

International standardised checklist focused on all areas related to image quality in neonatal images.

The checklist was completed by the researcher and evaluated areas on:

Positioning (rotation, tilt, centering point).

Breathing technique.

Lead marker.

Radiation protection.

Exposure parameters.

Collimation.

Phase 2: Training

- Based on the outcome of the checklist
- Opportunity to grow and develop
- In- service training

It is now time for the next phase of the study.

Based on the outcome of the checklist, areas which can be enhanced has been identified.

Now the researcher will offer radiographers the opportunity to grow and develop their skills through training.

The training will be done during in service training hours.

The training will consist out of two sessions.

Additional sessions can be scheduled based on the needs and interest of the radiographers.

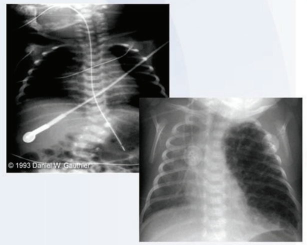
Practical sessions will be scheduled being in a group or individual.

The idea behind the training sessions is not for the researcher to teach the radiographers BUT rather for the radiographers to teach each other AS WELL AS the researcher.

The gathering of knowledge and skills in this way will enable the researcher to distribute this to a wider radiographer population, leading to improved radiographic quality not just in one institution but in many.

Phase 3: Re- evaluate

- After completion of training
- Indicate effectiveness of training
- In the end, neonatal chest image quality will improve



After we have completed the training, the researcher will re-evaluate neonatal chest image quality,

utilising the same checklist as used in phase 1.

This re- evaluation will show how effective training is as a tool to improve image quality and in essence the performance of radiographers.

In the end, neonatal chest image quality will be improved even if each individual only grows in one small aspect.

Participation Include

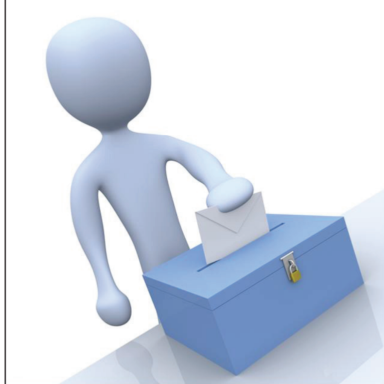
- Opportunity for developing radiographic skills
- CEU's
- Both sessions

In addition to opportunity for developing radiographic skills and in a smaller sense knowledge; the researcher will also offer each participant CEU's – for free.

BUT to get these CEU's the radiographer MUST attend all 2 the training sessions.

If unable to attend, a private or secondary session can be orginased.

How to become participant



- Information form
- Signed consent
- Returned to the researcher.

To become part of the research, the radiographer will have to read an information form and sign a consent to participate.

The consent from can then be returned to the researcher.

The 2 official dates for the formal training portion of the study is:

???

???

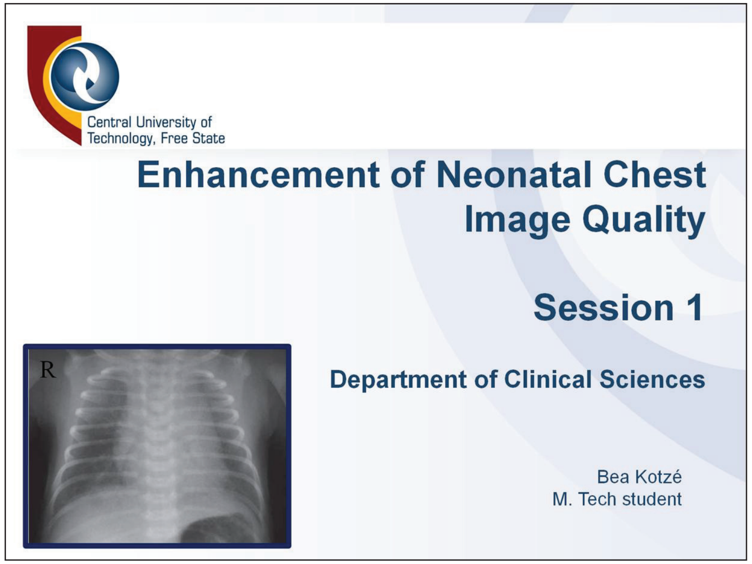
Practical sessions are optional.

Appendix I: Educational programme introduction


Central University of
Technology, Free State
ThanK
YoU!
Contact details
Bea Kotzé
M. Tech student
Tel.: 083 270 4663
E-mail: bekotze@cut.ac.za
www.cut.ac.za | Bloemfontein (051) 507 3911 | Welkom (057) 910 3500

APPENDIX J:

Educational programme session 1 (PowerPoint and footnotes)



Purpose of presentation:

Enhance current neonatal image quality through educational session.

Discussion session to identify and problem-solve.

Foot notes will be taken during discussion.

6 Areas will be targeted by the discussion today – rest during session 2:

positioning technique;

breathing technique;

lead marker;

radiation protection;

exposure parameters and;

collimation.

Important ground rules that a radiographer should keep in mind when visiting a NICU according to Fuller (2009:online) is to wash hands before entering the unit, when exiting the unit and between neonates imaged.

Care should also be taken to not run with the mobile unit into the incubator since even such a mild collision can cause haemorrhage in a neonate.

The radiographer must use the image receptor (IR) tray; if it is available in the specific incubator.

Hardy and Boynes (2003:95-96) further indicated that it is important to request assistance from the NICU nursing staff since they are the specialists who know each specific neonate, what illnesses they suffer from and are skilled at handling the neonate.

The radiographer must not move a neonate without the nursing staff's permission.

Hardy and Boynes (2003: 95-96) as well as Fuller (2009:online) indicated that the radiographer must consider radiation protection for self, the nursing staff and the neonate.

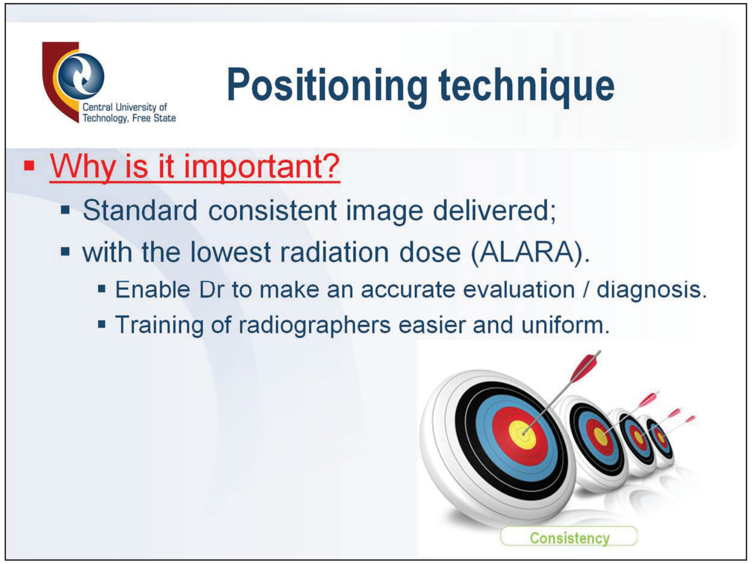
Ballinger and Frank (1999:140) describes the greatest danger that faces all neonates as hypothermia.

Hypothermia can be described as a lower than normal body temperature.

The danger of hypothermia for neonatal patients is their inability to prevent body temperature loss because of their greater surface area in comparison to body mass.

Fuller (2009:online) advises that to prevent hypothermia, radiographers performing neonatal examination in the infant's incubator, should work fast and effectively to prevent temperature loss.

Contact between the neonatal skin and IR should also be avoided to ensure no loss in body temperature (Ballinger and Frank, 1999:140; Hardy and Boynes, 2003:95-96).



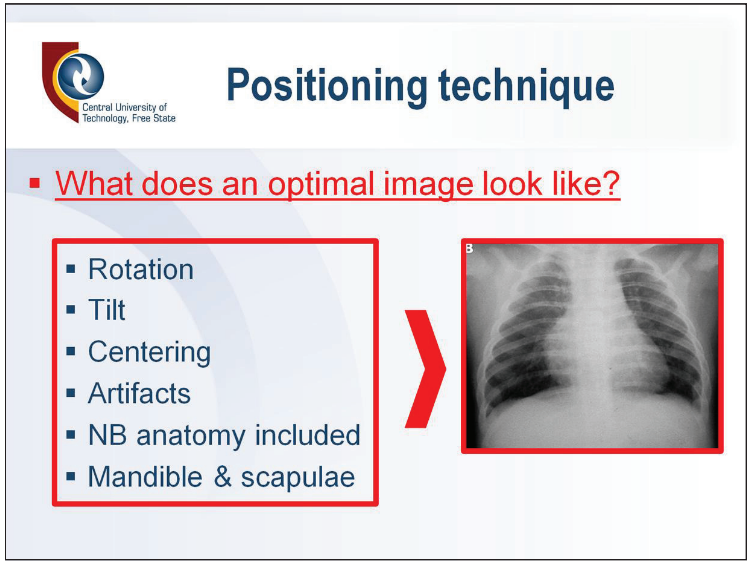
Why is it important?

Standard consistent image delivered for comparison.

Lowest radiation dose (ALARA) – neonate sensitive to radiation.

Enable Dr to make an accurate evaluation / diagnosis.

Training of radiographers easier and uniform – everyone is utilising the same technique and criteria for evaluation.



What does an optimal image look like?

Rotation.

Tilt.

Centering.

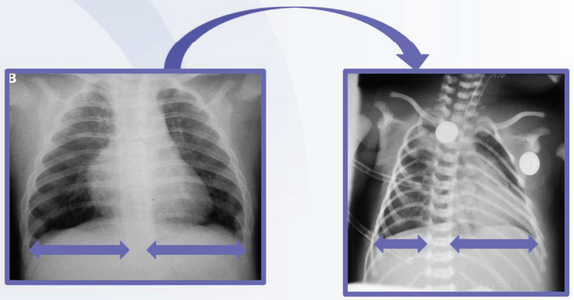
Artifacts.

NB anatomy included.

Mandible & scapulae.

Positioning technique

- **Rotation**
  - Equal distance to midline structure (SP).

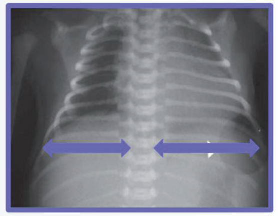


Rotation evaluated by the equal distance of the lung border to the spine.

(European Commission, 1996:27; Morris, 2003:460-461; Slade *et al.*, 2005:609; Loovere *et al.*, 2008:201; McQuillen Martensen, 2011:121-124; Bontrager and Lampignano, 2014:631).

Positioning technique

- **Rotation**
  - Can suggest:
    - Cardiomegaly
    - Mediastinal shift
    - Increased translucency of lung fields



Rotation on an image can suggest:

Cardiomegaly.

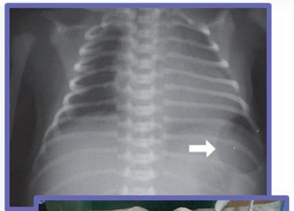
Mediastinal shift.

Increased translucency of lung fields.

(Morris, 2003:460-461).

Positioning technique

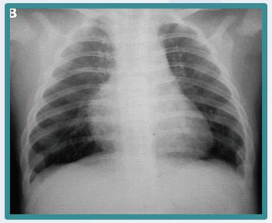
- **Rotation**
  - Ensure non rotational image:
    - Pelvis not rotated;
    - both shoulders in contact and;
    - no additional support structure under neonate (drip).

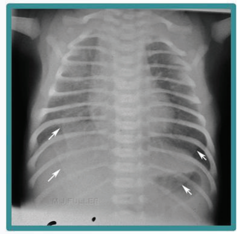


Hardy and Boynes (2003:118) further indicated that a true AP positioning can be achieved by ensuring no rotation of the thorax or pelvis, by ensuring the neonates shoulders are in contact with the incubator surface with no additional support structure (drip bag for example) underneath the neonate.

Positioning technique

- **Tilt**
  - Horisontal appearance of ribs.
  - Posterior rib ends ↑ to anterior rib ends.
  - Clavicles superior to lung apices (arms lateral).



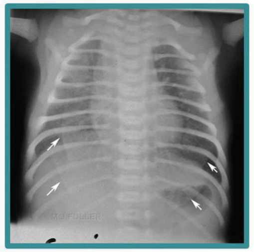


Tilt evaluated by the trapezoid shaped chest and/or horizontal rib appearance

(European Commission, 1996:27; Loovere *et al.*, 2008:201; McQuillen Martensen, 2011:121-124).

Positioning technique

- Tilt
  - Can suggest:
    - Misplaced ETT (endotracheal tube).
    - Increased opasification.
    - Decrease lung volume.
    - Shift pathological manifestation.



Can suggest:

Misplaced endotracheal tube.

Increased lung opasification.

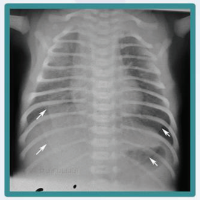
Decreased lung volume.

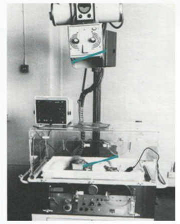
Shift pathological manifestation up or down.

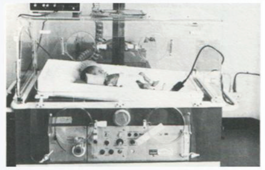
(Morris, 2003:460-461).

Positioning technique

- Tilt
  - Ensure correct angulation of tube:
    - 5-10° ↓ OR tilt incubator bed (feet).
    - Tube inferior surface // to sternum.





