DEMONSTRATING THE CERVICOTHORACIC JUNCTION: A COMPARISON OF TWO RADIOGRAPHIC X-RAY TECHNIQUES

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Abstract

The most important projection of a patient with suspected cervical spine trauma is the lateral projection demonstrating C7 as well as T1. It frequently happens that the first and sometimes the second set of images do not demonstrate the cervicothoracic junction C7- T1. Literature underlines this statement through reports by Daffner (Daffner, 2000: Online) where the swimmer's projection needed to be repeated in 41% of their sample. In addition, 34% of the patients required a third radiograph. In this investigation, the swimmer's projection C7- T1 was compared to an alternative method to demonstrate C7-T1 as described in literature. The objectives were to ascertain which technique would yield the better identification of pathology, better image quality and less repeat films. A sample of 45 patients was examined at a tertiary level hospital. Two exposures were done on each member of the sample: the first was the swimmer's projection and the second with the patient reversing the orientation of their arms. The images were evaluated by three radiologists using a standardised checklist. The results revealed that the alternative swimmer's projection has comparable image quality where the p-value of spatial resolution equalled 0.7120 indicating that the overall impression of the two films was equal. The weighted Kappa for repeat rate amongst the three radiologists lies between -1 and 0.5 indicating poor agreement. The results for pathology were inconclusive. The results validate the use of the adapted swimmer's projection as an alternative that could decrease radiation exposure by limiting repeat projections.

Keywords: Trauma, Cervicothoracic, Swimmer's projection, Adapted swimmer's projection

1. INTRODUCTION

The anatomy and biomechanics of the cervicothoracic junction presents unique challenges when imaged. There is a gradual transition from lordosis in the cervical region to kyphosis in the thoracic region. The single most important radiographic projection of the cervical spine is the lateral projection (including T1) that is done with a horizontal beam in cases of trauma (cross-table lateral projection) (Ahmad, 2003: Online; Berquist, 1988: 668).

The lateral projection is done first because the anatomy under investigation is not moved and because intervertebral spaces and prevertebral soft tissue can be evaluated. This ensures that possible pathology is quickly identified (Ahmad, 2003: Online).

For the patient with trauma to the cervical spine the lateral projection is done first to evaluate alignment and stability (Mirvis & Young, 1992: 292). In Figure 1 three lines (A, B and C) are used to assess the aforementioned aspects of the cervical architecture: Line A, the anterior longitudinal ligament (ALL) is a broad fibrous band that extends from the anterior arch of the atlas (C1) caudally to the sacrum, Line B is the posterior longitudinal ligament (PLL) extends along the posterior aspect of the vertebral bodies and Line C, the laminospinal line connects the base of the spinous process and the laminae. In addition, spinal stability is provided by the interspinous and supraspinous ligaments posteriorly, the intertransverse ligament laterally, and the capsular ligaments and ligamentum flavum (Mirvis & Young, 1992: 292). Disruption of the normal path of these lines demonstrated on the swimmer's projection may indicate underlying pathology.

