

**DEMONSTRATING THE CERVICOTHORACIC
JUNCTION: A COMPARISON OF TWO
TECHNIQUES**

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IGZIABEHER!

DECLARATION

I declare that *Demonstrating the cervicothoracic junction: a comparison of two techniques*, 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.

A handwritten signature in black ink, appearing to be 'RW Botha', written over a horizontal line.

RW Botha

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KEYWORDS

Trauma

Cervicothoracic

Swimmer's projection

Adapted swimmer's projection

Criteria

Alternative

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SUMMARY

Motivated by the challenges associated with demonstrating the cervicothoracic junction, a study was conducted at Pelonomi Regional Hospital from May 2006 to June 2007. In this study, two projections of the cervicothoracic junction were done, with the only difference between them being the orientation of the arms. One projection was done using the swimmer's projection and the other using an adaptation of the swimmer's projection where the orientation of the arms was reversed. The sample, consisting of 45 patients, was referred from the emergency department and wards. Most of the patients (95.5%) were examined using a computed radiography system providing digital images that were printed using a laser film printer. Other patients were examined using conventional film/screen systems. The objectives of this study were to compare the two imaging techniques with reference to diagnostic quality of the projections, diagnosis of pathology and repeat rate.

Radiographers obtained the two projections of the cervical spine; the researcher collected the images and distributed these to three participating radiologists on a rotational basis. The radiologists evaluated the films using a set of criteria; a biostatistician analysed the results of these evaluations.

In all the criteria of image quality the swimmer's projection showed better results. There were also, however, instances where the adapted swimmer's had better results. The differences in percentages were not significant enough to show any statistical difference between the resultant images of the two techniques. No valid deduction could be made in relation to the demonstration of pathology due to variable instances of pathology evaluated by the radiologists. The repeat rate of the adapted swimmer's projection compared well with the swimmer's projection.

Though the swimmer's projection had better results for most of the criteria used in this study, no unequivocal, statistically significant evidence of it demonstrating C₇-T₁ better could be found. What was evident was the validity

of the adapted swimmer's projection as an alternative under certain conditions. Knowing that there is an alternative method to visualising the C₇-T₁ junction could be beneficial not only to radiography, but also to our patients. In cases where the swimmer's projection is not possible due to extremity injuries, an alternative arm orientation can be useful. The alternative can also address the problem regarding multiple repeats of the swimmer's projection.

OPSOMMING

'n Studie gemotiveer deur die uitdagings met die demonstrering van die servikotorakale aansluiting is vanaf Mei 2006 to Junie 2007 uitgevoer by Pelonomi Streekshospitaal. In hierdie studie is twee opnames van die servikotorakale aansluiting geneem waar die enigste verskil die orientasie van die arms was. Een projeksie was gedoen met behulp van die swemmers projeksie en die ander met 'n aanpassing tot die swemmers waar die orientasie van die arms omgekeerd was. Die proefgroep van 45 pasiënte was verwys vanaf die noodafdeling en sale. Meeste van die pasiënte (95.5%) was ondersoek met 'n gerekenaariseerde radiografie stelsel wat digitale beelde lewer wat met 'n laserkamera uitgedruk is. Ander pasiënte was ondersoek met konvensionele film/skerm sisteme. Die doelwitte van die studie was om die twee tegnieke te vergelyk ten opsigte van diagnostiese kwaliteit van die projeksies, diagnose van patologie en herhaaltempo.

Radiograwe het die twee opnames gedoen, die navorser het die beelde versamel en op 'n rotasie basis versprei onder die drie deelnemende radioloë. Die radioloë het die films geëvalueer met behulp van 'n stel kriteria; 'n biostatistikus het die resultate van hierdie evaluerings geanaliseer.

In al die kriteria van beeldkwaliteit het die swemmers projeksie better resultate gelewer. Daar was ook gevalle waar die aangepaste swemmers better resultate gehad het. Die verskil in persentasies was nie betekenisvol genoeg om statistiese verskille tussen die resulterende beelde van die twee tegnieke aan te toon nie. Geen geldige afleidings kon gemaak word met betrekking tot die demonstrering van patologie as gevolg van die variërende gevalle van patologie deur die radioloë geëvalueer. Die herhaaltempo van die aangepaste swemmers het goed vergelyk met die van die swemmers projeksie.

Alhoewel die swemmers projeksie better resultate gehad het vir meeste van die kriteria wat in die studie gebruik is, was geen onweerlegbare statisties betekenisvolle bewyse gekry dat dit C₇- T₁ better demonstreer. Wat wel duidelik was, was die geldigheid van die aangepaste swemmers as 'n

alternatief onder sekere omstandighede. Kennis van 'n alternatiewe metode om C₇- T₁ te demonstreer kan nie net vir radiograwe voordelig wees nie, maar ook vir ons pasiënte. In gevalle waar ekstremiteit beserings die swemmers projeksie onmoontlik maak, kan 'n alternatiewe arm orientasie van hulp wees. Die alternatief kan ook die probleem van veelvuldige herhalings van die swemmers projeksie aanspreek.

Chapter 1

OVERVIEW OF THE STUDY

1.1 INTRODUCTION

When an ambulance with howling sirens arrives at any trauma centre, it evokes a degree of alertness due to the fact that it announces a life-threatening emergency. It also means that the person is lucky to have received medical help. This assistance continues in the trauma centre, where additional disciplines are incorporated to facilitate optimal diagnosis and treatment. When a person that has suffered from spinal trauma sustained in for instance, a serious motor vehicle accident arrives at an x-ray department, s/he is in most cases strapped onto a fracture board. Patients are hurt, disorientated and bloodied, with drips and monitors connected to them. Multiple examinations related to the mechanisms of injury and the patient's physical and mental condition are usually requested. Immediately, the radiographers become adrenalised, analytical and focussed on the imaging examination and the related events that are to follow.

The ultimate value of an imaging examination, such as the cervicothoracic junction examination, is the expected diagnostic information 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. To improve the physicians' choice of imaging examination, it is suggested by Kuhns (Kuhns, 1989: 4) that they should informally use rigorous decision analysis methodology. According to Kuhns (Kuhns, 1989: 4), the physician needs to ask two interrelated questions when deciding whether to request an imaging examination or not, namely:

1. Is this examination going to affect the diagnostic certainty and, if so, to what degree?
2. Will the information provided by the examination change the diagnosis to the extent where the treatment is significantly affected?

Influenced by clinical conditions, radiographic procedures in general and trauma radiography specifically are very unpredictable. Keeping this in mind along with the physicians' choice of diagnostic intervention, the radiographer has to decide which examination protocol to use. 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 mold 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 by being able to answer the aforementioned questions.

In this study, a standardised set of criteria were used to compare the adapted swimmer's projections* of demonstrating the cervicothoracic junction as described by Ahmad (2003: Online), Hagler (1993:255), and Bell and Finlay (1986:152), to the swimmer's projection[†].

In this chapter, the importance of correct diagnosis of pathology of the cervicothoracic junction will be emphasised, and current methods of demonstrating cervicothoracic junction (C₇-T₁) will be discussed. The challenges associated with the current routine method used to demonstrate the cervicothoracic junction will be identified and associated objectives as well as possible outcomes, will be listed. An aperitif of the methodology, infused with summarised findings from the literature study, is presented here. Chapter one also includes a prospective layout of the dissertation.

1.2 IMAGING OF CERVICAL SPINE INJURY

It is logical that the modality of imaging and the imaging procedure used directly impacts on the diagnosis. Plain film radiography is considered the essential first step in an imaging examination of the cervical spine because it

*[†] The adapted swimmer's projection, where orientation of the arms in relation to the image receptor differs from the swimmer's projection. The swimmer's projection are discussed in detail in Appendix 4.

is relatively inexpensive, widely available, reliable, quick to perform, and portable.

It is clear from the feedback of the Specialty Focus Groups Diagnostic Radiology, under the auspices of the South African Department of Health, that there is an irrational spread of services in South Africa (South African Department of Health, 1999: Online). This irrational spread is governed by the geographical spread of the population, resources and the availability of specialised skills. Tertiary services such as Computed Tomography (CT) (Appendix 1 - Terminology) and Magnetic Resonance Imaging (MRI) (Appendix 1 - Terminology), that facilitates faster and relatively easier diagnosis of possible trauma to the cervical spine, are only available in larger centres (South African Department of Health, 1999: Online). The rural population has limited tertiary services and plain film images have to hold the frontline in diagnosis of pathology to C₇-T₁.