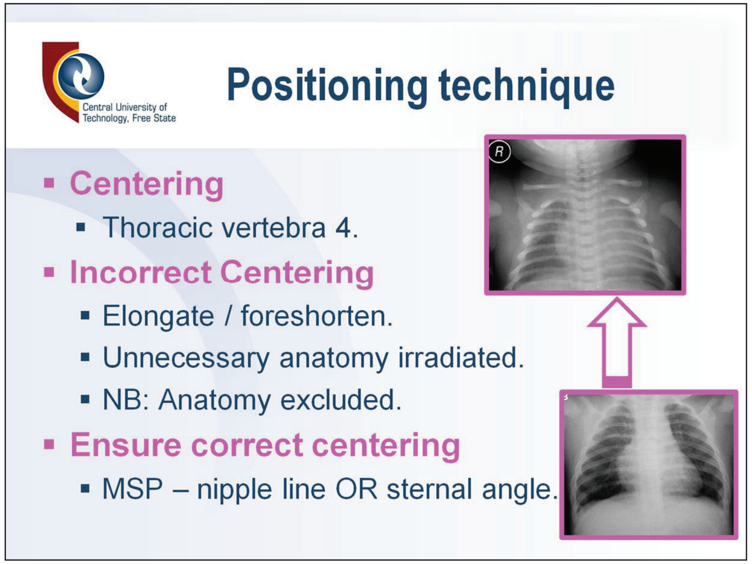


The image is produced in a supine body position with the sternum not as a rule parallel to the IR because of the body position.

To ensure proper parallel alignment of the chest; the main radiation beam can be tilted 5° to 10° degrees caudally (direction of feet)

OR the tray of the bed on which the neonate is recumbent can be tilted until the sternum is parallel to the IR or perpendicular to the main radiation beam

(Swallow, Naylor, Roebuck and Whitley, 1986:141).



Thoracic vertebra four centered to the collimated field

(Loovere *et al.*, 2008:201; McQuillen Martensen, 2011:121-124; Bontrager and Lampignano, 2014:631).

Incorrect Centering

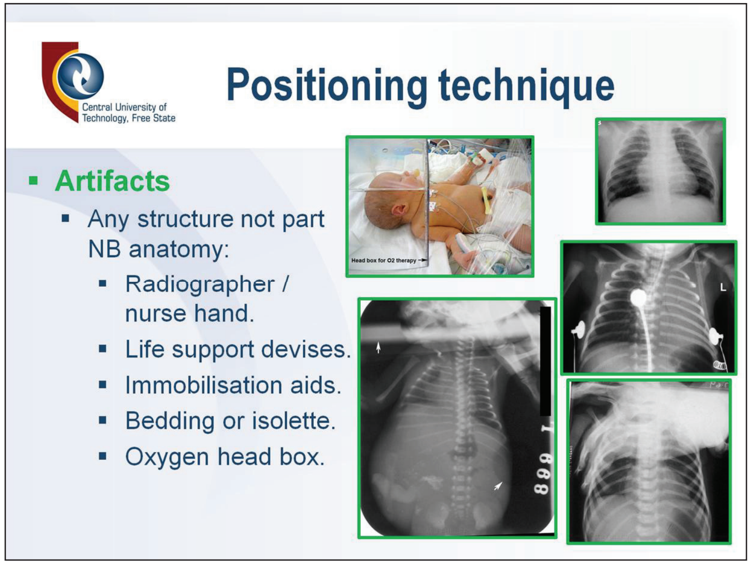
Elongate / foreshorten of anatomical structures.

Unnecessary anatomy irradiated.

Important anatomy may be excluded.

(Morris, 2003:460-461).

Bontrager and Lampignano (2014:631) advises that the center indicator of the main radiation beam should be focused to the center of the chest in the mammillary (nipple) line which is the topographic landmark for the level of thoracic vertebrae four in neonates.

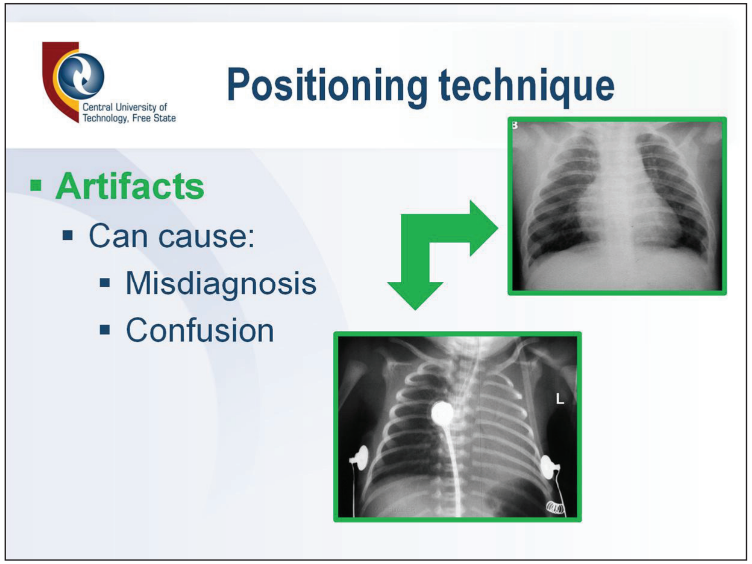


Artefacts is seen as foreign objects superimposed on the normal chest anatomy and impairs the visibility of anatomy (Hardy and Boynes, 2003:1180).

Artifacts superimposed on chest anatomy including the mandible over lung apices

(Morris, 2003:460-461; Loovere *et al.*, 2008:201; McQuillen Martensen, 2011:121-124; Bontrager and Lampignano, 2014:631).

All artifacts should be removed and the following images show common artefacts found in the NICU.

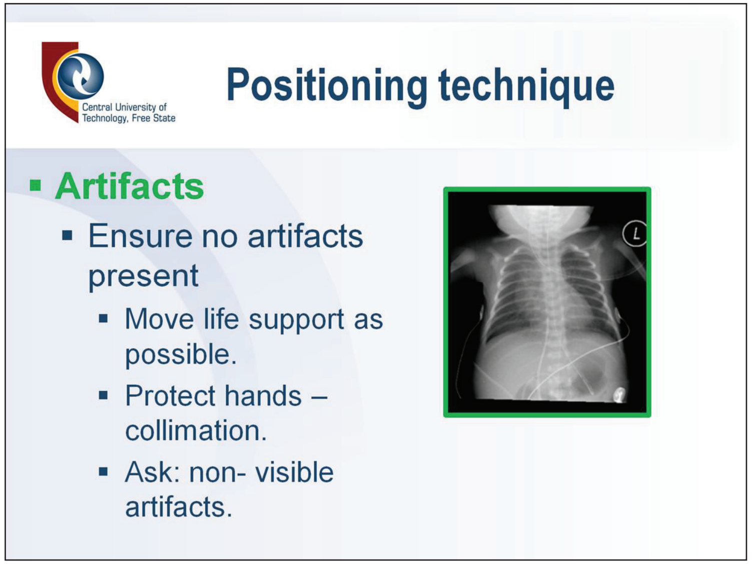


Artifacts can cause:

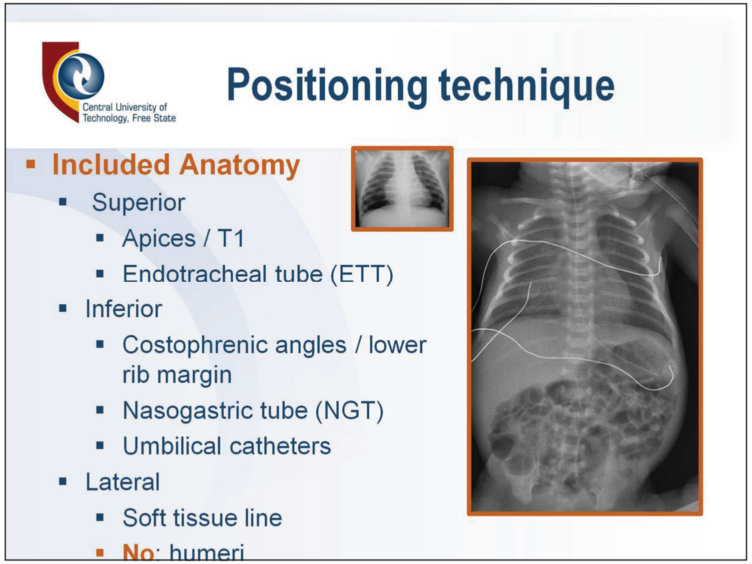
Misdiagnosis because pathology is superimposed and not visible.

Confusion for newly qualified medical staff. They will not be familiar with an artefact and will se it as an possible pathological manifestation.

(Morris, 2003:460-461).



Loovere *et al.* (2008:179) and Fuller (2009:online) advises that artefacts such as electrocardiogram (EKG) lines, cardio- respiratory monitoring leads, oxygen apparatus, staff members hands and supporting additional linen should be removed, if possible and allowed.



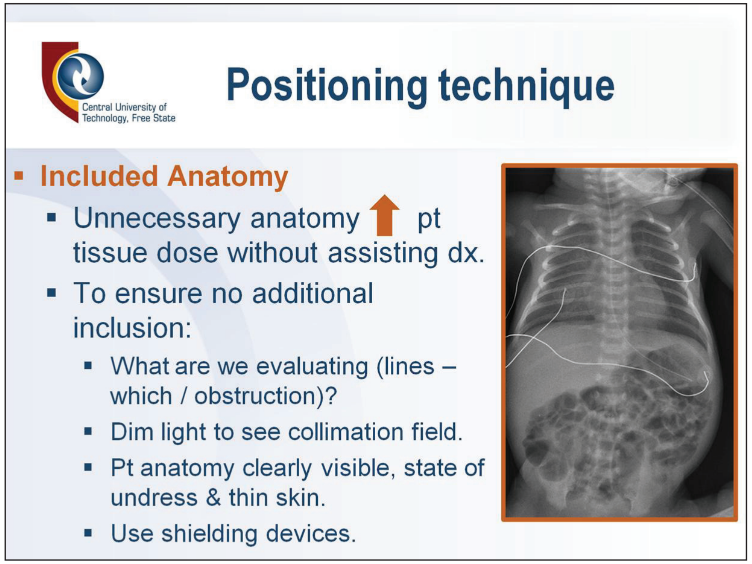
Superiorly, cervical vertebra seven is included (European Commission, 1996:27; Morris, 2003:460-461; Slade *et al.*, 2005:609; Loovere *et al.*, 2008:201; McQuillen Martensen, 2011:121-124; Bontrager and Lampignano, 2014:631).

Bilateral the shoulders are included (European Commission, 1996:27; Morris, 2003:460-461; Slade *et al.*, 2005:609; Loovere *et al.*, 2008:201; McQuillen Martensen, 2011:121-124; Bontrager and Lampignano, 2014:631).

Inferiorly, costophrenic angles are included (European Commission, 1996:27; Morris, 2003:460-461; Slade *et al.*, 2005:609; Loovere *et al.*, 2008:201; McQuillen Martensen, 2011:121-124; Bontrager and Lampignano, 2014:631).

Bilateral lungfields included (European Commission, 1996:27; Morris, 2003:460-461; Slade *et al.*, 2005:609; Loovere *et al.*, 2008:201; McQuillen Martensen, 2011:121-124; Bontrager and Lampignano, 2014:631).

Appendix J: Educational programme
session 1



Unnecessary anatomy increases pt tissue dose without assisting dx.

To ensure no additional inclusion of anatmoy:

Ask the question what are we evaluating (lines – if yes, which lines / obstruction - more of the abdomen should then be included)?

Dim light to see collimation field if the lights in the NICU is to bright.

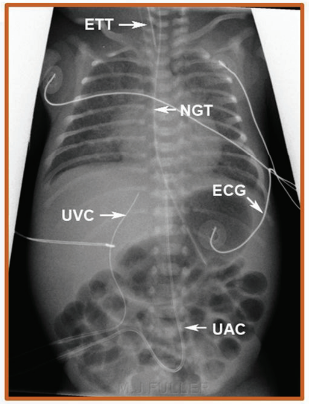
Pt anatomy clearly visible, state of undress & thin skin.

Use shielding devices always.

(Morris, 2003:460-461).

Positioning technique

- Included Anatomy
  - Line position & definition:
    - ETT: endotracheal
      - Midway between thoracic inlet (T1) & carina (T5).
    - UAC: Umbilical artery catheter
      - Deviates ↓ before ↑ .
      - 2 possible levels T6-9 OR L3-4



Desired location of medical lines in a neonate:

Endotracheal tube (ETT)

Level of thoracic vertebra 4 - midway between Carina (T5) and thoracic inlet (T1).

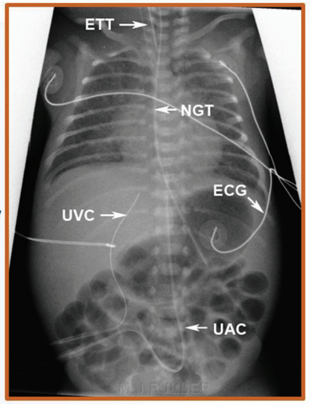
Umbilical artery catheter (UAC)

Level of thoracic vertebrae 6 to 9 or lumbar vertebrae 3 to 4.

(Arthur, 2001:311; Hardy and Boynes, 2003:115-118; Fuller, 2009:online and McQuillen Martensen, 2011:91-94).

Positioning technique

- Included Anatomy
  - Line position & definition:
    - UVC: Umbilical vein catheter
      - Appears shorter then UAC.
      - On entering body, directly ↑ & little to right of MSP.
      - Should be ↑ diaphragm BUT ↓ the heart.
    - NGT: Nasogastric tube
      - Should demo in stomach.



Umbilical vein catheter (UVC)

Junction between the inferior border of the right atrium (heart) and the right hemi-diaphragm.