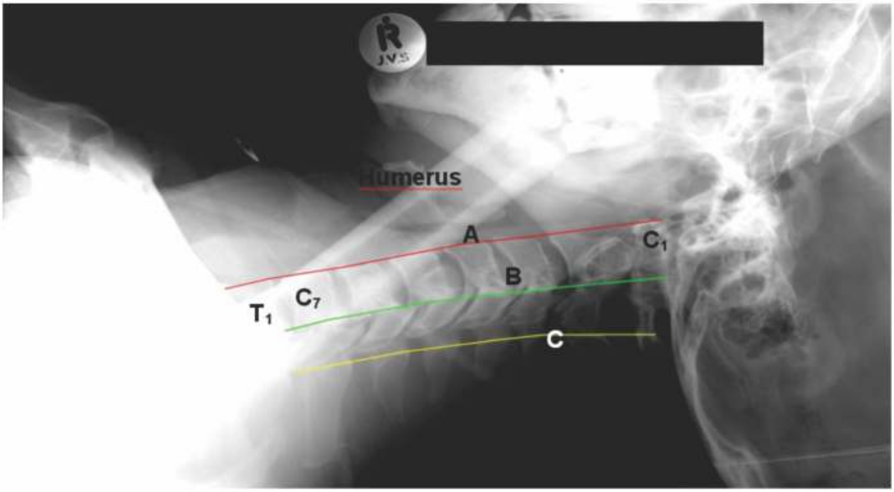

Figure 1: Shows line A, the anterior longitudinal ligament, line B, the posterior longitudinal ligament and line C, the laminospinal line. These lines are used to evaluate the relationships between the different vertebrae as an indication of underlying trauma (adapted from Graber & Kathol, 1999: Online)

The problem is that one does not always see these lines and other anatomical structures on plain film. The single most important radiographic projection of the cervical spine is the lateral projection that is done with a horizontal beam in cases of trauma (cross-table lateral projection) (Ahmad, 2003: Online; Berquist, 1988: 668). The lateral projection is done first because the anatomy under investigation is not moved and because intervertebral spaces and prevertebral soft tissue can be evaluated. This ensures that possible pathology is quickly identified (Ahmad, 2003: Online). If the transition architecture between C7 and T1 is not demonstrated on the lateral projection, then a swimmer's projection, where the bulk of the shoulder girdle is displaced, needs to be done. After a study on patients who had sustained blunt trauma to the cervical spine area. Jelly (2000: S251) reported that between 9% and 18% of all cervical spine injuries occur at the cervicothoracic junction. Radiographs of the cervicothoracic junction that allow adequate visualisation of this transition may be technically difficult to obtain, and in at least 26% of all trauma patients the C7-T1 joint space is not visualised (Jelly, 2000: S251).

Approximately 10% of patients with spinal trauma and normal clinical findings at an initial neurological examination will subsequently incur neurological deficit including paraplegia (Woodring, 1992: 698). In an autopsy series of vehicular fatalities, 21% of the victims were found to have a cervical spine injury identified by post-mortem cervical spine radiographs (Ivy & Cohn: 1997: 591). Blackmore (2003:283) found that imaging of the cervical spine is used liberally resulting in only 0.9% to 2.8% of such studies demonstrating injury. The frequency of inadequate or false-positive radiograph series increases with more severely injured patients, with a corresponding decrease in radiograph specificity influencing diagnosis (Blackmore, 2003:283).

The value of an imaging examination, such as the cervicothoracic junction examination, is the expected diagnostic information that it provides. Physicians use the evidence gathered during clinical evaluation and applicable testing to make a diagnosis. Medical imaging forms part of the evidence-gathering process. The choice of imaging procedure should be complimentary in order to improve the physicians' choice of imaging examination. Kuhns (1989: 4) states that physicians should informally use rigorous decision analysis methodology recommend it.

Radiographic procedures in general and trauma radiography specifically are unpredictable due to the influenced of individual patients' clinical conditions. Bearing this in mind together with the physicians' choice of diagnostic intervention, the radiographer has to decide which examination protocol to utilise. The chosen protocol should deliver the expected images that will assist the physician in order to optimise diagnosis and formulate therapeutic interventions beneficial to the patient. Radiographers soon learn that their work environment requires them to think creatively, adapt, and mould proven methods around individual patients with specific conditions.

The validity of the accepted method of any procedure or imaging technique is that it is transcending and can be adapted. An alternative method of demonstrating pathology has its validity in allowing physicians to achieve diagnostic certainty. Daffner (2000: Online) reports that the swimmer's projection needed to be repeated in 41% of all the patients in their study group. A close examination of the aforementioned revealed that 34% of the projections that were repeated needed to be repeated again. What influence would an adaptation of technique have on the results achievable? Would it be necessary to repeat three or even four times?