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), (Berquist, 1988: 668 ; Ahmad 2003: Online).

The lateral projection is done first for the following reasons:

- the anatomy under investigation is not moved;
- the bodies and spinous processes of C₂-C₇ are fully visualised;
- intervertebral spaces and prevertebral soft tissue can be evaluated;
- pathology or possible problems can be quickly identified and
- possible intervention can be planned (Ahmad, 2003: Online)

When imaging cervical spine injury, it is extremely important that not only should C₇ be visualised, but also T₁. In doing so, it will allow us to evaluate the relationship of the transitional architecture between C₇ and T₁ in order to not overlook less obvious fractures. If the transition is not demonstrated, then a swimmer's projection, where the bulk of the shoulder girdle is displaced, needs to be done.

1.3 DEMONSTRATING C₇-T₁ USING THE SWIMMER'S PROJECTION

In the demanding environment of a trauma department, having to repeat projections due to unsatisfactory results is not only stressful for the radiographer, but also costly and life threatening to the patient, as it is time-consuming and leads to an increase in radiation dose. It is thus evident that the radiographic examination of a patient with suspected cervical spine trauma may be difficult and is usually limited to a few projections. These projections include a lateral projection, an anteroposterior projection, and an odontoid projection also known as the 3-view/projection series (Jenkins, 1999: 216; Murphy, 2000: Online). The difficulties are firstly related to other life-threatening injuries taking priority in the management of the critically ill trauma patient. The patient frequently has associated injuries such as pneumo- and/or hemothorax, skull as well as extremity injuries. These injuries often delay diagnosis of cervical spine injury. Secondly, unnecessary movement of patients with suspected cervical spine injuries increases the risk of damage to the spinal cord (Ahmad, 2003: Online). It is thus essential that patients with cervical spine trauma should be treated as though they had an injury to minimize the potential for iatrogenic spinal cord injury. When cervical spine injury is suspected, the imaging evaluation of the cervical spine after trauma should proceed quickly and cautiously.

At this stage the three methods mentioned below forms the protocol prescribed to Radiography learners of the Central University of Technology, Free State for demonstrating C₇-T₁.

The first method is the upright (erect) swimmer's lateral projection, also known as the Twining method. The patient is positioned in a lateral position, either seated or standing with the left side against the image receptor. The arm that is closest to the image receptor (grid and cassette with film) is elevated to a vertical position and the elbow is flexed. The other arm is depressed along the patient's body (Bontrager, 2006: 311).

The second method is the swimmer's positioning for trauma, where the patient is in the supine position. The arm that is closest to the image receptor is elevated to a horizontal position, parallel to the patient's neck and the elbow is flexed (McQuillen-Martensen, 1993: 338). Thirdly is the recumbent swimmer's lateral projection, also known as the Pawlow method. The patient lies on his/her side in a lateral recumbent position. The arm that is closest to the image receptor is abducted and positioned lateral to the neck and the elbow is flexed (Ballinger & Frank, 1999: 416).

Due to difficulties and challenges associated with effective demonstration of C₇-T₁ when using the swimmer's method, uncertainty exists between normal radiological findings and pathology at the cervicothoracic junction. This grey area described by Köhler in *Borderlands of normal and early pathological findings in skeletal radiography* (Köhler & Zimmer, 1993:498) is primarily influenced by the patient's body habitus and the patient's mental as well as physical condition. If we can minimise the size of this grey area by adapting our technique, lives can literally be saved.

Daffner (2000: Online) reports that the swimmer's projection needed to be repeated in 41% of all the patients in their study group. Additionally, 34% of the patients required three radiographs and one patient each (2% of the study group) required four, and five repeated radiographs respectively (Daffner, 2000: Online). Looking closer at the above, 34% of the films 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 four or even five times?

It is sometimes necessary for radiographers to stabilise the position of cervical trauma patients during x-ray exposure. The amount of radiation received by staff assisting in immobilisation or maintaining the image receptor-beam alignment is determined by the amount of repeats. This is a logical deduction from the results of Singer (1989: 818) that examined the hazard of ionising radiation associated with neck stabilisation using a phantom. He found that a radiographer radiated while assisting in stabilising the position of a cervical trauma patient four times per week without shielding their hands would receive the mean measured exposure of 581 mRem

(Appendix 1). This measurement represents the routine trauma projections plus the swimmer's projection to the unprotected finger of the hand positioned nearest to the tube. This measurement according to Singer (1989: 818) is more than twice the maximum allowable annual occupational radiation extremities exposure recommended by the National Council of Radiation Protection and Measurements (NCRP, 1989: 13).

1.4 PROBLEM STATEMENT

The challenge for radiographers is to produce good quality images of diagnostic value in a short amount of time while functioning in a highly stressful and demanding environment. The swimmer's projection demonstrates C₇-T₁, where these structures are not visible on the routine lateral projection of the cervical spine.

Using the method as specified in Appendix 4 does not guarantee optimal demonstration of C₇-T₁ in all cases. Particularly in patients with broad shoulders it could lead to an increase in repeat films and radiation exposure of the same projection with only a variation in exposure techniques.

It should also be noted that in cases of trauma, where time is of the essence, obtaining the desired results in the minimum amount of time could be life saving. This is emphasised by the *Golden hour principle* (Appendix 1). The question is whether an alternative to the swimmer's projection could have a direct impact on the diagnostic quality of projections, repeat rate as well as the radiation dose to patients and overall examination time.

1.5 PURPOSE OF THE STUDY

The purpose of this study is to evaluate the efficiency of the adapted swimmer's projection, with a difference in arm orientation, in demonstrating the cervicothoracic junction (C₇-T₁). The adapted swimmer's projection will be compared to the swimmer's projection (Appendix 4), with reference to the best diagnostic result of what is known as "the most commonly overlooked site of injury" (Ahmad, 2003: Online).

1.6 AIMS AND OBJECTIVES OF THE STUDY

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

- Quality of projections (Appendix 9).
- Diagnosis of pathology (Appendix 9).
- Repeat rate (Appendix 9).

It should be emphatically stated that although different acquisition modalities were used at Pelonomi Hospital, like Bucky cassette systems (Appendix 1), grid cassette system as well as Computed Radiography (Appendix 1), the aim was not to compare different modalities but to compare the two images obtained by using the techniques, as explained in Appendix 4.

1.7 PILOT STUDY

A pilot study was done as part of the researcher's B.Tech study (Appendix 11). A sample of 20 volunteers was examined at the Radiology Department, Universitas Hospital, Bloemfontein; none of the volunteers had cervical spine pathology or indications thereof. An "artificial" setting was thus created to facilitate the study. Using the same processor and film/screen combination, two exposures were done on each member of the sample. Firstly the standard swimmer's projection was performed. Then, for the adapted swimmer's projection, the orientation of the patient's arms were reversed. The results obtained were presented at the 17th National Conference of the Society of Radiographers of South Africa: "Facets of fusion", held at Durban International Conference Centre between 15 and 22 April 2004. Many questions were asked, prompting the researcher to further investigate the matter in a clinical setting. This study should compare the two methods of demonstrating the cervicothoracic junction, using patients in the hospital environment for a longer period which would increase the sample size. The evaluation criteria used during this study is rooted in the criteria of the pilot study with only slight amendments and one additional criteria.

1.8 RELATED STUDIES

An investigation of (i) other methods used to demonstrate the cervicothoracic junction and (ii) studies similar to this one, started during the pilot study and continued well into the dissertation construction. The following is a summary of some of the findings presented in the literature review (see Chapter 2):

In relation to other methods, three textbook references (Harris, 1993: 155; Redman, 1993:179 & Sclafani, 1991: 3.2) do not specify which arm is closest to the image receptor; which could be regarded as an indication that any arm could be placed against the image receptor. Bettinger and Eisenberg (1995:1303-4) disqualified angulation of the main beam during most cervicothoracic junction examinations. In studies by Ahmad (2003: Online), Hagler (1993:255), and Bell & Finlay (1986:152), the orientation of the arms are different indicating a difference in positioning in comparison with the methods described by Bontrager (2006: 311) and Ballinger and Frank (1999: 416) - Appendix 4. This adaptation and the validity of this difference is what triggered the current investigation. In four comparative studies (Contractor, 2002:550; Daffner, 2002: 325; Jenkins, 1999:215; Ireland, 1998: 151) related to demonstrating the cervicothoracic junction, the swimmer's projection is compared to supine oblique projections. The supine oblique projections had better results related to specific criteria, but not significantly good enough to eliminate the role of the swimmer's projection.