Nasogastric tube (NGT)

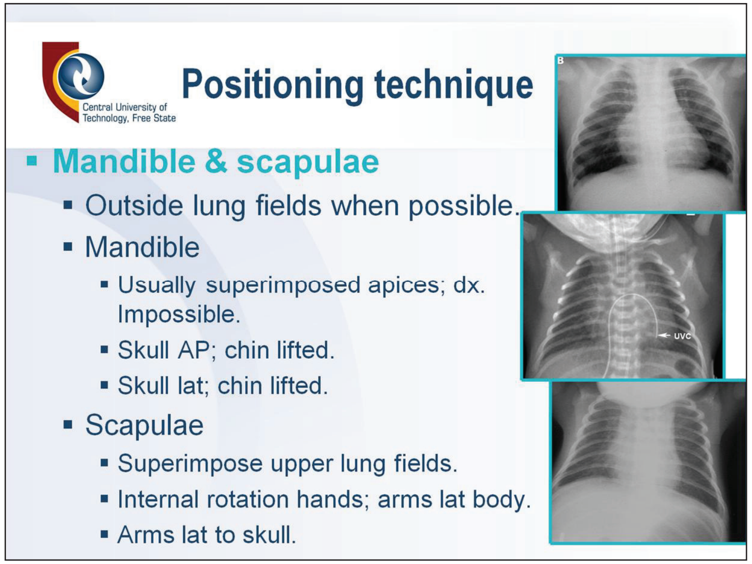
In the stomach, on the level of lumbar vertebrae 2 to 3.

(Arthur, 2001:311; Hardy and Boynes, 2003:115-118; Fuller, 2009:online and McQuillen Martensen, 2011:91-94).

A request by a referring physician to establish optimal medical line, tube and catheter placement requires a radiographer to include abdominal anatomy up to the level of the third lumbar vertebrae.

The third lumbar vertebra according to Ballinger and Frank (1999:140-143) in agreement with Bontrager and Lampignano (2014:111) is on the level of the lower costal margin which is a palpable topographic landmark.

Any additional inclusion beyond lumber vertebra three only adds to the radiation dose of the neonate without contributing to the diagnostic purpose of the produced image.



McQuillen Martensen (2011:91) indicated the importance of ensuring that the neonatal mandible is not rotated from side to side and in addition elevated, to ensure that it is not superimposing over the lung apices.

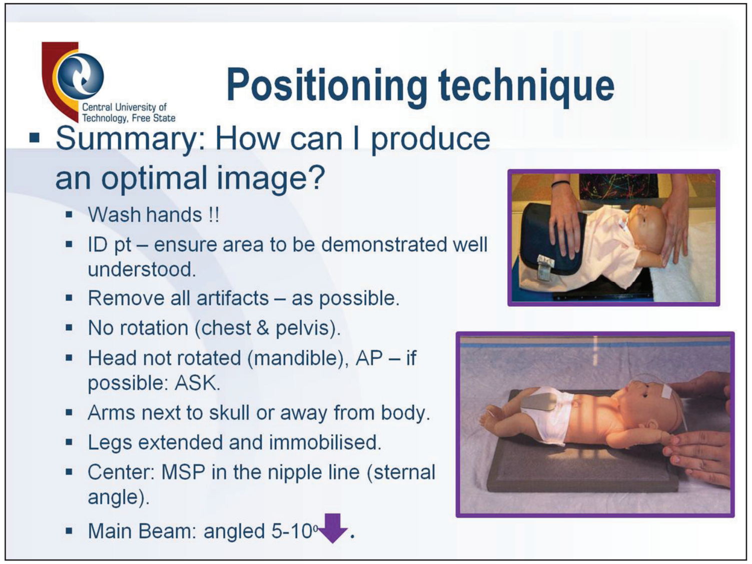
Hardy and Boynes (2003:118) states that should the mandible be rotated to the side, it can displace the ETT making it difficult to evaluate correct tube placement.

The correct position if the mandible is obtained by first ensuring that there is no rotation of the head and then elevating the neonates chin, done by a NICU staff member, during the production of the chest image (Bontrager and Lampignano, 2014:631).

The neonate's arms should also be extended to remove the scapulae from the lung fields (Bontrager and Lampignano, 2014:631).

In addition, the internal rotation of both hands can also ensure displacement of the scapulae outside the lung fields (Ballinger and Frank, 1999:142). On the image, this positioning technique will ensure that lungfields are clearly visible without any superimposition by the scapulae.

In addition, if the arms of the neonate are shifted away from the collimated area, the amount of scatter radiation produced will be minimised which inherently lowers the radiation dose to the neonate (Carlton and Adler, 2014:234).



Summary: How can I produce an optimal image?

Wash hands beforehand!!

Identify the pt – ensure the anatomical area to be demonstrated well understood.

Remove all artifacts with assistance of NICU staff and as possible.

No rotation (chest & pelvis contact with incubator mattress).

Head not rotated (mandible), AP if possible: ASK nursing staff assistance. Provide them with lead protection and let them keep the head elevated, not to superimpose the apices.

Arms next to skull or away from body – lowers scatter and removes scapulae.

Legs extended and immobilised.

Center: MSP in the nipple line (sternal angle).

Main Beam: angled 5-10° caudally.

Positioning technique

- **Is there more than one way?**
  - Yes – radiographer must adapt to situation.
  - BUT – image quality should remain OPTIMAL.
  - More experience – more techniques.
  - Do not be afraid to ASK.

Is there more than one way?

Yes.

Radiographer should adapt to situation found in the NICU as well as the physical condition of the pt.

BUT image quality should remain OPTIMAL and uncompromised.

With more experience in the NICU your technique will improve and you will also develop more techniques of your own – please share some that I have not included here during our discussion.

Do not be afraid to ASK the NICU staff for support and advise.

Positioning technique

- **Statistics from phase 1:**
  - Rotation
    - 56.7% found
  - Tilt
    - 41.6% absent
  - Centering
    - 64.9% incorrect
  - Artefacts
    - 56.4% present
  - NB anatomy included
    - 92.9%

Rotation – 56.7% found on images.

Tilt – 41.6% found on images.

Centering – 64.9% centered incorrectly with most images centered to inferiorly.

Artefatcs – 56.4% present and superimposed on lungfields.

Important and relevant anatomy was found on 92.9% of images.

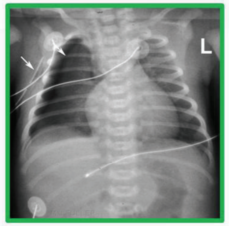
Breathing technique

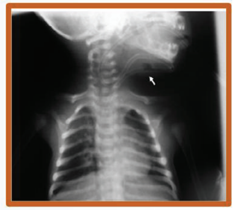
- Why is it important?
  - Ensure visualisation of entire lung field.
  - Ensure sharp & clear image.

Ballinger and Frank (1999:142) advised that the IR must be exposed on suspended inspiration to produce an image considered optimal because of aerated lungfields.

Breathing technique

- What does an optimal image look like?
  - Suspended inspiration:
    - Posterior rib pair 8 – 9 visible above diagraphms.
    - Sharp diagraphms & heart borders.
  - Incorrect image
  - Suspended expiration:
    - Posterior rib pair 5-6 visible above diagraphms.
    - Sharp diagraphms & heart borders.
  - Normal breathing:
    - Blurred diagraphms & heart borders.





Suspended inspiration; demonstrated by 8-9 posterior ribs seen above the diaphragm (European Commission, 1996:27; Morris, 2003:460-461; McQuillen Martensen, 2011:121-124; Bontrager and Lampignano, 2014:631).

Normal breathing or respiration; suggested by blurred representation of the diaphragm, heart border and lung markings (Morris, 2003:460-461; Slade *et al.*, 2005:609; Bontrager and Lampignano, 2014:631).

Suspended expiration; demonstrated by 5-6 posterior ribs seen above the diaphragm (McQuillen Martensen, 2011:121-124; Bontrager and Lampignano, 2014:631).

Breathing technique

- How can I produce an optimal image?
  - Experience and practice.
  - Calm and controlled attitude.
  - Observe breathing
    - Sternum rises.
    - Abdomen expands
    - Neonate stops crying
  - Ventilator
    - Ask for guidance on specific ventilator used in NICU.

According to Bontrager and Lampignano (2014:631) an image on suspended inspiration can be obtained by observing the neonates breathing for a few seconds.

Inspiration is evident when the sternum rises, abdominal cavity expands or the neonate stops crying (Swallow *et al.*, 1986:143).

An exposure should be made immediately after a full inspiratory breath (Hardy and Boynes, 2003:118).

Appendix J: Educational programme
session 1

Breathing technique

- Statistics from phase 1:
  - Suspended inspiration
    - 54.2%
  - Suspended expiration
    - 15.6%
  - Normal breathing
    - 30.2%

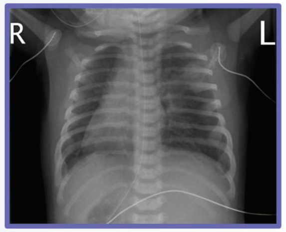
Suspended inspiration observed on 54.2% of images.

Suspended expiration was observed on 15.6% of images.

Normal breathing was found on the remaining 30.2% of images.

Lead Marker

- Why is it important?
  - To ensure correct anatomical labeling.
  - NB: first image (situs inversus / dextrocardia).

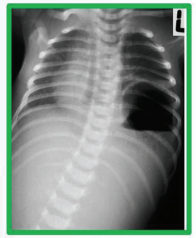


The SA Government Gazette (1973:8-9) indicates the utilisation of lead markers in the NICU as of utmost importance.

The main obstacle is that a lead marker can appear on the image, almost as big as the premature neonate's skull and may superimpose important anatomy.

Lead Marker

- What does an optimal image look like?
  - Includes anatomical marker.
  - Inside collimation.
  - Not imposing NB anatomy.

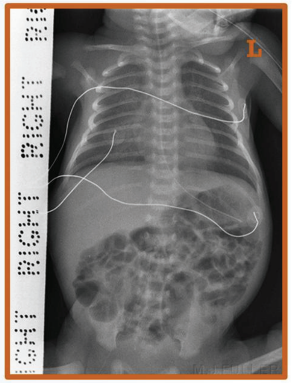


Lead marker visibility in the collimated field (Morris, 2003:460-461; Slade *et al.*, 2005:609).

Lead marker placed anatomically correct (Morris, 2003:460-461; Slade *et al.*, 2005:609).

Lead Marker

- How can I produce an optimal image?
  - Marker clean or dedicated to neonate.
  - Place in collimated area.
  - Use perforated lead strip.



Dedicated neonatal lead markers that are smaller in size are a practical but expensive solution to ensure no superimposition by the lead marker (Fuller, 2009:online).

Another solution is to incorporate lead markers with collimation as a perforated lead strip – will be more completely unpacked in session 2.

Lead Marker

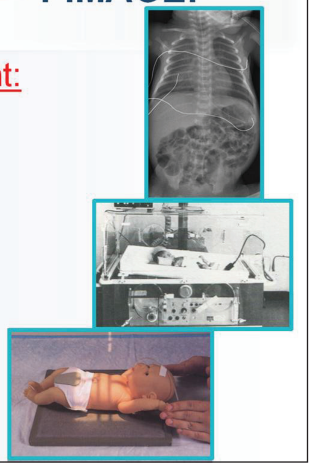
- Statistics from phase 1:
  - Anatomical marker visible.
    - 33.6%
  - Anatomical marker not over NB anatomy.
    - 32.7%

Lead markers were found in 33.6% of images.

Lead markers included and not superimposed on important anatomy were found in 32.7% of images.

CXR & AXR – 1 IMAGE:

- **Must decide as department:**
  - Centre point
    1. Midway between C7 & SP.
    2. T4, open cones.
  - Tube tilt
    1. No tilt, chest foreshortened.
    2. Tilt, no chest foreshortening.
  - Lead protection (more next session)
    1. Protect gonads.
    2. Protect areas in open cone fields with lead strips on incubator.
  - Unified utilisation.



Must decide as department:

Centre point:

Either midway between C7 & SP OR on

T4 but with the cones open which includes the skull in the main radiation beam.

Tube tilt:

No tilt, which will cause the chest to be foreshortened.

Tilt, no chest foreshortening.

Lead protection is part of the regulation code of SA (more next session):

Protect gonads which type will you use and why?

Protect areas in open cone fields with lead strips on incubator – especially when cones are opened to include the skull.

Unified utilisation – all must stick to one technique.

Conclusion

- Positioning technique
  - Rotation
  - Artifacts
  - Tilt
- Breathing technique
  - Investigate ventilator.
- Lead marker
  - Make a conscious decision to use.

Decide on 1 standard technique in department to ensure a CONSTANT image quality.

Technique should be based on sound radiography principles and practical application.

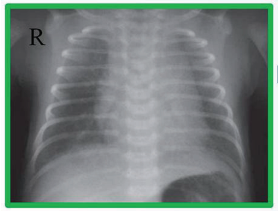
Once a decision is made – is should be adhere to as far as reasonably possible.

APPENDIX K:

Educational programme session 2 (PowerPoint and footnotes)

Enhancement of Neonatal Chest Image Quality

Session 2



Department of Clinical Sciences

Bea Kotzé
M. Tech student

Introduction

- Session 1
  - Positioning techniques
  - Breathing techniques
  - Lead marker placement
- Concluded
  - 2 possible techniques
    - Center on T4 OR
    - Midway between SP & T1
  - Demo both & decide on 1

During session 1

Positioning techniques (rotation, tilt, centering and important anatomy included).

Breathing technique.