The aim of this study was to compare the two methods of demonstrating the cervicothoracic junction with reference to the image quality of projections, diagnosis of pathology as well as comparing the rate of repeated images. In this study, a standardised set of criteria are used to compare the adapted swimmer's projections to the swimmer's projection as described by Bontrager and Lampignano (2010: 311). For the adapted swimmer's the arm that is further from the image receptor is flexed to be in the same orientation as the cervical spine, whereas for the swimmer's projection, the arm that is closest to the image receptor is flexed so as to be in the same orientation as the rest of the cervical spine.

An investigation of (i) other methods used to demonstrate the cervicothoracic junction and (ii) studies similar to this one, can be summarised as follow: In relation to other methods, three textbook references (Harris, 1993: 55; Redman, 1993:179 & Sclafani, 1991: 3.2) do not specify, which arm is closest to the image receptor when performing the swimmer's projection. This omission could be regarded as an indication that any arm could be against the image receptor. Bettinger and Eisenberg (1995:1303-4) disqualified angulation of the main beam during most crevicothoracic junction examinations as prescribed by Bontrager and Lampignano (2010: 311). In studies by Ahmad (2003: Online), Hagler (1993:255), and Bell and Finlay (1986:152), the orientation of the arms are different indicating a difference in positioning in comparison with the methods described by Bontrager and Lampignano (2010: 311) and Ballinger and Frank (1999:416). This adaptation and the validity of this difference is what triggered this investigation. In four comparative studies (Contractor, 2002:550; Daffner, 2002: 325; Jenkins, 1999:215; Ireland, 1998: 151) of demonstrating the cervicothoracic junction, the swimmer's projection is compared to supine oblique projections. The supine oblique projections had better results related to demonstration of the posterior elements (Contractor, 2002:550; Ireland, 1998: 151), but not significantly good enough to eliminate the role of the swimmer's projection.

2. OBJECTIVES OF THE STUDY

The aim is to compare the two methods of demonstrating the cervicothoracic junction with reference to:

- Quality of projections
- Diagnosis of pathology
- Repeat rate.

It should be emphatically stated that although different acquisition modalities were used at the hospital were the study was conducted, like Bucky cassette systems, grid cassette system as well as Computed Radiography, the aim was not to compare different modalities but to compare the two images obtained by using the techniques.

3. METHODOLOGY

The research project is characterised as quantitative, meaning it was formulated, and is explicitly controlled with a precisely defined range (Mouton and Marais, 1991:159). Images were obtained using a specified procedure, and the radiologists used a standardised set of criteria compiled from literature (Ballinger & Frank, 1999: 416; Jenkins, 1999: 215) to evaluate two films. The study was controlled - through regular interaction and visibility of the researcher at the x-ray department.

Permission to execute the study was obtained from the Ethics committee of the University of the Free State, Faculty of Health Sciences, ETOVS number 41/06. Two scheduled information sessions were held with the qualified radiography staff to inform radiographers about the study. The procedure for the projections and obtaining informed consent were explained to all participants.

During the study period patients with lower cervical/upper thoracic vertebrae pathology, including trauma and post manipulation/instrumentation were included. Patients had to be conscious and able to give consent. Patients had to understand the procedure as well as what was expected of them. Patients reliant on life support systems were excluded from the study. In addition, pregnant female patients were excluded because of the possibility of irradiating the foetus. Patients with limited mental capability and patients younger than 16 years were excluded from the study. Moreover, patients with associated extremity injuries were excluded after being evaluated by the radiographer.

After being explained the procedure, informed consent was obtained from each patient by the radiographer examining the patient.

3.1 Examination Procedure

Each member of the sample was examined using the swimmer's method, as well as the adapted swimmer's method. The same image recording principles such as film/screen combination and imaging plate characteristics, source-to-image distance and geometric characteristics related to focal spot size as well as grid used were employed for both projections per individual. The positioning technique, followed by the radiographer, to get the swimmer's projection is as follow:

Position of part (swimmer's projection)

The position of the part presented here is the general radiographic technique of the swimmer's projection and has to be adapted to the patient's clinical condition.