From the pilot study, done on 20 volunteers, it was found that reversing the orientation of the arms when doing the swimmer's projection (the adapted swimmer's) equally demonstrates the bony elements of the cervicothoracic junction (Botha, 2006: 9).

1.9 METHODOLOGY

1.9.1 Study Design

A quantitative approach to research, as described by Mouton and Marais (1991:159), can be described as research that is more formulated, as well as more explicitly controlled with a precisely defined range. The research project is characterised by the aforementioned elements. Images were obtained using a specified procedure (Appendix 4), and the radiologists used a

standardised set of criteria to evaluate two films obtained (Appendix 9). The study was controlled - through regular interaction and visibility of the researcher at Pelonomi Hospital.

Since the study aims to evaluate the effective demonstration of C₇-T₁ by using the adapted swimmer's projection, it can also be classified as experimental interventional due to the fact that it evaluates an intervention. Katzenellenbogen states that one of the criteria of experimental research is that the intervention should be compared to another group or intervention – for this study we are comparing two projections used to visualise C₇-T₁ (Katzenellenbogen, Joubert and Abdool Karim, 1999: 69).

1.9.2 Permission

Permission to execute the study was obtained from a number of stakeholders. The stakeholders included the head clinical services of Pelonomi Hospital (Appendix 2), the head of the radiology department at University of the Free State (UFS) and the Ethics committee of the University of the Free State, Faculty of Health Sciences, ETOVS number 41/06 (Appendix 5).

1.9.3 Preparation

The project was conducted at Pelonomi Regional Hospital: a tertiary level academic hospital with trauma facilities. As an introduction to the study two formal information sessions were held with the radiography staff at Pelonomi Hospital.

Topics discussed at this session included:

- A general introduction to the research project
- Examination protocols to be followed
- Remuneration for participation in project

1.9.4 Sampling

An interview session was held with 11 qualified radiographers to try and approximate the eventual size of the sample. The approximate eventual size of the sample equals ± 20 patients per month. Patients that understood the purpose of the study and were able to give consent formed part of the sample. Qualified radiographers performing the examinations will obtain consent for the additional projection from the patients.

1.9.5 Equipment

The primary X-ray Department at Pelonomi Hospital, which service hospitalized patients, is equipped with 8 general x-ray machines and 2 processors. At the Casualty Department, located within the newly established Emergency Department, they have a newly installed Computed Radiography (CR) system.

1.9.6 Procedure

Two lateral projections were taken of the cervicothoracic junction, with the only difference being the orientation of the patient's arms. The generic variables, such as image recording principles to create an image of C₇-T₁, remained constant.

1.9.7 Comparison of Diagnostic Quality

Before data collection, one-on-one discussions were held with three specific radiologists willing to help the researcher by reporting on the radiographs that formed part of the research project. In using the set criteria (Appendix 9), the radiologists compared overall acceptability.

1.9.8 Statistical analysis

The Department of Biostatistics at the University of the Free State conducted the analysis of data that was presented to them by the researcher in a MS Excel spreadsheet format (Appendix 13).

1.10 OUTCOMES OF THE STUDY

The primary outcome of this study was to obtain an M.Tech qualification in Radiography (Diagnostic). Additionally presentations/posters presented at CPD-accredited seminars at the Central University of Technology, Free State (CUT) and the congress of the South African Society of Radiographers are a future positive spin-off of the study. An article will be submitted for publication in The South African Radiographer, as published by the Society of Radiographers of South Africa as well as the Journal for New Generation Sciences as published by CUT.

1.11 STRUCTURE OF FINAL DISSERTATION

Now that the scene for the study has been set, the following breakdown serves to give an indication of the layout regarding this report so as to assist the reader in order to satisfy their specific needs.

Chapter 1

Overview of the Study

The first chapter serves as a general overview of the study and its objectives. This section aims to identify problems associated with the current method of demonstrating the cervicothoracic junction and sets the scene for the rest of the chapters.

Chapter 2

Literature Study

This chapter provides the theoretical framework within which the research was conducted, as well as an integrated discussion of related research findings. It also includes a clear definition of the core concepts that are used in the dissertation.

Chapter 3

Methodology

This chapter contains the research method and materials used, in attaining the specific objectives. These include the pilot study; sampling strategies; sampling size; target population; empirical research; dependent and independent variables, measuring instruments and the characteristics of and reasons for using these; statistical techniques used and the reason for using them.

Chapter 4

Results

The research findings are presented in this chapter.

Chapter 5

Discussion and Recommendations

Analysis, interpretation and discussion of the findings from the previous chapter are presented. This chapter also contains recommendations for the use of the research findings and addresses weaknesses in the research.

1.12 SUMMARY

Physicians request medical imaging to confirm diagnostic certainty and choice of treatment. Correct diagnosis of possible pathology through medical imaging is influenced by the modality used and the imaging procedure. Since plain film imaging is widely available, positioning procedures used should allow for the creation of images with a high sensitivity (Appendix 1) for the specific anatomical region. In this chapter, evidence pointing to the importance and the difficulty associated with the demonstration of the cervicothoracic junction were presented. Challenges related to the use of the swimmer's projection to demonstrate C₇-T₁ have been identified. The purpose of this study is to evaluate the efficiency of the adapted swimmer's projection in demonstrating the cervicothoracic junction (C₇-T₁). The adapted swimmer's projection will be compared to the swimmer's projection (Appendix 4) with reference to the best diagnostic result of what is known as "the most commonly overlooked site of injury" (Ahmad, 2003: Online).

In chapter 2, the literature study, the researcher reviews literature (books, journal articles, and online databases) relevant to the project.

Chapter 2

LITERATURE STUDY

2.1 INTRODUCTION

The purpose of reviewing literature for this research project was, firstly, to underscore the importance of accurate initial diagnosis of pathology to the C₇-T₁ junction: the transition between the flexible, lordotic (Appendix 1) cervical spine and the rigid, kyphotic (Appendix 1) thoracic spine. Secondly, since some of the challenges of the swimmer's projection are revealed in section 1.2 and 1.3, chapter 1, the value-adding effect of deviation from the commonly acceptable swimmer's method of demonstrating C₇-T₁, will be discussed. The literature study also has to investigate similar studies in relation to design, sample size and findings that can be useful in ascertaining the relevance and credibility of this study. It serves to verify the results of this study. In doing the literature study the importance of the project, viewed in a broader radiographic context, also became clear.

2.2 LITERATURE SEARCH

The literature study started by basic analysis of the swimmer's projection as described in textbooks by Bontrager (2006: 311), Ballinger and Frank (1999:416) and McQuillen-Martensen (1993:338). The literature study gave guidance in formulating the research objectives, and the quest for relevant studies proceeded by using resources such as books and journals, available in the library at the CUT as well as the Frik Scott library situated on the UFS campus.

Online searches proceeded by using specific search phrases such as swimmer's, cervicothoracic and cervical. Search alerts were registered on online literature databases for scientific, technical, and medical research like ScienceDirect, Medline and AuntMinnie. Valuable information regarding similar studies was accessed, downloaded and studied to thus facilitate

comparisons related to method and results. As publications related to the search become available, the researcher was alerted via electronic mail. Several search alerts registered on online databases have, as yet, only heralded a few publications or articles related to the study. The interlibrary loan service provided by the CUT, library facilitated the acquisition of documents not available on the various databases used.

NEXUS is a search engine sponsored by the National Research Foundation of South Africa. It serves as a database for research conducted as well as research in progress. It alerts researchers to similar research that has been completed or is in the process of completion. Evidence of the submission of this research project to the database is attached as Appendix 3. The Nexus search done to find out if similar projects exist had no results.

2.3 THE IMPORTANCE OF CORRECT DIAGNOSIS

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. For the patient with trauma to the cervical spine the lateral projection (including T₁) is the first projection of the 3-projection series done to evaluate the lines A, B and C (Mirvis & Young, 1992: 292 in figure 2.1). 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; it is important in maintaining alignment and stability. Line B, the posterior longitudinal ligament (PLL) extends along the posterior aspect of the vertebral bodies in a similar fashion. 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 may demonstrate underlying pathology. Pathology will influence further positioning techniques to obtain the anteroposterior, odontoid and oblique projections and thus complete the examination.