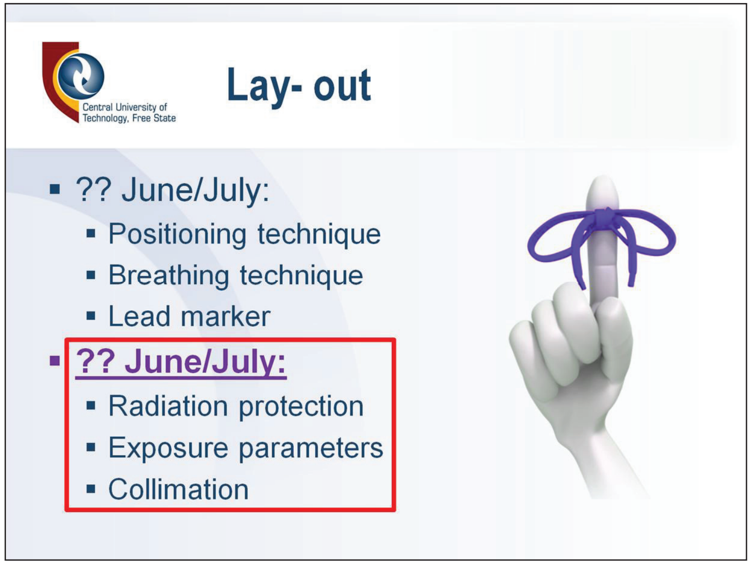
Lead marker placement.

Concluded

2 possible techniques (Babygram or only well collimated chest image).

Center on T4 or Midway between SP & T1.

My suggestion - demo both & decide on 1 that will be utilised by all of the staff.



Previous date ?? June/July:

Positioning technique.

Breathing technique.

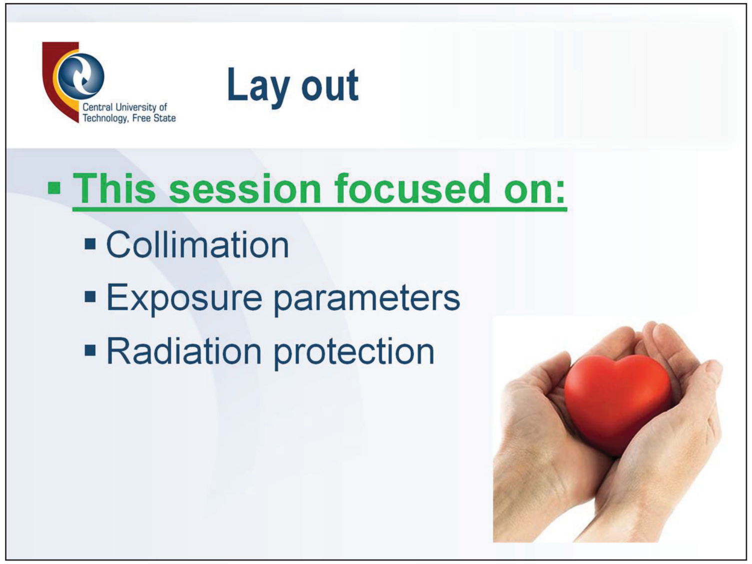
Lead marker.

Now ?? June/July:

Radiation protection.

Exposure parameters.

Collimation.



This session focused on:

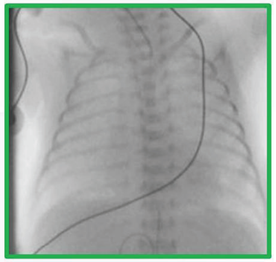
Collimation.

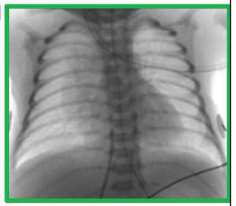
Exposure parameters.

Radiation protection.

Collimation

- **Function of collimation?**
  - Main radiation beam restrictor
  - Consist out of sets of lead shutters
  - ***Advantages***
    - Reduce area exposed
    - Reduce radiation hazard
    - Lowers amount of scatter radiation produced
    - Subject contrast is improved
    - Signal to noise ratio is improved
  - ***Disadvantages***
    - Intensity of radiation reaching IR reduced
    - {Compensatory increase in kVp or mAs is needed}





As a general consideration Bontrager and Lampignano (2014:53) as well as Hardy and Boynes, (2003:23) advice radiographers to restrict the main radiation beam closely to ensure optimal image quality.

Ballinger and Frank (1999:140) resonates this consideration and also emphasises that bone marrow, which is active in blood cell formation, is distributed throughout a neonatal patient skeleton and that blood cell damage is associated with ionising radiation.

The radiographer should take cognisance of this fact each and every time a neonate is exposed to ionising radiation without sufficient collimation of the main radiation beam.

Many imaging departments still do not use recommended radiographic collimation parameters during imaging of neonates.

A study by Duggan, Warren- Forward, Smith and Kron (2003:232) aimed to investigate dose reduction techniques for neonates in the NICU.

The said study recommended radiographers to collimate precisely to the region of interest, being careful not to exclude relevant anatomy.

According to neonatal dose limitation literature consulted, poor collimation is the most significant mistake made by diagnostic radiographers when imaging neonates (Duggan *et al.*, 2003:232; Smans, Struelens, Smet, Bosmans and Vanhavere, 2008:147; Willis, 2009:273).

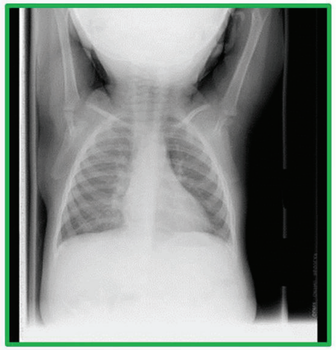
Insufficient collimation gives rise to an unnecessary high patient dose and deteriorates image quality.

A too large field size will impair contrast and resolution by adding unnecessary scatter radiation to the image.

The area irradiated should also be kept as small as possible to keep the dose to the patient tissue as low as possible as prescribed by the ALARA principle (Smans *et al.*, 2008:147; Willis, 2009:273).

Collimation

- **Why is it important?**
  - Neonate specific
    - Lower scatter produced
    - Lower radiation dose to neonate, radiographer & NICU staff
    - Improve image quality and signal to noise ratio

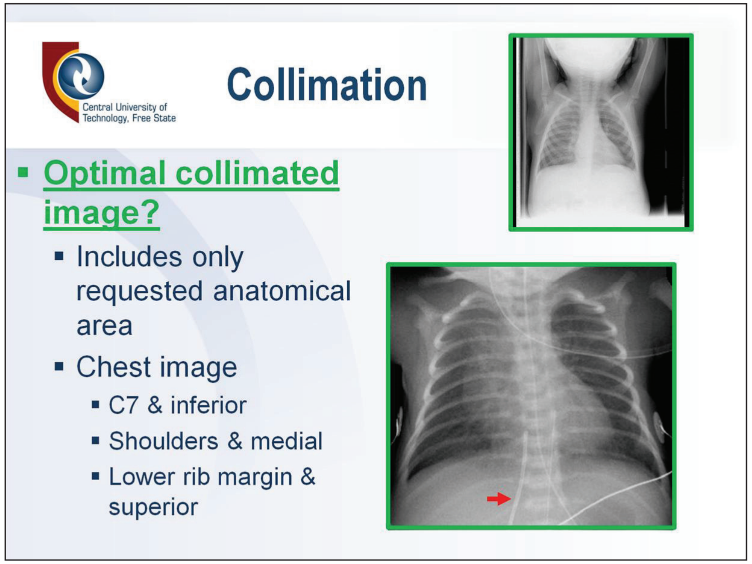


Why is it important?

Lower scatter produced when the main radiation beam enters the neonate.

Lower radiation dose to neonate, radiographer & NICU staff.

Improve image quality and signal to noise ratio.



Collimation was evaluated by ensuring that only the necessary anatomical areas were visible within the collimated field indicated by authors European Commission (1996:27), Morris (2003:460-461), Slade *et al.* (2005:609), Loovere *et al.* (2008:201), McQuillen Martensen (2011:21-124) with Bontrager and Lampignano (2014:631).

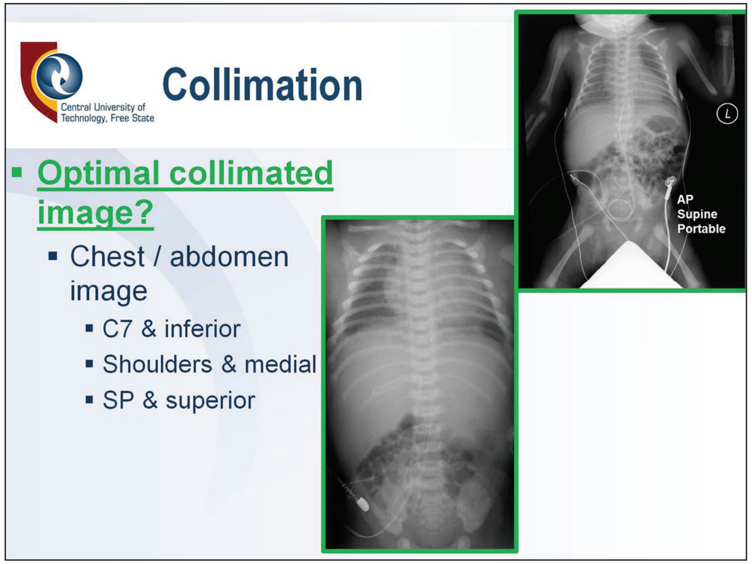
A radiographer can ensure correct collimation of the main beam by adequate knowledge of the external anatomical landmarks (Smans *et al.*, 2008:147; Willis, 2009:273).

From authors Swallow *et al.* (1986:145), Ballinger and Frank (1999:140) with Bontrager and Lampignano (2014:631):

Superiorly - upper margin of the thyroid cartilage / mid-cervical (neck) area.

Bilaterally - to the soft tissue line.

Inferiorly - to the lower costal margin.

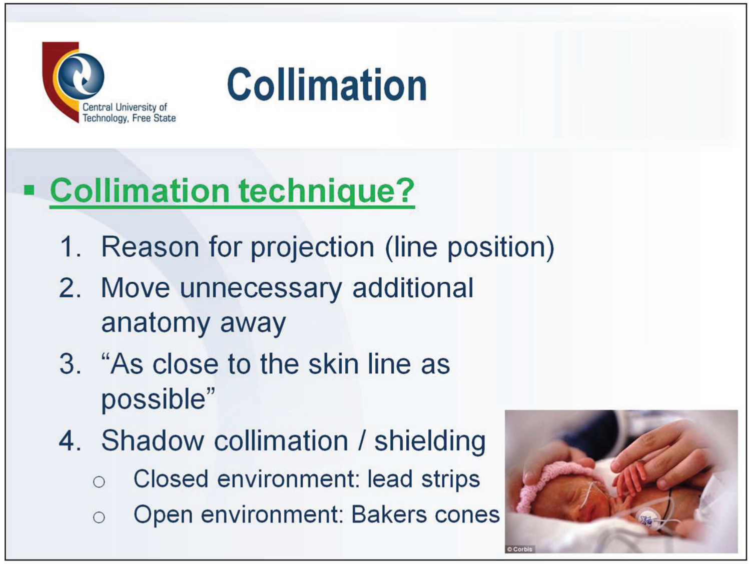


From authors Swallow *et al.* (1986:145), Ballinger and Frank (1999:140) with Bontrager and Lampignano (2014:631):

Superiorly - upper margin of the thyroid cartilage / mid-cervical (neck) area.

Bilaterally - to the soft tissue line.

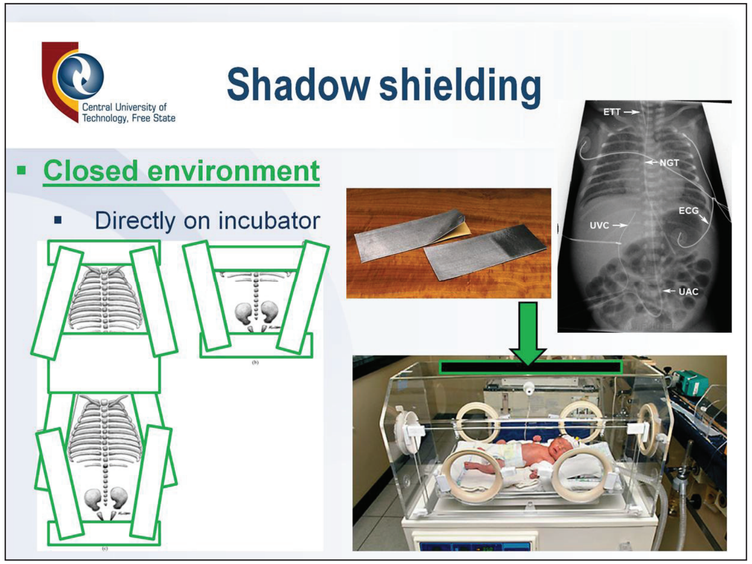
Inferiorly - SP.



Collimated area will still include unnecessary soft tissue and bone areas (humeri for example) due to the fact that the overhead collimation can only close in a rectangular shape.

Additional collimation can be applied to the neonate in the form of shadow shielding (Jones, Palarm and Negus, 2001:920; Fuller, 2009:online).

Two different types of shadow shielding are available based on the two types of incubators (open and closed incubators) available in the participating institutions' NICUs.



For closed incubator Jones *et al.* (2001:924) advised that lead strips (2 mm thick) should be placed on the lid of the incubator.

These lead strips should be placed to follow the skin line of the neonatal chest on figure.

Figure illustrates the placement of the lead strips in a graphical format for chest, abdominal and a combination between the two images.