- The patient is erect / supine
- The midcoronal plane of the body is centred to the midline of the grid.
- The patient is moved close enough to the grid cassette so that the shoulders can rest firmly against the grid for support.
- The arm that is closest to the grid is flexed so as to be in the same orientation as the rest of the body
- The elbow flexed, and the forearm rested on the patient's head
- The height of the cassette was adjusted so that it was centred at the level of C7-T1
- The patient's mid-saggital plane adjusted parallel to the cassette and the midcoronal plane was perpendicular.
- The patient's shoulder that is farthest from the cassette is depressed in the same orientation as the rest of the body as much as possible.
- The main beam is horizontal and perpendicular to the centre of the image receptor (Bontrager and Lampignano 2010: 311).

The positioning technique to get the adapted swimmer's projection presented below has no reference since the technique has not been described in literature and was specifically formulated for this study:

Position of part (Adapted swimmer's projection)

In formulating the adapted swimmer's projection the general radiographic technique of the swimmer's projection described above was be adapted to reflect a change in the orientation of the patient's arms. Again as in the case of the swimmer's projection, the positioning can be changed to best suite the patient's clinical condition.

- The patient is erect / supine
- The midcoronal plane of the body is centred to the midline of the grid.
- The patient was moved close enough to the grid so that the shoulders can rest firmly against the grid for support.

- The arm that is farther from the grid is flexed so as to be in the same orientation as the rest of the body
- The elbow flexed, and the forearm rested on the patient's head
- The height of the cassette was adjusted so that it was centred at the level of C7-T1
- The patient's mid-saggital plane adjusted parallel to the cassette and the midcoronal plane was perpendicular
- The patient's shoulder that was closest to the cassette was depressed in the same orientation as the rest of the body as much as possible.
- The main beam is horizontal and perpendicular to the centre of the image receptor

The films were marked either A or B by participating radiographers. Films (hard copies) and appendixes were collected and digital images were downloaded and printed from the central archive of the radiology department.

Before data collection, individual discussions were held with three specific radiologists willing to assist the researcher by reporting on the radiographs that formed part of the research project. The years of trauma experience between the radiologists ranged from five years to 20 years; one radiologist worked in the private sector while the other two worked in the government sector, all having trained at the same tertiary institution. One of the two radiologists working in the government sector was the principle radiologist of the specific x-ray department, while the other is the head of interventional radiology at a different x-ray department. Additionally the radiologist working in the private practice has experience in both private and government sectors. On a rotational basis all images and copies of the evaluation rubric, Table 1 were distributed to the three participating radiologists in order for them to evaluation the images. Apart from academic excellence, sensitivity to the problems associated with demonstrating C7-T1 and willingness to assist were used to select the three participating radiologists who would report on the radiographs generated in the research project.

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Table 1: The assessment rubric used during this study

Criteria	Film A , where 4 is the best and 1 is the lowest	Film B , where 4 is the best and 1 is the lowest
1. Lateral vertebrae C_7-T_1, not appreciably rotated		
2. Shoulders separated from each other		
3. Demonstration of the bony structures of the cervicothoracic vertebrae		
4. Demonstration of pathology C_7-T_1 (where applicable)		
5. Sharpness C_7-T_1		
6. Spatial resolution C_7-T_1		
Total:		

A
B Which of the 2 views has the least radiological diagnostic quality: which has to be repeated?

A scoring system illustrated in Table 2, ranging from 4 to 1 was used to evaluate the criteria presented in table 1.