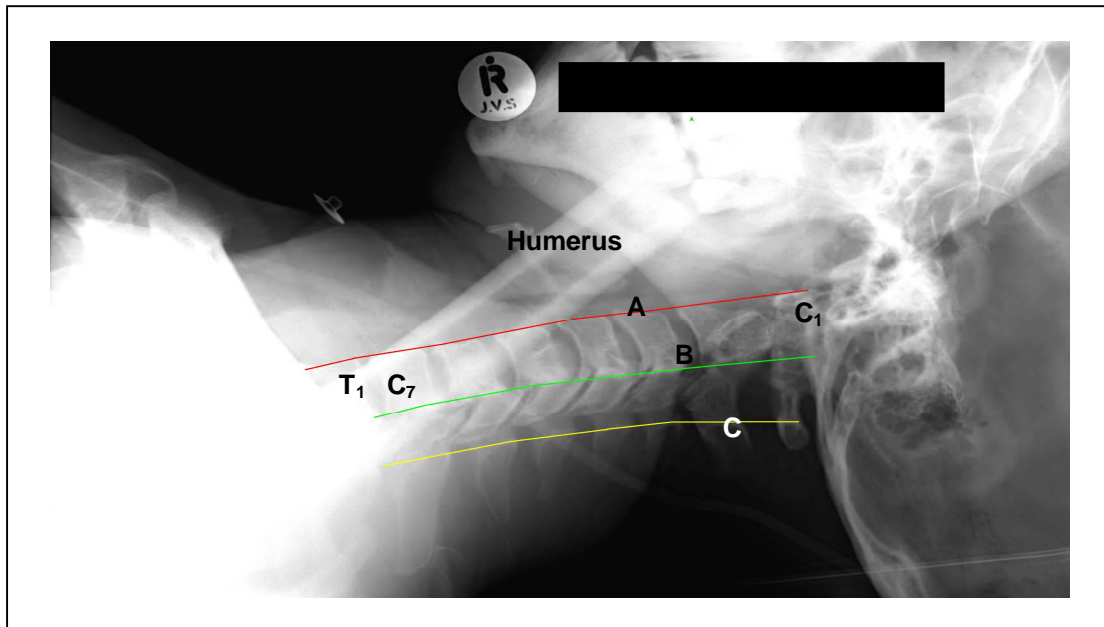


Figure 2.1 Shows line A, the anterior longitudinal ligament, line B, the posterior longitudinal ligament and line C, the laminospinal line. These lines are used to evaluate the relationships between the different vertebrae as an indication of underlying trauma (adapted from Graber & Kathol, 1999: Online)

The problem is that one does not always see these lines and other anatomical structures on plain film. 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 (Appendix 1) influencing diagnosis (Blackmore, 2003:283).

In trauma of the cervical spine, the initial radiographic series typically contains lateral, anteroposterior, and open mouth odontoid projections also known as the 3-projection series (Jenkins, 1999: 216 and Murphy, 2000: Online). The sensitivity of the 3-projection series influenced by the patient condition is said to be as high as 93%. The sensitivity of an imaging procedure is its ability to detect a disease in a patient who does have the disease (Murphy, 2000: Online). Streitweiser (1983: online) challenged the accuracy of the 3-projection series

(lateral projection, anteroposterior projection, and odontoid projection) for demonstrating cervical abnormalities; he calculated the sensitivity of 93% and a specificity, and accuracy of 71%, and 84% respectively. In Murphy's study, the cross-table lateral radiograph is 74% to 86% sensitive in detecting cervical spine injuries (Murphy, 2000: Online). For the cross-table lateral projection Streitweiser had a sensitivity of 82%, this correlates with Murphy's findings for both categories. In Streitweiser's results, the cross-table lateral projection also had a specificity of 70%, and an accuracy of 77% for detecting fractures.

In a retrospective study reported by Bland *et al.* (1985: 243), where two physicians evaluated the cross-table lateral of 128 patients it was found that using this technique alone, is unreliable and potentially dangerous as a screening exam. The diagnostic accuracy of the cross-table lateral alone was 74.2% and 79.7% for the physician and radiologist, respectively. It was also found that 35% of C₁, 14.8% of C₂, and 42.4% of C₆ abnormalities were missed by both the physician and the radiologist. These findings mirror those of Murphy and Streitweiser, where the sensitivity ranges between 74% to 86%.

Injuries of the cervical spine primarily occur at two levels, with almost one third of fractures at C₂, and one half at C₆ or C₇ (Ivy & Cohn: 1997: 591); these structures are in close proximity to the cranio-cervico junction and the cervicothoracic junction. At the cervicothoracic junction there is an abrupt change from the flexible cervical vertebrae to the rigid thoracic vertebrae. 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).

To obtain optimal information regarding C₇-T₁, arm traction is used when positioning patients for the swimmer's projection. Ohioenoya (1996: online) studied the success of arm traction in 98 trauma patients. The aim of the study was to formulate a probability system to predict the visualisation of C₇-

T₁. Vertebral bodies were divided into four zones. The fifth cervical vertebra was used as the starting level (zone 1); zone 5 indicates the upper first zone of C₆. Two images of the lateral cervical spine were obtained, pre and post arm traction. Analysis of the acquired images show that if the pre traction film showed less than zone 10 (mid-C₇ vertebra), the probability of showing zone 13 (upper body of T₁) with arm traction was only 7.7%. In situations where the upper one third of the body of C₇ vertebra is not seen, CT, swimmer's, or oblique projections should be considered.

It can be seen from the statistics that the eventual outcome of spinal trauma can be directly associated with the first investigation. This plain film investigation is the first step to making a diagnosis or confirming pathology of the cervical spine pointing to the relevance and importance of the current study.

2.4 ELEMENTS RELATED TO THE IMAGING OF C₇-T₁

Being able to see C₇-T₁ is influenced by the correct application of various imaging recording and positioning principles. It is important to outline all the important elements used in conducting the research as well as the relevance thereof. In relation to this, it should be understood that the smaller data elements, like important imaging and positioning principles have to be clarified since they support the main data elements aligned with the anticipated aims and objectives (Section 1.6) of the project. These variables and principles of operation blend together to obtain the desired effect. A discussion of elements, related to the methodology, serves as the skeleton on which the procedure to execute the research is fleshed. Most of these aspects are generic to both methods of demonstrating the cervicothoracic junction that were compared.

2.4.1 Equipment

The radiology department at Pelonomi Hospital has different sections, namely: the primary department, casualty department, vascular and mammography department as well as the theatres. The primary x-ray department at Pelonomi Hospital is equipped with 8 general x-ray machines that use Bucky cassette holders (moving grid systems). In some cases no

Bucky cassette holders with moving grid was available, hence the use of stationary grid systems (grid cassettes). At the casualty department they have a newly installed Computed Radiography (CR) system. Although different ways to capture the images were used, one needs to keep in mind that the primary aim of the investigation is related to optimal diagnosis of C₇-T₁ with one variable that is changing the orientation of the arms.

2.4.2 The Image Recording Principles for Demonstrating C₇-T₁

A summary of a number of the imaging principles like film/screen combination, distance (object-to-image distance, source-to-image distance), geometric characteristics, and motion, as well as their relationships, is shown in figure 2.2 (Adapted from Carlton & Adler, 2006: 444). The principles, generic to obtaining clearly defined diagnostic recorded detail for both methods of demonstrating C₇-T₁ used during this study, will be described in the following section.

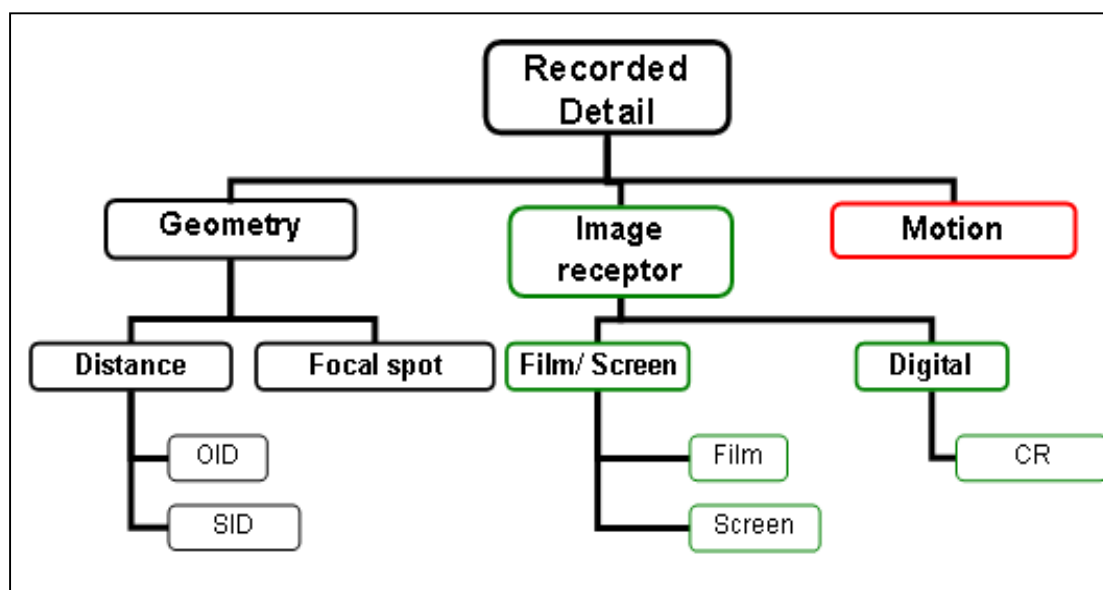


Figure 2.2 Radiographic image quality: factors affecting recorded detail (Adapted from Carlton & Adler, 2006: 444)