Shadow shielding

- **Open environment**
  - Directly over neonate – Bakers Cones
  - Not in contact with neonate skin
  - Introduced by England radiographer – Jan Baker
  - *Solves 2 basic problems*

    Can now cone of humerii.

    Can ensure that lead marker will not superimpose important anatomy

The open incubator has no upper lid.

To accommodate shadow shielding Jan Baker, a British radiographer, created the Baker Cone apparatus.

This device ensures both shadow shielding and allows for optimal lead marker placement without coming into contact with the neonates skin (Fuller, 2009:online).

Shadow shielding: Bakers cones

- **Cones consist:**

  Lead rubber with words “left” OR “right” punched along one side of the lead.

This Baker cones consist of the lead strips (see figure 3.2) and a holder device (shown in figure 3.3).

Baker cones are essentially made up off pieces of lead strips that have been punctured on either the left or right side with an appropriate right or left description (Fuller, 2009:online).

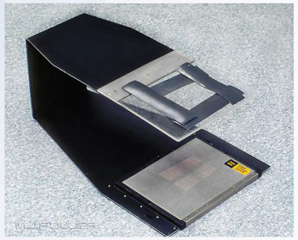
The punctured description is then displayed on the image as indicated in figure.

It is crucial though to remember to place the punctured lead strip on the correct anatomical side (Fuller, 2009:online).

Shadow shielding: Bakers cones

- **Holder consist:**

Cones are supported by a custom made centering device. It has a cassette holder which is placed under the baby's mattress & has a centering point marked on the Perspex above.



The Baker cones holder device is a custom made centering unit.

It has an IR holder in its base which is placed under the neonates' mattress and a centering point marked on the Perspex lid (Fuller, 2009:online).

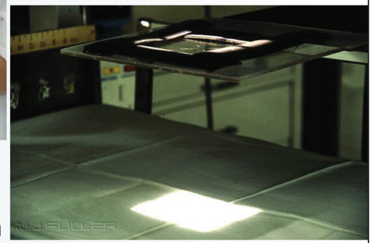
As can be seen in the figure the base slides underneath the mattress, moved to the center of the neonates chest and then additional Baker Cones can be placed on the Perspex lid to collimate according to the prescribed diameter (Fuller, 2009:online).

Appendix K: Educational programme
session 2

Shadow shielding: Bakers cones

- **Technique demonstrated:**

Under mattress



Custom shaping of Main Beam

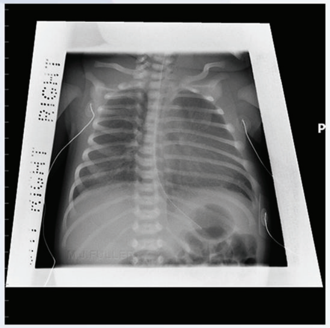
The Baker cones holder device is a custom made centering unit.

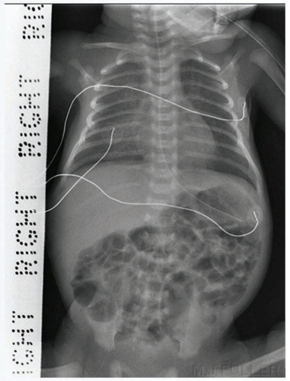
It has an IR holder in its base which is placed under the neonates' mattress and a centering point marked on the Perspex lid (Fuller, 2009:online).

As can be seen in the figure the base slides underneath the mattress, moved to the center of the neonates chest and then additional Baker Cones can be placed on the Perspex lid to collimate according to the prescribed diameter (Fuller, 2009:online).

Shadow shielding: Bakers cones

- **Images:**





This Baker cones consist of the lead strips (see figure 3.2) and a holder device (shown in figure 3.3).

Baker cones are essentially made up off pieces of lead strips that have been punctured on either the left or right side with an appropriate right or left description (Fuller, 2009:online).

The punctured description is then displayed on the image as indicated in figure.

It is crucial though to remember to place the punctured lead strip on the correct anatomical side (Fuller, 2009:online).

The Baker cones holder device is a custom made centering unit.

It has an IR holder in its base which is placed under the neonates' mattress and a centering point marked on the Perspex lid (Fuller, 2009:online).

As can be seen in the figure the base slides underneath the mattress, moved to the center of the neonates chest and then additional Baker Cones can be placed on the Perspex lid to collimate according to the prescribed diameter (Fuller, 2009:online).

Shadow shielding: Bakers cones

- **Disadvantages:**
  - Incorrect side marker placement if not careful.
  - Can drop holder on neonate – not to date.
  - Cannot be used without cassette holder.
  - Not suitable for babies continuously moving.
  - Because lead cones is made out of cast of lead aprons, not suitable to absorb high primary x- ray beam (spectrum from 60 kVp upwards).

Possible disadvantages when utilising the described device is that it can only be used with the IR holder.

It is also not very appropriate for neonates that are continuously moving.

The device can possibly also be dropped on a neonate (Fuller, 2009:online).

Collimation

- **Statistics from phase 1:**
  - Included humerii
    - 63.4%
  - Included femurs
    - 30.6%
  - Included mandible
    - 43.7%
  - Included whole skull
    - 18%

Laterally - Humeri included on 63.4% of images.

Inferiorly – Femurs included on 30.6% of images.

Superiorly – Mandible included on 43.7% and the whole skull on 18% of images.

Exposure parameters

- **Why is it important?**
  - Main controller of radiation dose to neonate.
  - Main controller of image quality delivered.

Why is it important?

Main controller of radiation dose to neonate.

Main controller of image quality delivered.

Exposure parameters

- **What is kVp?**
  - Quality of the beam.
  - Penetrability of beam.
  - Influences image contrast (grey scale).
  - Higher kVp reduce radiation dose to structures in main beam.

The kVp-setting also known as the penetrability of the main radiation beam (Carlton and Adler, 2014:234) was evaluated by observing the spine, paraspinal structures, retrocardiac lung, trachea and proximal bronchi on the image.

European Commission (1996:27), Lowe *et al.* (1999:56), Slade *et al.* (2005:609), Dougeni *et al.* (2007:810), Loovere *et al.* (2008:201), McQuillen Martensen (2011:121-124) as well as Bontrager and Lampignano (2014:631).

Quality of the beam.

Penetrability of beam.

Influences image contrast (grey scale).

Higher kVp reduce radiation dose to structures in main beam.

Exposure parameters

- **What is mAs?**
  - Quantity of the beam.
  - Must use mAs with the shortest time when working with neonates.
  - Density of image (amount of blackness).
  - Higher mAs increased radiation dose.

Density differences between soft-tissue, air and bone which indicates optimal mAs-settings (Carlton and Adler, 2014:234), was evaluated by the visibility of vascular patterns in the central half of the lungs.

These vascular patterns included the hila and lung markings found in the central half of the lungfields.

Other anatomical areas evaluated for mAs include the visibility of the mediastinum, any inserted catheter tips and the parenchymal markings with in the entire lungfields.

European Commission (1996:27), Lowe *et al.* (1999:56), Slade *et al.* (2005:609), Dougeni *et al.* (2007:810), Loovere *et al.* (2008:201), McQuillen Martensen (2011:121-124) as well as Bontrager and Lampignano (2014:631).

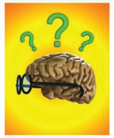
Quantity of the beam.

Must use mAs with the shortest time when working with neonates.

Density of image (amount of blackness).

Higher mAs increased radiation dose.

Exposure parameters



- **What is exposure index?**
  - Measures the amount of radiation received by the IR.
  - Indicates image quality.
  - Each manufacturer can supply EI value for optimal image.
  - Film: accuracy of exp based on image appearance.
  - Digital: post-process images & display adequate contrast & brightness at wider range.
  - Therefore, adequate exposure can only be assessed through image noise.
  - Radiographer workstations are often of lower resolution & brightness than those used for diagnosis.
  - Because of this, it is often difficult to assess whether an image is noisy or not for diagnosis purposes.
  - EI value solves this dilemma.

According to Bontrager and Lampignano (2014:61) exposure parameters refer to the kVp, mA and time (in seconds) selected by the radiographer.

A high optimal kVp with lowest optimal mAs should be selected.

The exposure time should be very short to compensate for involuntary motion (beating of the heart).

In addition, Hardy and Boynes (2003:118) indicated that the selected exposure parameters should be within the manufactures recommended exposure range.

CR systems have replaced most screen- film systems and have an indirect tool to monitor patient exposure.

The exposure index (EI) calculates the dose to the image receptor.

It does not indicate the exposure value used, but is an index to track the compliancy of the exposure to pre-determined target exposure factors.

This will ensure that "exposure creep" does not occur in a radiography department (Cohen, Cooper, Piersall and Apgar, 2010:592; Goske *et al.*, 2010:611).

Exposure creep, as defined by Gibson and Davidson (2012:458), is the systematical increase in exposure parameters selected by radiographers which results in increased radiation dose.

It is a phenomenon due to the wide-exposure latitude of CR systems.

As a specific digital image consideration, Bontrager and Lampignano (2014:47) advise radiographers to evaluate the EI values for previous images.

The EI value verifies that previous utilised exposures are in the correct exposure range.

This exposure range should ensure optimal image quality with the least amount of radiation dose to the neonate.

When a radiographer encounters an EI value outside the recommended range, the necessary exposure parameters must be adjusted.

The checklist for this study included the exposure indexes of each image evaluated.

Dougeni *et al.* (2007:814) showed that high kVp techniques resulted in lower entrance skin dose (ESD) with no significant loss in image quality during chest radiography of a neonatal patient.

Carlton and Adler (2014:488) advised that all radiology departments compile an exposure chart to ensure the production of consistent high quality images at the lowest possible dose to the patient.

Such an exposure chart should include patient anatomical thickness measurements, kVp parameters, mAs parameters as well as the expected EI value (Carlton and Adler, 2014:333).

Exposure parameters

- **Agfa**
  - Uses log median exposure (LgM).
  - Compares the exposure level of the image to a baseline established for the department.
  - Based on a log system, an increase of 0.3 means the dose was doubled.
  - An optimal exposure lies between 1.9 and 2.5.

The exposure indexes of the images were also documented.

EI values vary between different institutions utilising equipment of different manufacturers.

In this study, two specific manufacturers with two different exposure index recommendation levels were included. Agfa utilise the Log Median Exposure (LGM) value for Agfa CR-systems (CRCPD, 2010:22).

The LGM value shows the deviation of the exposure from the median exposure level as a logarithmic value. For an Agfa image to be optimal a LGM value should be between 1.9 and 2.5 (CRCPD, 2010:22).

{The remaining 150 images were produced utilising a Kodak CR-system.

This manufacturer utilise the exposure index value (EI value) (CRCPD, 2010:22).

The acceptable EI value according to Kodak is found between 1500 and 1800 (CRCPD, 2010:22). }

Exposure parameters

- **What does an optimal exposed image look like?**
  - Visualise
    - Vascular pattern
    - Trachea
    - Proximal bronchi
    - Diaphragms & costophrenic angles
    - Spine & paraspinal structures
    - IVD spaces through heart shadow
    - Retrocradiac lung & mediastinum
    - Catheter tips

The kVp-setting also known as the penetrability of the main radiation beam (Carlton and Adler, 2014:234) was evaluated by observing the spine, paraspinal structures, retrocardiac lung, trachea and proximal bronchi on the image.

European Commission (1996:27), Lowe *et al.* (1999:56), Slade *et al.* (2005:609), Dougeni *et al.* (2007:810), Loovere *et al.* (2008:201), McQuillen Martensen (2011:121-124) as well as Bontrager and Lampignano (2014:631).

Density differences between soft-tissue, air and bone which indicates optimal mAs-settings (Carlton and Adler, 2014:234), was evaluated by the visibility of vascular patterns in the central half of the lungs.

These vascular patterns included the hila and lung markings found in the central half of the lungfields.

Other anatomical areas evaluated for mAs include the visibility of the mediastinum, any inserted catheter tips and the parenchymal markings with in the entire lungfields.

European Commission (1996:27), Lowe *et al.* (1999:56), Slade *et al.* (2005:609), Dougeni *et al.* (2007:810), Loovere *et al.* (2008:201), McQuillen Martensen (2011:121-124) as well as Bontrager and Lampignano (2014:631).

Exposure parameters

- **How can I produce an optimal image?**
  - Use previous exposures after consulting LgM value.
  - Decide as department on an exposure chart.
  - Consult with Doctor Naude on topic.

How can I produce an optimal image?

Use previous exposures after consulting exposure index.

Decide as department on an exposure chart.

Consult with Doctor Naude on topic.

Exposure parameters

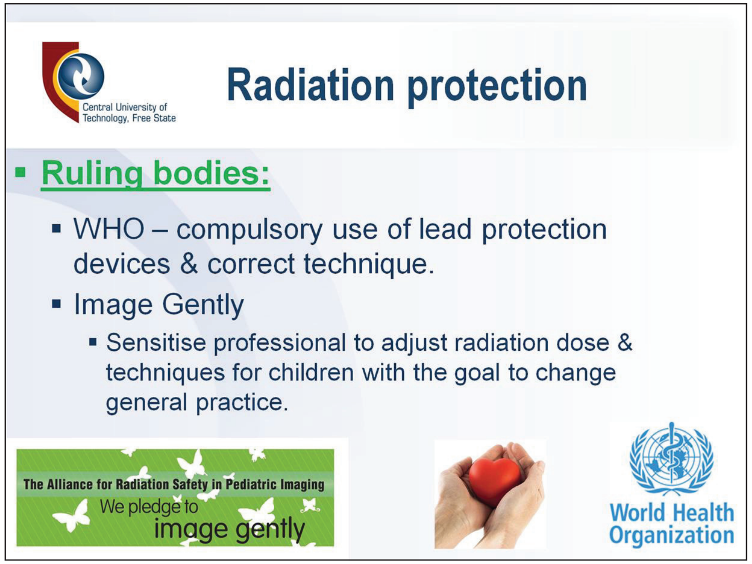
- **Statistics from phase 1:**
  - Overexposed
    - 50.9% of 38.2%
  - Underexposed
    - 49.1% of 38.2%
  - Correct exposed
    - 61.8%

Overexposed images 50.9% of 38.2%.
Underexposed images 49.1% of 38.2%.
Correct exposed images 61.8%.