Table 2: The scoring system

Qualifier	Interpretation
4	Excellent
3	Acceptable
2	Needs attention
1	Poor

The Department of Biostatistics at the University of the Free State conducted the analysis of the data. Results were summarised by frequencies and percentages (categorical variables) and percentiles (numerical variables). The class interval 3&4 (Acceptable and Excellent) were used for comparison of acceptability, the figures in the results section of this paper does only represents the incidence of the mentioned class intervals.

The two techniques, as well as other subgroups were compared using 95% confidence intervals for differences in percentage. The weighted Kappa was used to evaluate the level of agreement amongst the three radiologists.

4. RESULTS

Objective 1: Quality of Projections

Lateral Vertebrae C7-T1, Not appreciably Rotated

The frequency distribution for rotation is presented in Figure 2, where two of the three radiologists judged the swimmer's projection (film A) as being more acceptable with 53.3% (I) and 46.7% (III) respectively. These results imply that 46.7% (I) and 53.3% (III) of the sample were deemed either poor or needed attention for the two radiologists respectively. For radiologist II, the adapted swimmer's was higher with 66.7%. P-value of 0.8415, 0.7963 and 0.5921 respectively indicate that the difference is not significant.

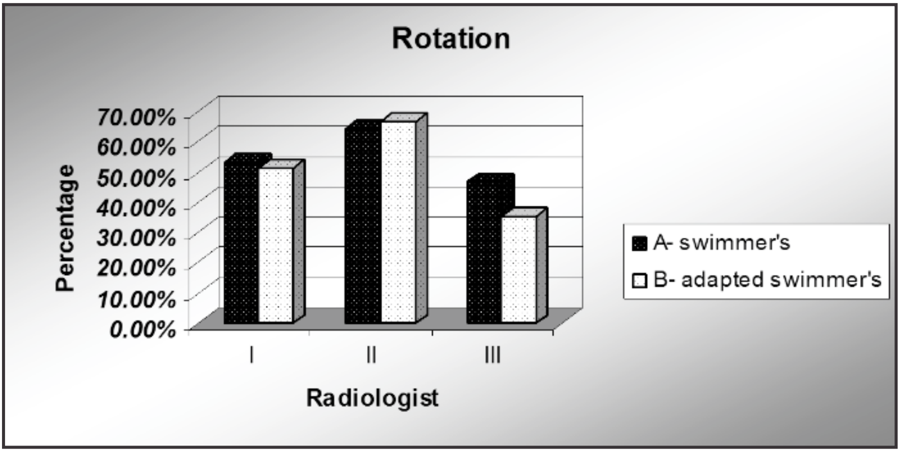

Figure 2: The percentage of acceptable films for rotation per radiologist for films A & B

Shoulder Separation from each other

For shoulder separation presented in Figure 3, two radiologists judged the swimmer's projection or the adapted swimmer's projection as acceptable. The first radiologist judged them equal by awarding both 53%. The p-values of 1.00, 0.4652 and 0.3525 again indicate no significant evidence of superiority between the two methods.

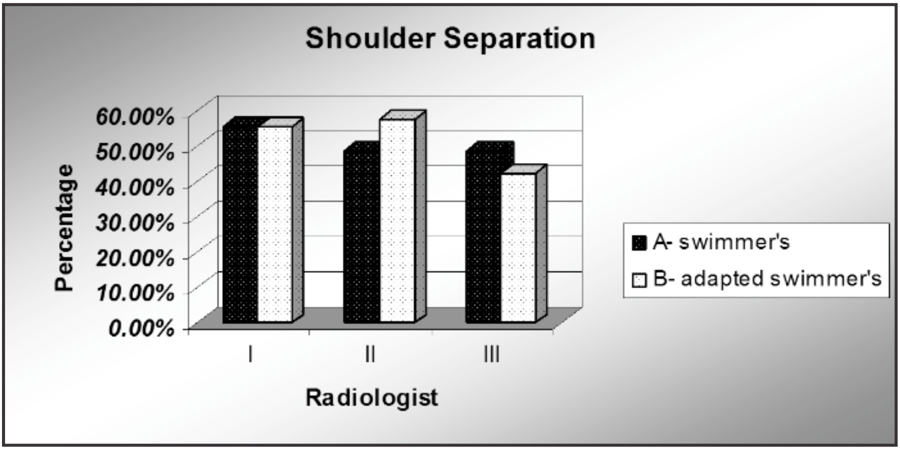

Figure 3: The percentage of acceptable films for shoulder separation per radiologist for films A & B