2.4.2.1 *Film/Screen Combination used at the Primary Department*

In the primary department, analogue film/screen combinations are used: multi purpose cassettes (Agfa) loaded with light sensitive films [Agfa-Curix CPG plus (Curix is a trademark of Agfa-Gevaert N.V., Belgium)] sandwiched between light emitting intensifying screens. CPG-plus films allow for sharp detailed images with high spatial resolution that can distinguish subtle density changes between soft tissue and air (Agfa imaging: Online). Often

abnormalities in soft tissue can indicate underlying pathology; this is especially true in the case of the cervicothoracic junction. The intensifying screens work on the basis of fluorescence (Appendix 1) to form the image on the photosensitive film (Carlton & Adler, 2006: 320). The green light emission of the screens used is based upon the GadoliniumOxySulphide phosphor. Agfa CPG 400, 400 speed screens ensure a compromise between a higher speed screen (meaning a reduction in dose to patients) as well as the definition and noise of the images (Agfa imaging: Online).

2.4.2.2 *Imaging Plate used at the Casualty Department*

Computed Radiography (CR) can be regarded as the first step into the digital age (Bushberg, 2002: 297). A conventional x-ray machine with a grid and conventional cassettes are used in CR, but the basis of image acquisition is phosphorescence (Appendix 1) rather than fluorescence (Appendix 1). No intensifying screen is used with this system, but an image storage plate, also known as an imaging plate is used (Bushberg, 2002: 297).

The imaging plate is made of barium fluorohalide bromide (BaFBr:Eu) or barium fluorohalide iodide (BaFI:Eu), both europium activated. Transmitted x-rays from the patient deposit their energy in the plate (Carlton & Adler, 2006: 357). This analogue "image" is digitised by the analogue-to-digital converter of the CR reader and is available for display on high resolution monitors (Bushberg, 2002: 296).

2.4.2.3 *Distance: OID and SID*

Due to human anatomy, the shoulder is positioned closer to the image receptor and the cervical spine is at a distance from the image receptor, when the patient is in the swimmer's position. Objects that are further from the image receptor will be magnified and resolution decreases. When objects within a structure are at different levels (figure 2.3, objects A and B) they will be projected onto the image as different sizes (Carlton & Adler, 2006: 444)

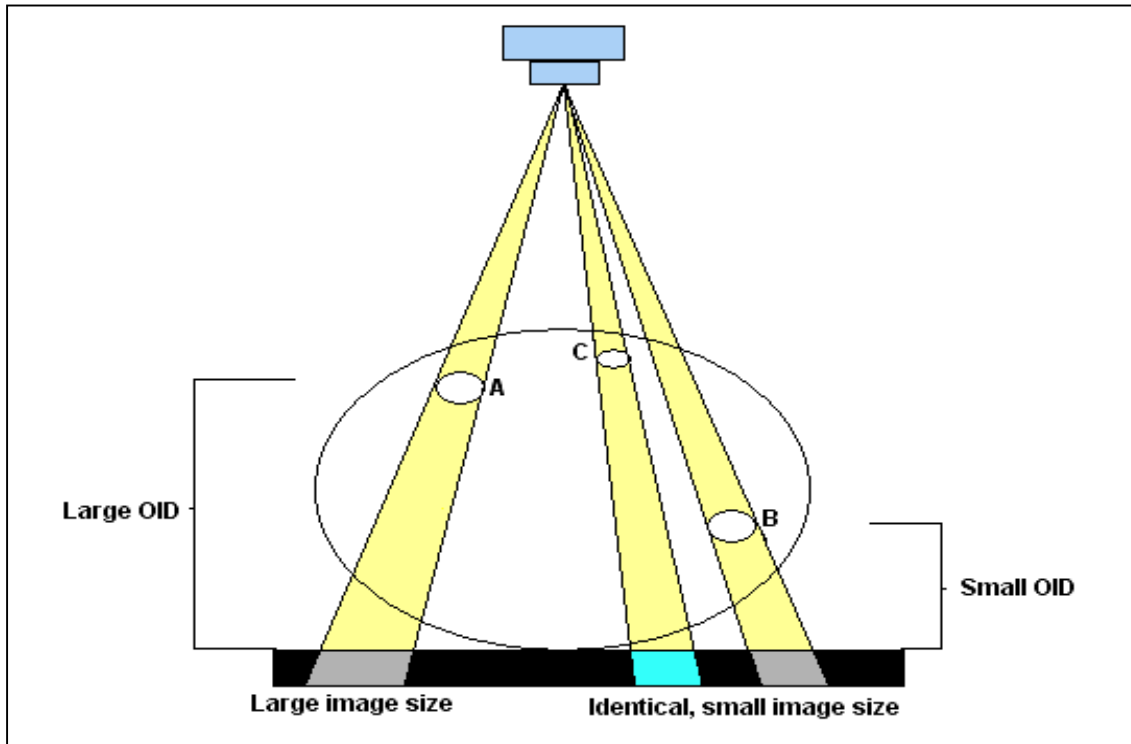


Figure 2.3 The effect of OID on image size magnification. A and B are identical in size but their images on the receptor are of significantly different sizes. C is smaller than B, but the image sizes are identical because of C's greater OID (Adapted from Carlton & Adler, 2006: 458)

The problem of structures at different levels relative to each other, causing differences in magnification, is overcome by increasing the source-to-image distance (SID). The swimmer's projection is usually performed at an SID of 150cm instead of a 115cm SID because the object-to-image distance (OID) cannot be reduced due to the distance between the neck and shoulder (Carlton & Adler, 2006: 445). The x-ray machine at Pelonomi Hospital has a fixed SID at 115cm and, consequently, all images are taken at this SID.

2.4.2.4 Air gap technique

An unlikely advantage of a larger object-to-image distance is that it allows the use of the air gap technique that combats image fog, where secondary (scattered) radiation, caused by anatomy, increases the overall greyness of the image, thereby degrading contrast and diagnostic value. The air gap technique is effective in restoring a portion of the desired image contrast (Carroll, 1990: 216).

2.4.2.5 Geometric Unsharpness

Geometry unsharpness occurs because x-rays are generated on a finite area (focal spot), and once generated, these x-rays diverge from that source. The larger the focal spot size, the more unsharpness on the film (De Vos, 1995: 37). When the x-ray beam begins its divergence at a smaller area, the image will have less blur thus the radiographers employed a small focus to obtain sharper images and reduced geometric unsharpness. Small focus was thus used for imaging in this study.

2.4.2.6 Motion Blur

Patients arriving at the X-ray Department after an accident are usually disorientated, in pain, sometimes medicated or under the influence of alcohol; they do not want to be hospitalised and move constantly. The patient's movement affects recorded detail because it fails to permit enough time for a well-defined image to form. Instead, the image is spread over a linear distance and appears as a blurred series of densities in which fine detail cannot be perceived (Carlton & Adler, 2006: 451).

The two methods employed to reduce motion blur during the study were exposure time reduction and immobilisation. Reducing exposure time with a corresponding increase in milliamperage (mA) maintained sufficient mAs and film density (Carlton & Adler, 2006: 451). Reducing exposure time was also achieved by using 400 speed screens (section 2.5.2.1) in the two cases where film/screen systems were used. Increasing the kilovoltage (kVp) was another method used to decrease exposure time.

When exposure time reduction were not sufficient to reduce motion, communicating specific instructions to the patient and partial immobilisation was used. Immobilisation devices, such as foam pads, angle sponges, and sandbags, were used as positioning aids to address the issue of patients moving during the procedure.