Radiation protection

- **Why is it important for neonate?**
  - Life longer consequently longer exposed to radiation through out life.
  - Greater period for the potential expression of delayed radiation effects.
  - Neonate receives multiple images during treatment.
  - “Radiation exp in first 10 years of life may have an attributed lifetime risk 3 to 4 times greater then that after the age of 30 years.”
  - Therefore methods to reduce radiation dose in children is of paramount importance!

Gonadal shielding is mandatory for all studies according to the Directorate Radiation Control South Africa (SA Government Gazette, 1973:12).
Gonadal shielding should only be removed if explicitly requested by the referring physician.
Special care of radiation protection during examinations on neonates is justified by the fact that it is exactly the neonate's irradiation, which increases the population's generic risk.
Neonatal patient have a potential longer life expectancy and therefore a longer timespan for the manifestation of radiation induced malignancies (Puch-Kapst, Juran, Stoever and Wauer, 2009:1557).
An inconsistent and often unoptimised examination technique leads to large absorbed dose in neonates and will not always produce an optimal image.
All methods to lower radiation dose to neonates during diagnostic imaging should be of importance while still maintaining clinically satisfactory image quality.
The main reason for lowering radiation dose is that neonatal patients have a greater period for the potential expression of the delayed effects of radiation because of their long life expectancy (Pedrosa de Azevedo, Osibote and Boechat, 2006:1637; Dougeni, Delis, Karatza, Kalogeropoulou, Skiadopoulos, Mantagos and Panayoitakis, 2007:807; Puch-Kapst, Juran, Stoever and Wauer, 2009:1557).
With the greater period for the potential expression of the delayed effects of radiation in mind, it is prudent to also mention that these neonates are usually small in size, placing most organs within the useful radiation beam.
This results in a higher effective dose per image.
These organs within the radiation beam consist out of intense proliferation and differentiation cells.
These proliferating cells, irradiated, are susceptible to the induction of cancer, because the sensitivity of a tissue to radiation is directly proportional to its rate of proliferation (Dougeni *et al.*, 2007:807; Olgar, Onal, Bor, Okumus, Atalay, Turkyilmaz, Ergenekon and Koc, 2008:416).
According to Dougeni *et al.* (2007:807) most neonates require multiple imaging examinations during their stay in the neonatal intensive care unit (NICU), depending on underlying disease.
This aspect has also been highlighted by Lowe, Finch, Boniface, Chaudhuri and Shekhdar (1999:55).
Neonates frequently suffer from a wide spectrum of severe to life-threatening complications, usually resulting from disease processes in the respiratory and/or cardiovascular system.
Prompt diagnosis and therapy is of utmost importance for such an infant to survive.
Diagnostic radiography offers a prompt and visible assessment of the neonatal respiratory and mediastinal anatomy (Lowe *et al.*, 1999:55; Dougeni *et al.*, 2007:807).
Due to the prompt assessment provided by diagnostic radiography of underlying disease processes multiple imaging examinations will be done during a neonates stay in the NICU, leading to radiation dose.
Should these multiple chest examinations be done without any form of radiation protection, the radiation dose will be more severe due to increased field of view and scatter/secondary radiation production.
In addition, images of poor quality will require repeat imaging which will also increase the radiation dose.
Radiation exposure during childhood results in a likely two- to three- fold increase in lifetime risk for certain detrimental effects, compared with that in an adult.
These detrimental effects include solid cancers (Loovere, Boyle, Blatz, Bowslaugh, Kereliuk and Paes, 2008:198).
This increased lifetime risk statement was also mentioned in the research done by Pedrosa de Azevedo *et al.* (2006:1637-1638), which also refers directly back to the research done by the United Nations Scientific Committee on the Effects of Atomic Radiation.



Gonadal shielding is mandatory for all studies according to the Directorate Radiation Control South Africa (SA Government Gazette, 1973:12).

Gonadal shielding sh

According to Bader *et al*. (2007:584) shortcomings in the guidance professionals working with preterm infants receive, combined with a usually heavy work load and unintentional oversight of existing guidelines, may lead to radiographers failing to use gonadal shielding and collimation.

The World Health Organization's (WHO) recognises and supports the International Commission of Radiological Protection (ICRP).

This body paid special attention within its recommendations on the restriction of radiological diagnostic procedures on children.

According to the ICRP, it is compulsory to use lead shielding devices for example lead aprons or strips when working with pediatric patients.

In addition, the correct radiographic techniques are seen as vital.

Justification is essential when deciding to do an ionising examination on pediatric patients (ICRP, 2013:online).

Finland implemented a decree (423/2000 of Finnish Ministry of Social Affairs and Health) concerning patients and a law (1142/1998) concerning radiological personnel.

According to this decree, singular protection requirements are needed for imaging during childhood and pregnancy.

These stipulate the correct radiological apparatus, practical techniques and ancillary equipment for the medical exposure of children (Kettunen, 2004:12).

The Commission of the European Communities (EC) produced a document containing guidelines on "good radiographic techniques".

The aim of these guidelines is to lower entrance skin dose (ESD) in the context of optimal image quality for common everyday pediatric examinations. These guidelines assist to balance dose and image quality (European Commission, 1996:12; Lowe *et al*., 1999:55; Dougeni *et al*., 2007:808).

The Pan American health organization recognises and embodies the same regulations as specified by the ICRP recommendations.

The organisation also includes similar criteria for radiation protection based on recent studies performed by the WHO, incorporated into the recommendations of the ICRP.

This organisation also stressed the importance of limiting radiation dose to a minimum for pediatric patients with specific requirements in relation to justification, risk versus benefit analysis, dose optimisation and spesialised equipment (Pan American health organization, 2012:online).

The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) is clear that the recommended dose limits for children should be lower than that of adults due to their increased lifetime risk and longer life expectancy.

In addition this agency also pays close attention to the justification for a diagnostic ionising examination of pediatric patients. Radiation protection and dose optimisation also receive attention in the regulations stipulated by this agency (ARPANSA, 2002:online).

In SA, the health services are striving to develop and improve service delivery.

This is facilitated by educationists at HEI during the training of health care professionals (General Ethical Guidelines for the Health Care Professions, 2008: 14).

In addition to thorough training, all health care professionals must also be registered with the HPCSA. The HPCSA strives to protect the South African public by ensuring good quality care and treatment delivered by registered health care professionals.

This statutory body requires registration as a professional with the required education and training, ethical conduct, continuous development of skills and conformation to healthcare standards as set out by the SA Health Professions Act (1974:22).

The SA Government Gazette (1973:8-9) has a public health Act that has a special reference to the medical exposure of any individual under the age of eighteen. According to Act 42 of 1971, examinations to this age group should only be done when absolutely required and then only with the most optimal of radiographic techniques.

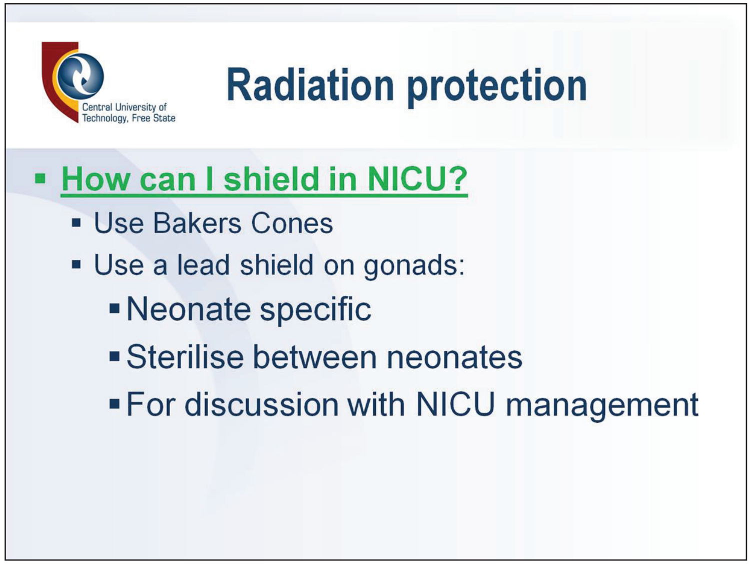
These techniques should include dose optimisation principles applied by the radiation worker to the best of his/her ability.

Dose optimisation includes radiation protection, collimation and optimal exposure parameters (SA Government Gazette, 1973:8-9).

The governmental regulations and codes reflect international bodies as well as the SA health body's emphasis in relation to the imaging of pediatric patients.

All of these bodies indicate that imaging of pediatric patients, that include neonatal patients, should only be done when justified.

If such an examination is justified, it should be completed with the correct equipment to ensure the lowest possible radiation dose to the patient but with the production of an optimal image.



There are three methods by which a radiographer can shield a neonate during mobile radiography.

The first is using a lead-lined collimator.

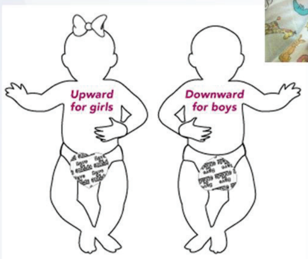
The second is to place lead strips on the incubator (Swallow *et al.*, 1986:143) or hanging a lead shadow from the collimator, this type of shielding cast a shadow protecting the area under the shadow from the primary beam.

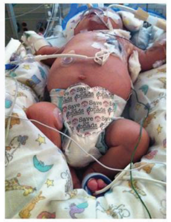
For the open environment, the previously discussed Baker Cone can be considered a form of shadow shielding.

The final and easiest method is to place a lead vinyl rubber shield directly on the neonate's body (Entrepreneur, 1997:online; Bontrager and Lampignano, 2014:61).

Radiation protection

- **Save the Gonads**
  - Light weight.
  - Easy sterilised.
  - Available different sizes.
  - 1mm thick lead.





A specific direct contact shield designed for neonatal patient's gonads is the "Save the gonads" shield (see figure).

This shield consists out of a thickness of 1 mm lead, in a heart shape which accommodates both male and female patients.

This shield is also infection control friendly and light weight for patient comfort (Natus, 2005:online).

Radiation protection

- **Statistics from phase 1:**
  - No shielding seen on any of the images (1.33%).

No shielding seen on any of the images (1.33%).

Action plan

- **Choose best shielding device for institution**
  - Implement according to law
  - Inform nursing staff of this important aspect

Choose best shielding device for your institution:

Implement & inform all that it is law and therefore mandatory.

Conclusion

- Thank you
- Final message – look after future generation not just by optimal images for neonates BUT also by training future radiographers
- Certificates

Thank you for your participation.

Final message – look after future generation not just by optimal images for neonates BUT also by training future radiographers.

Certificates delivered to head radiographer.

APPENDIX L:

Attendance register for the educational programme

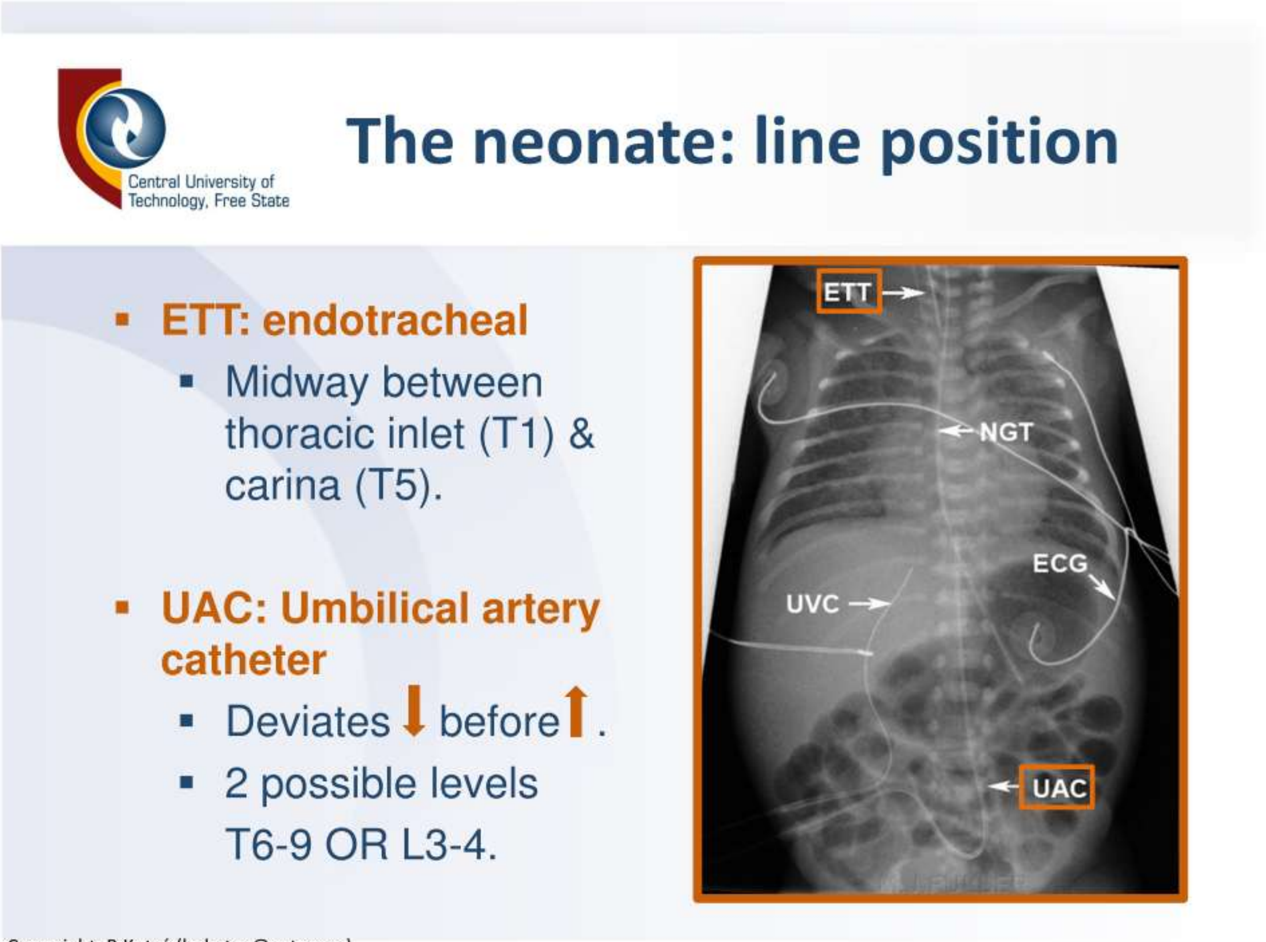
Neonatal Chest Image Quality **ATTENDANCE REGISTER**