Demonstration of the Bony Structures of the Cervicothoracic Vertebrae

Incorrect centering during positioning and incorrect alignment of the x-ray tube to C7-T1 causes image distortion. The frequency distribution is presented in Figure 4, where two of the three radiologists judged the swimmer's projection (film A) as acceptable films with a percentage difference of 8.9% and 4.5% respectively. For radiologist II, the adapted swimmer's was higher with a percentage difference of 2.2%.

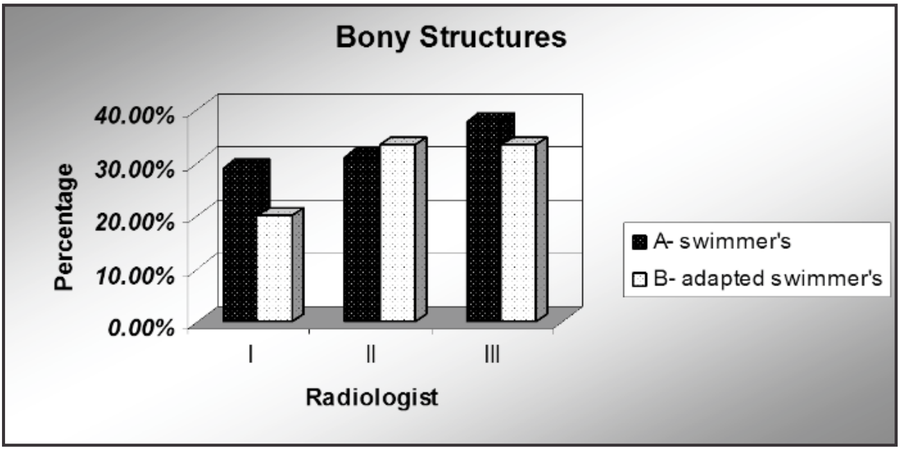

Figure 4: The percentage of acceptable films for bony structures per radiologist for films A & B

Sharpness of the Cortical Outlines

The frequency distribution of acceptable films for sharpness (see Figure 5) of the swimmer's projection (film A) was higher for all three radiologists with a percentage difference of 2.3%, 2.2% and 8.8% respectively. Once again the p-values indicate no significant difference between films A and B.

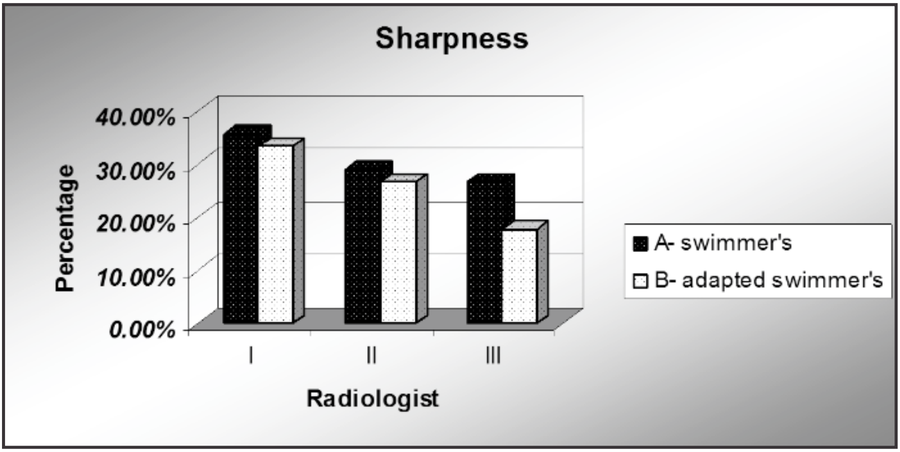

Figure 5: The percentage of acceptable films for sharpness per radiologist for films A & B