2.4.3 The Positioning Principles for Demonstrating C₇-T₁

2.4.3.1 Projection routines

The diagnostic value of radiographs depends on specific positioning of the patient before exposure. This is facilitated by the use of standard projections as discussed in Appendix 4. An accurate idea of the anatomic arrangement of the internal structures with relation to an external landmark, such as the jugular notch, helps in positioning of the patient for C₇-T₁. A convenient method is to visualise the part as though it were transparent, so that structures which appear on the radiograph may be identified in relation to an external landmark (Carroll, 1990: 234).

Imperfect centering of the part on the film during positioning and incorrect alignment of the tube to C₇-T₁ causes image distortion. Slight differences in positioning do not necessarily rule out the diagnostic value of the radiograph. Patient condition requires that a certain degree of latitude in positioning is permissible; this was also the case during the study (Carroll, 1990: 234).

2.4.3.2 Beam-Part-Film Alignment

During this study a horizontal beam, perpendicular to the cervical spine and image receptor, was used. The traditional rule of keeping the anatomical part perpendicular to the central ray and parallel to the film effectively minimises shape distortion in the image (Carroll, 1990: 222).

2.4.3.3 Off-Centering versus Angling

A centering point of 2,5cm superior to the level of the jugular notch will produce an image with minimal distortion of C₇-T₁, but negligible distortion at the levels above and below the junction since the beam diverges (Carroll, 1990: 222). Off-centering places C₇-T₁ in the diverging peripheral rays of the beam. These peripheral rays angle away from the center of the x-ray beam. The further they are from the center, the higher the degree of angle. Therefore, off-centering has identical effects to angling the beam or not positioning the part parallel to the image recorder, namely displacement of anatomy, elongation or foreshortening of anatomy (Carroll, 1990: 222).

The previous section serves to underpin the methodology of the study that is unpacked in Chapter 3.

2.5 ALTERNATIVE PROJECTIONS USED TO DEMONSTRATE C₇-T₁

The swimmer's projection may be employed to better demonstrate the C₇-T₁ vertebrae, which, on the standard lateral projection, are obscured by the overlapping clavicle and soft tissue of the shoulder girdle. One technique should ideally sufficiently demonstrate the cervicothoracic junction. A single imaging technique is, however, often inadequate and should be complimented by additional projections, CT and MR (Murphy, 2000: Online).

Berquist (1992: 44) states that the Mayo Clinic routinely requests the swimmer's projection on all patients if C₇ and T₁ are not visible on the lateral projection. This projection is taken with the patient in the supine position and the arm closest to the film elevated above the head. Occasionally even this technique does not adequately demonstrate C₇ and T₁ in all patients (Berquist, 1992:44).

Sclafani (1991: 3.2) used two cross-table oblique projections and in some cases, lateral flexion/extension films and myelography to allow demonstration of the pedicles and facets. The author recommends that conventional tomography, and computed tomography (CT) should be done in cases where the swimmer's projection is unsuccessful (Sclafani, 1991: 3.2).

The aforementioned recommendation is echoed by Streitwieser (1983: online) in a study of 71 patients where CT was compared to the cross-table technique of demonstrating cervical spine. In eight cases, CT detected abnormalities where the cross-table technique had failed to show any (Streitwieser, 1983: Online). The claim that CT is superior in the detection of pathology of bony structures of the cervical spine should be contextualised. Blackmore concluded that CT has higher sensitivity in high-probability subjects when compared with plain film radiography. CT has a higher sensitivity but cost more than radiography in subjects with moderate probability for fracture; the probability of a fracture is weighted against the cost of the examination. In patients with a low probability of cervical spine

fracture, CT is not cost-effective, and plain film radiography is the preferred strategy (Blackmore, 2003: 288).

2.5.1 Inconsistencies in the Technique Used to perform the Swimmer's Projection Found in Literature.

Inconsistencies in the technique used to perform the swimmer's projection primarily relates to the authors not mentioning which arm should be extended above the head. One example of this is found in *Radiology of Trauma*, where Sclafani (1991:3.2) mentions various variations of the lateral projection to demonstrate C₇-T₁ including the swimmer's lateral projection with one arm extended above the head.

Harris, Harris (junior) and Novelline (1993: 55) define the swimmer's projection as placing the arms in the position as though one were swimming the "Australian crawl" (free-style swimming stroke). The authors continue by indicating that the advantage of this method is that it demonstrates alignment and integrity of the cervicothoracic vertebral bodies. The researchers experienced difficulty in patient positioning, and found that there was superimposition of other skeletal parts such as the shoulders and clavicles, as well as failure to visualise posterior vertebral parts. A major shortcoming of the method is that no reference is made to which arm should be elevated or which shoulder should be depressed.

Redman (1993:179) states that the swimmer's projection distributes the bulk of the shoulders more evenly by elevating one arm above the head. This displaces the ipsilateral pectoral girdle cranial as well as slightly anterior. The other shoulder is deviated as far caudally as is feasible. The central ray is angled a few degrees caudal so as to "shoot over" (and thus project more inferiorly) the caudally deviated shoulder. Again, no reference is made to which arm should be elevated or which should be depressed.

2.5.2 Literature Evidence of Differentiation from the Swimmer's Projection

When performing the swimmer's projection, it is recommended by Bontrager (2006: 311), Ballinger and Frank (1999:416) and McQuillen-Martensen (1993:339) that the central ray be angled to ensure that the beam is parallel

to the intervertebral spaces. Bettinger and Eisenberg (1995:1303) propose a modification to the swimmer's projection, by directing the central beam perpendicular to the line formed by the spinous processes. The beam should pass through the T₁ vertebral body, approximately 2cm below the prominence of the C₇ spinous process. The resulting radiograph optimally visualises the cervicothoracic junction and the vertebral bodies of the upper thoracic vertebrae (Bettinger and Eisenberg, 1995:1303-4).

The resultant evidence from Eisenberg's study (1995:1303), that the central beam should almost never be angled caudally, suggest a deviation from the main beam direction found in the literature of Bontrager (2006: 311), Ballinger and Frank (1999:416) and McQuillen-Martensen (1993:338).

When performing the modified cervicothoracic lateral projection (fig 2.4), as stated by Cullinan (1992: 134), a horizontal beam technique can be used. The patient's arm adjacent to the image detector should be moved anterior to the thorax and the arm closest to the x-ray tube moved posterior to the thorax. In doing this, the thickness of the shoulder girdle anatomy is significantly reduced. This modification of the cervicothoracic lateral position helps to balance density between the lower cervical and upper thoracic regions. The central ray is directed perpendicular to T₂-T₃ so as to enter the body anterior to the left shoulder (closest to the x-ray tube) and exit through the right shoulder. According to the method described in Appendix 3, the central ray is directed perpendicular to C₇-T₁, opening the intervertebral space of C₇-T₁. Centering to the level of T₂-T₃, as described above will not open the intervertebral space of C₇-T₁, since the beam diverges from a point source, but will still be useful if one were to examine vertebral alignment (Cullinan, 1992: 134).



Figure 2.4 Modification of cervicothoracic lateral position (Adapted from Cullinan, 1992: 134)

Bell and Finlay (1986:152) describe the right lateral swimmer's projection of the cervicothoracic junction where the patient lies in the true lateral position in the centre of the x-ray couch (figure 2.5). The patient's lower arm rests alongside the body (the arm closest to the image receptor) and raise the upper arm (the arm farthest to the image receptor) above the head. The patient is supported using a foam pad under the head. Direction of the central ray is vertical at 90° to the film. Although useful, this projection presents certain limitations in a trauma situation where the patient has to remain in a constant position, usually the supine position, while being examined. As can be seen from figure 2.5, the patient is turned on their side from the supine position, which is not the ideal since it can propagate further injury or pathology.



Figure 2.5 Right lateral (swimmer's) projection of cervicothoracic spine (Adapted from Bell & Finlay, 1986:152).

In comparison to section 2.5.1, the Bell and Finlay (1986:152) as well as Cullinan's (Cullinan, 1992: 134) studies specify the positioning of the arms. This was the first evidence found from the resources consulted during this literature study mentioning a difference in the orientation of the arms when demonstrating the cervicothoracic junction.

Figure 2.6 A shows that the swimmer's projection can also be taken with the patient placed prone on the table with the left hand abducted 180° and the right hand to the side, as if swimming. The image receptor is placed against the right side of the neck (Ahmad, 2003: Online).