Hospital ______________________

ATTENDANCE REGISTER			Date:		Session:		
Surname	Initial	Title	DR No.	E-mail Address	Tel	Fax	Institution

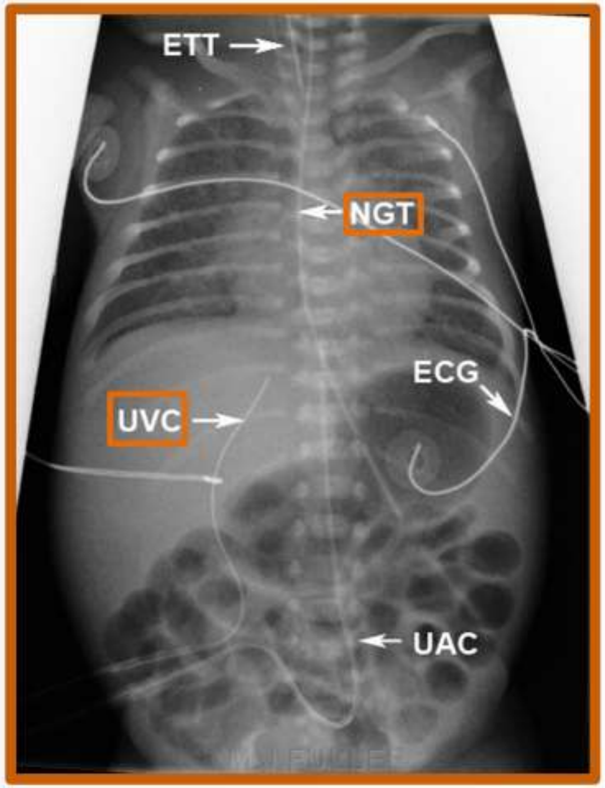
APPENDIX M:

Poster of medical lines, tubes and catheters



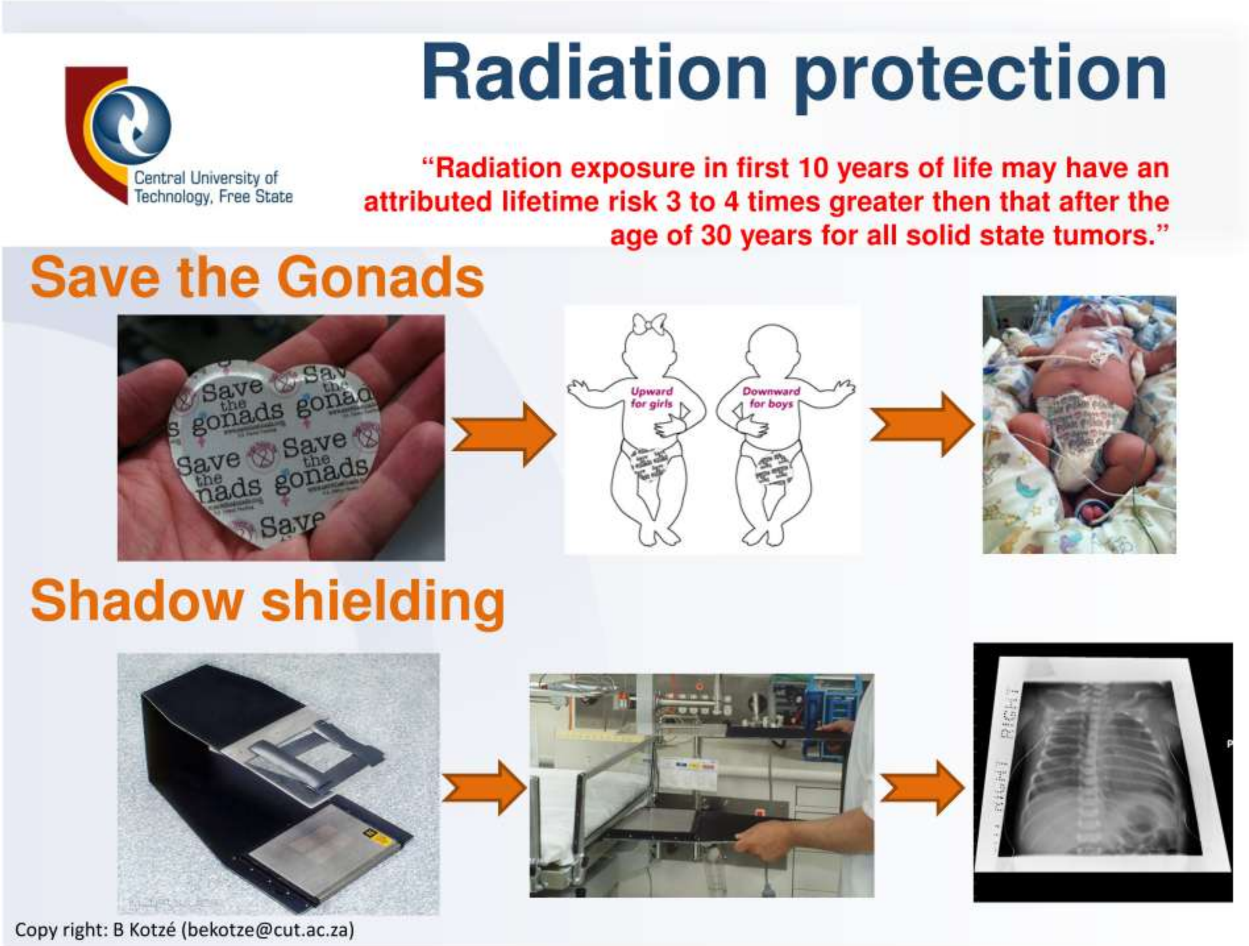
The neonate: line position

- **UVC: Umbilical vein catheter**
  - Appears shorter then UAC.
  - On entering body, directly ↑ & little to right of MSP.
  - Should be ↑ diaphragm BUT ↓ the heart shadow.
- **NGT: Nasogastric tube**
  - Should demo in stomach.



APPENDIX N:

Poster of shadow and gonadal shielding



APPENDIX O:

CPD accreditation for the educational programme

14 May 2012

Ms B Kotze
Central University of Technology, Freestate
20 President Brand Street
Bloemfontein
9300

RE: ALLOCATION OF CEU'S

Dear Ms Kotze

The Radiography CPD Committee has reviewed your Application was approved.

1. <u>Neonatal Chest Image Quality (May, July & August 2012)</u>

Level 1	2 CEU's (CEU's only for participants and not for presenter)
Total CEU's	6

Accreditation No. RCT038/

Please refer to the updated guidelines for Service Providers available from the Health Professions Council's website which clearly outlines your responsibilities as a Service Provider. Please note that you are responsible for the printing of certificates.

If you have any enquiries in this regard please feel free to contact me.

Yours sincerely

Deidre Guilo
Manager: CPD &SLP Office
Faculty of Health Sciences
Tel: 011 559 6715
Fax: 011 559-6932
Email: deidres@uj.ac.za

MAIN CAMPUS | Cnr Kingsway and University Road Auckland Park
PO Box 524 Auckland Park 2006 | Tel +27 11 559 2637 | www.uj.ac.za

UNIVERSITY OF JOHANNESBURG

APPENDIX P:

CPD certificate for the radiographers

FACULTY OF HEALTH AND ENVIRONMENTAL SCIENCES
PROGRAM: RADIOGRAPHY

Certificate of Attendance

I, the undersigned, acting as CPD Provider, hereby certify that

Initials and Surname

DR number

Attended the following approved CPD activity

Neonatal Chest Image Quality

at the Department of Clinical Sciences at the Central University of Technology, Free State (CUT) on date

RCT038/30/6/2011

and that the said person qualifies for a total of 2 Continuing Education Units (CEUs), obtained as follows:

	CEU
Level 1	2
Level 1 Medical Ethics	
Level 2	
Level 3	
Total	2

Official stamp

Signature on behalf of provider
Radiography Programme
CUT Campus
Designation: CPD provider
CPD provider no. RCT001/027/04/2010
Place: Bloemfontein

Radiography • Private Bag X20539 • Bloemfontein • SOUTH AFRICA • 9300 •
Tel: +27 51-507 3853 • Fax: +27 51-507 3354 • E-mail: bevdmerwe@cut.ac.za • Website: www.cut.ac.za

APPENDIX Q:

Visitation logbook

LOGBOOK for M. Tech visits

Date	Time In	Time Out	Location of visit	Reason for visit to location	
08.02.12	17:00	22:30	Univ NICU	Evaluate 20 films (07 & 08.02.12)	5½ hours
10.02.12	15:00	20:00	Univ NICU	Evaluate 21 films (09 & 10.02.12)	5 hours
13.04.12	09:00	14:00	Univ NICU	Evaluate 20 films (12 & 13.04.12)	5 hours
14.04.12	18:00	22:00	Univ NICU	Evaluate 16 films (14.04.12)	4 hours
16.04.12	16:00	21:00	Univ NICU	Evaluate 20 films (16.04.12)	5 hours
19.04.12	04:00	10:30	Univ NICU	Evaluate 25 films (17,18 & 19.04.12)	6½ hours
22.04.12	10:00	12:30	Univ NICU	Evaluate 9 films (20 & 22.04.12)	2½ hours

1.

LOGBOOK for M. Tech visits

Date	Time In	Time Out	Location of visit	Reason for visit to location	
26.04.12	14:00	18:00	Univ NICU	Evaluate 15 films (25 & 26.04.12)	4 hours
30.04.12	05:00	06:00	Univ NICU	Evaluate 4 films (29 & 30.04.12)	1 hour
19.06.12	12:00	13:00	Univ Intro Session	22 Radiographers	1 hour.
22.06.12	11:30	14:00	Univ Session 1	22 Radiographers	2½ hours
29.06.12	11:30	14:30	Univ Session 2	22 Radiographers	3 hours
06.08.12	05:00	08:00	Univ NICU	Evaluate 11 films (06.08.12)	3 hours
09.08.12	10:30	12:30	Univ NICU	Evaluate 9 films (09.08.12)	2 hours

2.

Central University of Technology, Free State

LOGBOOK for M. Tech visits

Date	Time In	Time Out	Location of visit	Reason for visit to location	
13.08.12	06:00	07:00	Univ NICU	Evaluate 4 images (13.08.12)	1 hour
16.08.12	06:00	08:00	Univ NICU	Evaluate 7 images (16.08.12)	2 hours
20.08.12	06:00	08:30	Univ NICU	Evaluate 9 images (20.08.12)	2½ hours
27.08.12	06:00	08:30	Univ NICU	Evaluate 10 images (27.08.12)	2½ hours
03.09.12	06:00	08:30	Univ NICU	Evaluate 10 images (03.09.12)	2½ hours
10.09.12	06:00	08:30	Univ NICU	Evaluate 10 images (10.09.12)	2½ hours
17.09.12	06:00	08:30	Univ NICU	Evaluate 9 images (17.09.12)	2½ hours

3.

LOGBOOK for M. Tech visits

Date	Time In	Time Out	Location of visit	Reason for visit to location	
25.09.12	07:00	08:00	Univ NICU	Evaluate 4 images (25.09.12)	1 hour
01.10.12	07:00	08:30	Univ NICU	Evaluate 6 images (01.10.12)	1½ hours
08.10.12	07:00	08:30	Univ NICU	Evaluate 7 images (08.10.12)	1½ hours
15.10.12	07:00	08:30	Univ NICU	Evaluate 6 images (15.10.12)	1½ hours
22.10.12	06:00	08:30	Univ NICU	Evaluate 10 images (22.10.12)	2½ hours
29.10.12	05:00	08:00	Univ NICU	Evaluate 12 images (29.10.12)	3 hours
05.11.12	08:00	08:30	Univ NICU	Evaluate 2 images (05.11.12)	½ hour

4.

LOGBOOK for M. Tech visits

Date	Time In	Time Out	Location of visit	Reason for visit to location	
12.11.12			Univ NICU	Evaluated 8 images (12.11.12)	2 hours
19.11.12			Univ NICU	Evaluated 6 images (19.11.12)	1½ hours
26.11.12			Univ NICU	Evaluate 10 images (26.11.12).	2½ hours
				Total Univ:	83. hours

5.