Spatial Resolution C_7-T_1

Spatial resolution is the ability to see small detail, meaning to distinguish between smaller objects in the image (Bushberg, Seibert, Leidholdt and Boone 2002:14). For spatial resolution (see figure 6) the frequency distribution of acceptable films for the swimmer's projection (film A) equalled 40.0% and the frequency distribution for the swimmer's (film B) equalled 28.9% for radiologist I. For radiologist II, the frequency distribution for the swimmer's equaled 31.1% and 28.9% favouring the swimmer's. The frequency distribution according to radiologist III, for both the swimmer's and the adapted swimmer's equaled 28.89%.

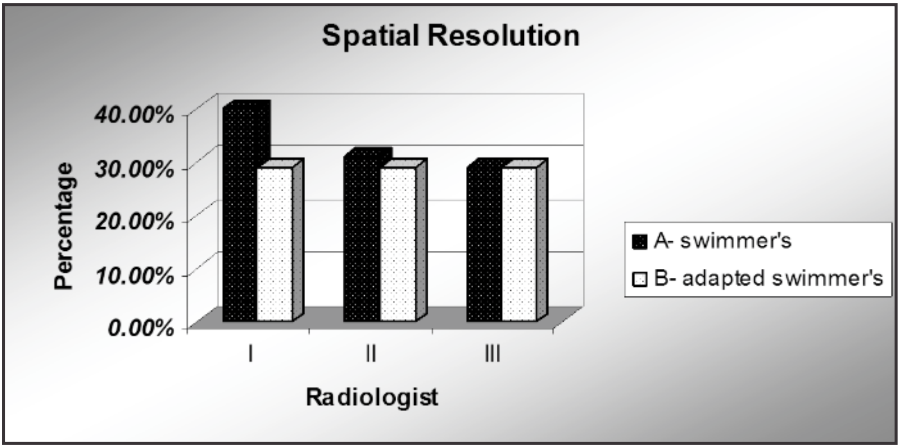

Figure 6: The percentage of acceptable films for spatial resolution per radiologist for films A & B

Objective 2: Diagnosis of Pathology

For our sample of 45 patients, the three radiologists evaluated pathology differently. The frequency distribution for the swimmer's projection (film A) equalled 22.7% and the frequency distribution for the adapted swimmer's (film B) equalled 13.6% for radiologist I (n=22). For radiologist II, the frequency distribution for the swimmer's equalled 100% (n=1) and 0% for the adapted swimmer's. According to radiologist III the frequency distribution, for both the swimmer's was 50% (n=2, with the other 50% in class interval 1&2 not acceptable) and the adapted swimmer's equalled 0%.

Objective 3: Repeat Rate

According to radiologist I the frequency distribution indicated that 35.6% of the swimmer's projection (film A) and 62.2% of the adapted swimmer's (film B) needed to be repeated. For radiologist II the frequency distribution for the swimmer's equaled 46.7% and 44.4% for the adapted swimmer's. The frequency distribution according to radiologist III for the swimmer's equaled 55.6% and for the adapted swimmer's equaled 57.8%.

5. DISCUSSION

The Quality of Projections

The swimmer's projection had better results for rotation (two of the three radiologists agreed). The result for sharpness of the cortical outlines should correlate with the results regarding the demonstration of the bony structures of the cervicothoracic vertebrae.