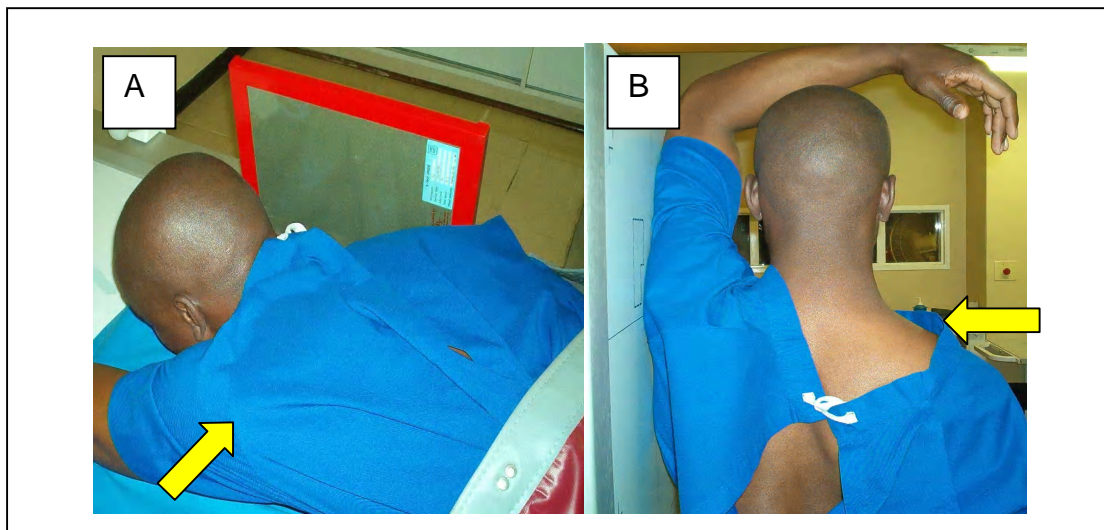


Figure 2.6 A - Patient in prone swimmer's position, B - Patient in swimmer's position (Adapted from Ahmad, 2003: Online).

The difference between the method indicated above and the study method used is that the patient is in the prone position and not the supine. The method illustrated in figure 2.6 A is the second textbook evidence found that prompted this study, where the patient is on the x-ray table with the arm farthest to the cassette extended, resting next to the ear.

The third evidence set of demonstrating C₇-T₁ discussed by Hagler (1993:255), is similar to the method to be compared to the swimmer's during this study with respect to arm orientation, see figure 2.7. Again no comparative results with the swimmer's method are presented. The shoulders must be moved in different directions while maintaining the lateral position of the thorax. This implies that if the swimmer's method does not result in good separation of the shoulders, or the patient has multiple injuries that preclude elevating the side closest to the film, then the arm positions can be reversed from the swimmer's method (Hagler, 1993: 255).



Figure 2.7 Alternate, upright cervicothoracic spine lateral (Adapted from Hagler, 1993:255).

It is clear that the primary reason for positioning the arms and indeed the shoulders in opposite directions is to minimize the size of the anatomy to be radiated. In doing so the overlapping anatomy in the shoulder girdle is minimized, allowing for better visualisation of C₇-T₁. This is not only applicable to plain film radiography, but also for CT, as illustrated by Wirth (2006:1757) and Kane (2004: Online).

Wirth compared three different arm-positioning strategies used for minimising shoulder girdle artifacts in cervical CT. For the first strategy 53 patients remained in a comfortable supine position on the bed; the next 46 patients relaxed their shoulders causing them to move more distally. The last group of patients (n= 47) were positioned with the aid of a pulling device. The length of the cervical area demonstrated increased from 8.5cm in group one to 10.4cm and 10.6cm in groups two and three respectively. Wirth recommends the investigation of swimmer's positioning during CT.

Kane (2004: Online) investigated the effectiveness of the swimmer's CT in ten patients where the conventional, arm-down cervical scans had shoulder artifacts rendering them nondiagnostic. In nine patients the use of the swimmers CT improved the overall diagnostic quality of scans related to soft tissue and C₇-T₁ instability.

2.6 COMPARATIVE STUDIES

Literature evidence suggests the use of 30° supine obliques as an alternative to the swimmer's projection. Turetsky, Vines, Clayman and Northup (1993: 689) discovered that in eight of eighty-three patients that underwent initial cervical examinations, diagnosis was confirmed in five cases by the supine obliques, whereas the swimmer's showed improved results in three patients (Turetsky et al, 1993: 689).

Jenkins (1999:215) uses a questionnaire survey to assess practices in the evaluation of the cervical spine in the conscious adult patient with suspected neck injury. One-hundred-and-ninety-one physicians participated in the study. If the C₇-T₁ junction could not be visualised on the initial views, 170 (89%) departments followed by using a swimmers projection. Of the 191 replies, twelve (6%) departments continue with supine oblique views. If the C₇-T₁ junction still could not be visualised, 106 physicians (55%) then proceeded to use CT scanning. One should keep in mind that this study was done in the UK where the availability of CT is much more widespread in comparison to South Africa - see section 1.2 (Jenkins, 1999:215).

Best evidence topic reports (BETs) summarise the evidence pertaining to particular clinical questions. One of the eight clinical questions investigated by Contractor (2002: 550) is the use of the swimmer's projection or supine oblique projection to visualise the cervicothoracic junction. The results presented in this paper showed no difference in visualising the vertebral bodies of the C₇-T₁ junction between swimmer's or supine obliques, but supine obliques did visualise the posterior elements more effectively. Contractor comments that more research is needed in this area (Contractor, 2002:550).

In an article entitled "Do supine oblique views provide better imaging of the cervicothoracic junction than swimmer's views?", Ireland's study (1998: 151) used two 20-week periods to compare supine oblique projections to swimmer's projections. Radiographers and doctors underwent a 12-week training period to ensure familiarity with the methodology to be employed. In the first phase the swimmer's projection was performed as an additional view,

when the cervicothoracic junction was not demonstrated. In the second phase paired supine oblique projections were done instead of the swimmer's projection (Ireland, 1998: 151). These were taken at 30° from the horizontal plane. In the first phase 230 patients were included, of whom 60 required swimmer's projections. In the second phase, 62 of 197 patients required supine oblique projections. Radiological analysis of 53 pairs of supine oblique projections shows that the vertebral bodies were adequately demonstrated at the cervicothoracic junction in 20 patients (38%), compared with 22 in the swimmer's group (37%), see table 2.1. The facet joints and posterior elements are, however, clearly seen in 37 (70%) of the supine oblique patients compared with 22 (37%) of the swimmer's group (p-value < 0.001). In injured patients, for whom the standard 3-projection series fails to demonstrate the cervicothoracic junction, swimmer's projections and supine oblique projections show the alignment of the vertebral bodies with equal frequency. However, supine oblique films are safer, expose patients to less radiation, and are more often successful in demonstrating the posterior elements, as is evident from the low p-value (Ireland, 1998: 151).

Table 2.1 Summary of comparative results obtained from 60 swimmer's projections and 62 supine oblique (Ireland, 1998: 151).

	Vertebral bodies and posterior elements	Posterior elements
Swimmer's	37% (22/60)	37% (22/60)
Supine oblique	38% (20/53)	70% (37/53)

Daffner concurs that the standard 3-projection cervical spine series should be amplified with a swimmer's or oblique projections. In a study of 196 patients with cervical trauma, it was found that the initial series failed to adequately visualise the cervicothoracic junction in 50 patients (26%). In comparison with when additional bilateral oblique views of the cervical spine were done on 129 patients, an improved failure rate of 13% failed to satisfactorily visualise the cervicothoracic junction (Daffner, 2002: 325).

One can conclude by recognising that most of the research done on alternatives to the swimmer's projection in demonstrating the cervicothoracic junction, were done using the supine oblique projection.

2.7 PROJECTION CRITERIA

As an example of the criteria used in similar studies, the following table is the radiologist's criteria used during Ireland's study for film acceptability:

Table 2.2 Radiologist's criteria used for film acceptability in comparing the supine oblique projections to the swimmer's projection (Ireland, 1998: 151).