LOGBOOK for M. Tech visits

Date	Time In	Time Out	Location of visit	Reason for visit to location	
06.02.12	05:00	08:30	Pel NICU	Evaluate 14 images (6,7 & 8.02.12)	3½ hours
13.02.12	14:00	19:00	Pel NICU	Evaluate 19 images (9, 10, 11, 12 & 13.02.12)	5 hours
18.02.12	08:00	13:00	Pel NICU	Evaluate 19 images (14, 15, 17 & 18.02.12)	5 hours
19.02.12	11:30	14:00	Pel NICU.	Evaluate 9 images (19.02.12)	2½ hours
28.02.12	18:00	22:30	Pel NICU	Evaluate 18 images (27 & 28.02.12)	4½ hours
29.02.12	07:30	09:00	Pel NICU	Evaluate 6 images (29.02.12)	1½ hours
02.03.12	07:30	09:00	Pel NICU.	Evaluate 6 images (01 & 02.03.12)	1½ hours

1.

Central University of Technology, Free State

LOGBOOK for M. Tech visits

Date	Time In	Time Out	Location of visit	Reason for visit to location	
11.04.12	18:00	21:30	Pel NICU	Evaluate 18 images (10 & 11.04.12)	4½ hours
13.04.12	18:00	21:30	Pel NICU	Evaluate 18 images (12 & 13.04.12)	4½ hours
15.04.12	14:30	18:00	Pel NICU	Evaluate 14 images (14 & 15.04.12)	3½ hours
18.04.12	06:00	08:30	Pel NICU	Evaluate 9 images (16 & 18.04.12)	2½ hours
06.07.12	11:00	12:00	Pel Intro Ses	18 Radiographers	1 hour
~~[illegible]~~	~~[illegible]~~	~~[illegible]~~	~~Pel Intro Session~~	~~Radiographers~~	1 hour
~~[illegible]~~	~~[illegible]~~	~~[illegible]~~	~~Pel Session 1~~	~~Radiographers~~	2 hours

CANCELLED

2.

LOGBOOK for M. Tech visits

Date	Time In	Time Out	Location of visit	Reason for visit to location	
13.07.12	12:00	14:00	Pel Session 1	18 Radiographers	2 hours
20.07.12	11:00	13:00	Pel Session 2	18 Radiographers	2 hours
~~[illegible]~~	~~[illegible]~~	~~[illegible]~~	~~Pel Session 2~~	~~Radiographers~~	2 hours
05.08.12	09:00	11:00	Pel NICU	Evaluated 9 images (3 & 5.08.12)	2 hours
12.08.12	09:00	12:30	Pel NICU	Evaluated 14 images (10 & 12.08.12)	3½ hours
19.08.12	10:00	12:30	Pel NICU	Evaluated 9 images (17 & 19.08.12)	2½ hours
24.08.12	16:30	19:30	Pel NICU	Evaluated 12 images (24.08.12)	3 hours

CANCELLED

3

LOGBOOK for M. Tech visits

Date	Time In	Time Out	Location of visit	Reason for visit to location	
26.08.12	10:00	12:00	Pel NICU	Evaluated 8 images (26.08.12)	2 hours
31.08.12	18:00	19:00	Pel NICU	Evaluated 4 images (31.08.12)	1 hour
02.09.12	9:30	11:00	Pel NICU	Evaluated 6 images (02.09.12)	1½ hour
09.09.12	9:00	12:00	Pel NICU	Evaluated 12 images (07 & 09.09.12)	3 hours
16.09.12	12:00	14:00	Pel NICU	Evaluated 9 images (14 & 16.09.12)	2 hours
23.09.12	12:00	14:00	Pel NICU	Evaluated 8 images (21.09. & 23.09.12)	2 hours
30.09.12	11:30	14:00	Pel NICU	Evaluated 10 images (28 & 30.09.12)	2½ hours

4.

LOGBOOK for M. Tech visits

Date	Time In	Time Out	Location of visit	Reason for visit to location	
07.10.12	09:00	12:30	Pel NICU	Evaluated 14 images (05 & 07.10.12)	3½ hours
14.10.12	09:00	12:00	Pel NICU	Evaluated 12 images (12 & 14.10.12)	3 hours
21.10.12	09:00	11:00	Pel ~~NICU~~ NICU	Evaluated 9 images (19 & 21.10.12)	2 hours
28.10.12	09:00	12:30	Pel NICU	Evaluated 14 images (26 & 28.10.12)	3½ hours
				Total:	29½ hours
				* Pel	

5.

Central University of Technology, Free State

LOGBOOK for M. Tech visits

Date	Time In	Time Out	Location of visit	Reason for visit to location	
08.02.12	12:00	14:00	Med NICU	Eval : 7 images. Dates: 06-08.02.12	2 hours
09.02.12	05:00	07:30	Med NICU	Eval : 9 images Dates: 09.02.12	2½ hours
15.03.12	05:00	07:00	Med NICU	Eval: 8 images Dates: 15.03.12	2 hours
18.03.12	10:00	12:30	Med NICU	Eval: 10 images Dates: 16,17,18.03.12	2½ hours
21.03.12	10:00	12:00	Med NICU	Eval: 7 images Dates: 19,20,21.03.12	2 hours
02.05.12	05:00	07:30	Med NICU	Eval: 9 images Dates: 30.04.12-02.05.12	2½ hours
05.05.12	05:00	07:30	Med NICU	Eval: 10 images Dates: 03-05.05.12	2½ hours.

1

LOGBOOK for M. Tech visits

Date	Time In	Time Out	Location of visit	Reason for visit to location	
08.05.12	05:00	07:30	Med NICU	Eval: 10 images Date: 6,7,8.05.12	2½ hours
11.05.12	16:00	20:00	Med NICU	Eval: 15 images Date 9,10,11.05.12	4 hours
14.05.12	05:00	07:30	Med NICU	Eval: 10 images Date: 12,13,14.05.12	2½ hours
17.05.12	06:00	07:30	Med NICU	Eval: 7 images Date 15,16,17.05.12	1½ hours
20.05.12	18:00	22:00	Med NICU	Eval: 15 images Date: 18,19,20.05.12	4 hours
24.05.12	06:00	07:00	Med NICU	Eval: 4 images Date: 22,23,24.05.12	1 hour
27.05.12	21:00	23:30	Med NICU	Eval: 11 images Date: 25,26,27.05.12	2½ hours

2

Central University of Technology, Free State

LOGBOOK for M. Tech visits

Date	Time In	Time Out	Location of visit	Reason for visit to location	
30.05.12	05:00	08:00	Med NICU	Goal: 13 images Date: 28, 29, 30.05.12.	3 hours
02.06.12	15:00	16:30	Med NICU	Goal: 6 images Date: 01+02.06.12	1½ hours
02.07.12	07:00	08:00	Med Info session	10 Radiographers	1 hour
04.07.12	07:00	08:00	Med Info session	6 Radiographers	1 hour
09.07.12	07:00	08:00	Med session 1	8 Radiographers	1 hour
11.07.12	07:00	08:00	Med session 1	8 Radiographers	1 hour
16.07.12	07:00	08:30	Med Session 2	8 Radiographers	1½ hour

3

LOGBOOK for M. Tech visits

Date	Time In	Time Out	Location of visit	Reason for visit to location	
23.07.12	07:00	08:00	Med session 2	8 Radiographers.	1 hour.
04.08.12	13:00	14:30	Med NICU	Goal: 6 images Date: 04.08.12	1½ hour
08.08.12	05:00	06:00	Med NICU	Goal: 4 images Date: 08.08.12	1 hour
15.08.12	05:00	06:30	Med NICU	Goal: 5 images Date: 11, 15.08.12	1½ hour
18.08.12	13:00	13:30	Med NICU	Goal: 2 images Date: 18.08.12	½ hour
22.08.12	05:00	06:00	Med NICU	Goal: 4 images Date 22.08.12	1 hour
25.08.12	13:00	14:00	Med NICU	Goal: 3 images Date: 25.08.12	1 hour.

4

Central University of Technology, Free State

LOGBOOK for M. Tech visits

Date	Time In	Time Out	Location of visit	Reason for visit to location	
29.08.12	18:00	18:30	Med NICU	Eval: 1 image Date: 29.08.12	½ hour
01.09.12	18:00	19:30	Med NICU	Eval: 7 images Date: 01.09.12	1½ hour
08.09.12	18:00	20:00	Med NICU	Eval: 8 images Date: 05,08.09.12	2 hours
15.09.12	18:00	20:00	Med NICU	Eval: 9 images Date: 12,15.09.12	2 hours
22.09.12	18:00	19:00	Med NICU	Eval: 5 images Date: 19,22.09.12	1 hour
26.09.12	05:00	07:00	Med NICU	Eval: 9 images Date: 26.09.12	2 hours
06.10.12	18:00	20:00	Med NICU	Eval: 8 images Date: 03,06.10.12.	2 hours

5

LOGBOOK for M. Tech visits

Date	Time In	Time Out	Location of visit	Reason for visit to location	
13.10.12	18:00	21:00	Med NICU	Eval: 11 images Date: 11,13.10.12	3 hours
17.10.12	05:00	06:00	Med NICU	Eval: 3 images Date 17.10.12	1 hour
20.10.12	18:00	19:30	Med NICU	Eval: 6 images Date: 20.10.12	1½ hour
27.10.12	18:00	18:30	Med NICU	Eval: 2 images Date: 24,27.10.12	½ hour
31.10.12	05:00	06:00	Med NICU	Eval: 3 images Date: 31.10.12	1 hour
04.11.12	05:00	07:00	Med NICU	Eval 8 images Date: 03, 07.11.12	2 hours
10.11.12	18:00	19:00	Med NICU	Eval: 4 images. Date: 10.11.12	1 hour

6.

LOGBOOK for M. Tech visits

Date	Time In	Time Out	Location of visit	Reason for visit to location	
17.11.12	18:00	20:00	Med NICU	Goal: 8 images Date: 14, 17.11.12	2 hours
24.11.12	18:00	19:00	Med NICU	Goal: 5 images Date: 21, 24.11.12	1 hour
28.11.12	05:00	06:00	Med NICU	Goal: 3 images Date: 28.11.12	1 hour
01.12.12	18:00	20:00	Med NICU	Goal: 7 images Date: 01.12.12	2 hours
05.12.12	05:00	06:00	Med NICU	Goal: 4 images Date: 05.12.12	1 hour
08.12.12	18:00	18:30	Med NICU	Goal: 1 image Date: 08.12.12	½ hour
15.12.12	18:00	19:00	Med NICU	Goal: 4 images Date: 12, 15.12.12	1 hour

7.

LOGBOOK for M. Tech visits

Date	Time In	Time Out	Location of visit	Reason for visit to location	
22.12.12	18:00	19:00	Med NICU	Goal: 4 images Date: 19, 22.12.12	1 hour
26.12.12	18:00	19:30	Med NICU	Goal: 6 images Date: 26.12.12	1½ hour
				Med Total :	83½ hours
				(x3) Grant T:	246 Hours
					(10.25 days)

8.

APPENDIX R:

Schedule plan for the educational programme

Session	Program for specific session	Format	Time
Introduction session	• Introduction to study • Informed consent • Written consent • Questions and answers	PowerPoint Slideshow (appendix H)	30 min
First theoretical session	• Radiographic technique • Breathing technique • Lead marker	PowerPoint Slideshow (appendix I)	60 min
Discussion session	• Radiographic technique • Breathing technique • Lead marker	Informal interaction dialogue	30 min
Practical session	Demonstration of: • Radiographic technique • Breathing technique • Lead marker placement	Hands-on demonstration in NICU	30 min
Second theoretical session	• Radiation protection • Exposure parameters • Collimation	PowerPoint Slideshow (appendix J)	60 min
Discussion session	• Radiation protection • Exposure parameters • Collimation	Informal interaction dialogue	30 min
Practical session	Demonstration of: • Radiation protection • Exposure parameters • Collimation with shadow	Hands-on demonstration in NICU	30 min

APPENDIX S:

Language edit document

ERICA WESSELS
Accredited Member of the South African Translators' Institute (No. 1000186)

18 October 2011

DECLARATION

I hereby declare that I am a qualified and professional language practitioner with the following qualifications from the Central University of Technology, Free State (CUT) in Bloemfontein, South Africa:

- National Diploma: Language Practice *(Cum Laude)*
- Baccalaureus Technologiae: Language Practice *(Cum Laude)*

I furthermore declare that I am a registered and accredited member of the South African Translators' Institute (SATI), with membership number: 1000186 ("accredited" meaning I passed the stringent linguistic examination administered by SATI).

In this capacity, I have linguistically revised (in English) the following title of a proposed dissertation:

STUDENT:
Ms B. Kotze

QUALIFICATION:
Magister Technologiae

INSTITUTION:
Central University of Technology, Free State
(School of Health Technology)

TITLE:
Addressing mobile neonatal image quality through an educational programme

Signed:

ERICA WESSELS
APTrans(SATI)

PO Box 3676
Bloemfontein
9300

Tel: (051) 507-3607
084 401 6560
Fax: (051) 507-3309
E-mail:
ewessels@cut.ac.za

HESTER SOPHIA HUMAN

Language Practitioner and Editor

18 C Ben Tindall Street
Heuwelsig
Bloemfontein
hettie.human@gmail.com
072 137 8991

To Whom It May Concern

3 June 2015

Client: Ms Beatrix Kotze

I declare that I edited and proofread the dissertation entitled, *Addressing mobile neonatal image quality through an educational programme*, prepared in fulfilment of the requirements for the degree Magister Technologiae in Radiography (Diagnostic) at the Department of Clinical Sciences, Faculty of Health and Environmental Sciences, Central University of Technology, Free State.

Yours sincerely

HSHuman

Hester Sophia Human

More than 25 years experience of editing academic, technical and popular publications. Member of South African Translators' Institute.