Two of the three radiologists said that the swimmer's demonstrated the bony structures of the cervicothoracic junction more satisfactorily. Since the swimmer's projection had better results for demonstrating the bony structures and for sharpness, a clear link to the visibility of anatomy can be established. The difference with regard to sharpness and visibility of anatomy between the swimmer's and the adapted swimmer's was not sizeable enough, since the p-values again showed no significant difference. Shoulder separation for the swimmer's and adapted swimmer's projections was equal. This result blurred the link between shoulder separation and rotation, sharpness and demonstration of the bony structures. The question is what could have influenced the results, since shoulder separation was equal. Could it be the enlarged humerus or the effect of rotation during positioning on the image? It can also be argued that the evaluations were mostly subjective; it depends on a wide range of variables, including ambient lighting and personal preferences. Carlton & Adler suggests that when consulting professionals rate images, it is better not to ask which is the best. "… because when any group of professionals are asked to select the best image there will be a difference of opinion, leaving no consensus as to which is the best image" (Carlton & Adler, 2006: 451).

Spatial resolution can be viewed as the one criterion that incorporates all the other criteria. According to two radiologists the swimmer's projection had better results, but there was quite a large difference (8.9%) in their evaluation. The other radiologist, on the other hand, evaluated the overall impression of the swimmer's projection and the adapted swimmers projection as equal. The high p-value of 0.7120 for spatial resolution also indicated that the overall impression of the two films were equal.

Diagnosis of Pathology

All three radiologists agreed that the swimmer's projection had better results. These results have to be contextualised. The differences amongst the radiologists' evaluation of pathology indicated large differences in interpretation and made meaningful conclusions difficult. What was clear was that the difference in the radiologists' evaluations increases the divide between making a positive diagnosis of pathology and permanent neurological problems associated with misdiagnosis. This is applicable on both the swimmer's and adapted swimmer's projections in the present study.

The differences in sample size did not permit validation of the results as being commonly acceptable and did not facilitate the calculation of p-values.

Repeat Rate

The difference in repeat rate for the first radiologist was 12 projections with the swimmer's projection requiring less repeats.

According to the second radiologist, the adapted swimmers projection had to be repeated less. The third radiologist evaluated less repeats for the swimmer's projection. Though the results were inconsistent, they indicated that the adapted swimmer's projection was a comparable alternative to the swimmer's projection.

There was good agreement on the individual incidents of the adapted swimmer's projection that needed to be repeated between radiologist I and II; and radiologist II and III. Between radiologist I and III, the weighted Kappa value was 0.3 - this can be regarded as a near-good agreement. The only weighted Kappa that had a value of near excellent agreement represents the incidents of the adapted swimmers projection that needed to be repeated as judged by radiologist I and III.

6. CONCLUSIONS

Similar to the studies conducted by Offerman (2006: 194), Turetsky et al. (1993: 689), Freemyer et al. (1989: 818), Blahd et al. (1985: 249), Ireland (1998: 151) and Contractor (2002:551), this study was aimed at improving the visualisation of pathology of the cervical spine. The studies mentioned have shown that in some instances other methods can be used advantageously.

Whether the swimmer's or adapted swimmer's projection optimally demonstrated the cervicothoracic junction is a similar dilemma shared by the mentioned comparable studies. The most important lesson learned from this study is that reversing the orientation of the arms can give results comparable to the swimmer's projection. The 95% confidence interval implies that in 50 of 1000 examinations (Kirkwood and Sterne, 2003: 52) the adapted swimmers can add value to the visualisation of C7- T1 and in 950 cases the results will be comparable to that of the swimmer's projection. The adapted swimmer's projection can thus be seen as an addition to the radiographers' arsenal and should be applied where the swimmer's projection do not presented the necessary diagnostic information of C7- T1.

7. LIMITATIONS AND RECOMMENDATIONS

It will be wise to factor a degree of latitude for all aspects participants other than the researcher are in control of since it has an implication on the time frame. Most of the images were done using the first and newly installed Computed Radiography system at the radiology department. The use of familiar machinery would have eased the experimentation. From the inconsistencies in the results of the three radiologists, the researcher recommends that a more consultative process should be followed for discussion, implication and application of the criteria used.

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