Projection	Criteria
Supine obliques	<ol style="list-style-type: none"> 1. Anterior arch of C₁ 2. C₂ odontoid peg 3. C₁-T₁ intervertebral foramina and their bony margins (uncinate processes, superior and inferior pedicles, facet joints) 4. C₁-T₁ articular masses and laminae 5. C₁-T₁ spinous processes 6. C₁-T₁ joint space demonstrated at its lowest extent
Swimmer's projection	<ol style="list-style-type: none"> 1. C₇-T₁ vertebral bodies 2. C₇-T₁ intervertebral foramina 3. C₇-T₁ joint space demonstrated at its lowest extent 4. C₇-T₁ spinous processes

From table 2.2, one can see that these researchers concentrated primarily on the visibility of anatomy, whereas the current study also includes lateral vertebrae not appreciably rotated, shoulders separated from each other, x-ray penetration of shoulder region, contrast and density, demonstration of the bony structures of the cervicothoracic vertebrae, demonstration of pathology (where applicable), sharpness and spatial resolution. The criteria used in Ireland's study is more specific, more related to orthopaedics, whereas the criteria of this study revolves around the more general radiological considerations. The aforementioned general radiological considerations were compiled from the evaluation criteria of the lateral cervical and the swimmer's

projections presented in textbooks by Bontrager (2006: 311), Ballinger and Frank (1999:415) and McQuillen-Martensen (1993:326). The evaluation criteria compiled from the mentioned textbooks are aimed at ensuring optimal radiographic technique for the demonstration of anatomy. The purpose of medical imaging is to demonstrate human anatomy and where abnormalities are present; it is also to demonstrate pathology. These criteria were tested during a pilot study (Appendix 11) using 20 volunteers was examined at the Universitas X-ray Department, Bloemfontein. None of the volunteers had cervical spine pathology or indications thereof. When compared with the pilot study, hospital and trauma patients were examined. The sample size was bigger and patients were examined by qualified radiographers, and not by the researcher, as were the case in the pilot study. An important difference to note is the use of three radiologists instead of one, as was the case in the pilot study.

For three of the six criteria used, the adapted swimmer's had improved outcomes. When evaluating penetration of the shoulder region, there was a 5% difference between the adapted swimmer's and swimmer's projections, with regards to contrast and density the difference was 6.25%. Finally, the difference for the demonstration of the bony structures of C₇- T₁ was 1.25% (Botha, 2006: 09). The swimmer's projection had a 16.25 higher percentage for lateral vertebrae not appreciably rotated as well as for shoulder separation with 7.5% higher.

The results indicates that the swimmer's had improved outcomes in 33.3% of the categories. Sharpness, on average, was equal for both projections (Botha, 2006: 09). The pilot study also presented an opportunity to evaluate the applicability of the criteria, where some changes needed to be made.

In an article focusing on the imaging of adult cervical spine trauma Berquist (1988: 669), compiled factors to be evaluated on the lateral projection of the lower cervical spine (C₃-C₇) based on studies done by himself (Berquist, 1986: np), Gehweiler, *et al.* (1980) and Templeton, *et al.* (1987:98).

The Berquist factors are as follow:

- A. Is the prevertebral fat stripe present and uniform along the anterior margin of the vertebrae from C₂ to the C₆ level?

- B. Does the retrotracheal space (the distance from the posterior wall of the trachea to the anterior inferior aspect of C₆) equal 22mm in adults or 14mm in children?
- C. Is the anterior spinal line smooth (free from abrupt discontinuity)?
- D. Is the posterior spinal line smooth (free from abrupt discontinuity)?
- E. Is the spinolaminar line smooth?
- F. Are the disk spaces normal in shape and approximately equal in height?
- G. Are the facet joints smooth and regular?
- H. Does the interspinous distance decrease in height regularly from superior to inferior? (Berquist, 1988: 669)

Through analysis, it is clear the eight criteria of the study at Pelonomi hospital - although general - can be aligned with each of Berquist's factors, where each of the eight criteria influences the answers of Berquist's questions.

2.8 SUMMARY

When reviewing the literature, it is evident that using the swimmer's projection to evaluate C₇-T₁ does not always deliver the desired diagnostic results. Minimising the size of the anatomy through various interventions is evidently the golden thread running through all these studies. In three cases, the arm closest to the image receptor is not specified (Harris, *et al.* 1993: 55; Redman, 1993:179 and Sclafani, 1991: 3.2). In one study the angulation of the main beam was, in most cases disqualified (Bettinger & Eisenberg, 1995:1303-4). In another study, the patient was prone and not supine (Ahmad, 2003: Online).

As described by Hagler (1993:255), reversing the orientation of the arms under different conditions may give improved results in some cases. Five studies (Ireland, 1998: 151; Contractor, 2002:550; Daffner, 2002: 325; Jenkins 1999:215 and Turetsky 1992: Online) that preach the superiority of supine oblique projections over the swimmer's projection in demonstrating the posterior bony elements were found. From the pilot study, there is an indication that reversing the orientation of the arms may improve the

visualisation of C₇-T₁ in certain cases, but since this was not a clinical setting, no true conclusion could be made.

Guidelines to sample size and the importance of pre-study training of radiographers were revealed. The criteria used during this study can be judged as being more inclusive, since they do not subscribe to a specific field of medicine. The literature study justifies the methodology used during this research project, which is outlined in the next chapter.

Chapter 3

METHODOLOGY

3.1 INTRODUCTION

The essence of the study is that two projections of the cervicothoracic junction were done and analysed, with the only difference between them being the orientation of the arms. The specific methodology presents a recipe that allows other researchers to not only duplicate the project but also modify it to attain their specific objectives. The study was done at a specific institution, which has its own identity and specific medical environment with reference to regulatory compliances and study preparation. On the other hand, it also has universal credits, especially sampling procedures, examination protocol, image evaluation criteria and statistical analysis. The manner in which all these factors culminate into an empirically confirmed diagnostic test is the central theme of discussion in this chapter. The specified methodology is designed to ensure the best practice in execution and results of the study by evaluating the possible value added when an alternative to the swimmer's projection was used. It should be noted that the term "film" refers to both hard (film) and soft copy (digital) images.

3.2 METHODOLOGY

It is important that the study design should articulate with the aims and objectives of the study (section 1.6). The aims and objectives lend themselves to a quantitative study design (section 1.9.1), as described by Mouton and Marais (1991:159). To be more specific, and again in reference to the objectives, we can also classify the study as experimental interventional - it evaluates an intervention (Katzenellenbogen et al, 1999: 69).

The methodology can be arranged into several parts such as the permission to execute the study, preparation for the study, sampling of patients, consent,

examination procedure, comparison of diagnostic quality and statistical analysis.

3.2.1 Permission to Execute the Study

Permission to execute the study was obtained from a number of stakeholders. This includes the head of clinical services at Pelonomi Hospital (Appendix 2), the head of the Radiology Department at UFS. The proposal was submitted to the Radiation Control Committee of the Faculty of Health Sciences, University of the Free State (no application form), and to a biostatistician for approval and notification of the study. Written feedback on the proposal was required from these bodies before submission thereof to the Ethics committee of the UFS in order for them to verify if the proposal complies with current ethical procedures.

After minor changes, the Ethics committee approved the study. The ETOVS reference number allocated to the project is 41/06. A copy of the letter of approval is included as Appendix 5.

3.2.2 Preparation for the Study

Two scheduled information sessions, where radiographers were introduced to the rationale and relevance of the study, were held with the qualified radiography staff at Pelonomi Hospital. During the meeting an open invitation was extended to radiographers to participate in the study, whereafter the methodology to be used was discussed and questions fielded. A summarised version of the study methodology was distributed to participants. Participating radiographers were asked to sign a declaration (Appendix 6), whereby they committed themselves to act according to the ethical principles outlined in the project. Likewise, they committed to provide accurate information and thus align themselves to the objectives of the study.

Before the start of the project, certain points of interest and questions related to sample inclusion and consent were addressed at additional unscheduled informal discussions. To identify possible pitfalls, the researcher also exposed himself and radiography staff to an overview and functionality of the newly acquired Computed Radiography system.

The topics discussed at the two information session included:

3.2.2.1 A General Introduction to the Research Project

The researcher gave his personal background and experiences in demonstrating C₇-T₁. He explained what prompted him to conceive this research project by referring to the pilot study and its shortcomings.

3.2.2.2 Examination Protocols to be followed

The methodology related to consent, the examination procedure, the use of the different appendixes and data collection by the researcher were all explained during these sessions.

3.2.2.3 Remuneration for Participation in Project

Remuneration served as a catalyst to encourage qualified radiographers to participate in the study. By doing so, they committed themselves to the overall improvement in the quality of projections demonstrating C₇-T₁. Thirty rand per case was promised to, and received by participating radiographers on completion of the examination procedure (section 3.2.6).

3.2.3 Sampling of Patients

Pelonomi Hospital currently uses the Medi-Tech® system for patient record keeping. Although this system records patient data, the statistics available are unreliable since only examinations that have been reported on by a radiologist were calculated. It often happens that patients with possible pathology to C₇-T₁ from the emergency department only receive a verbal report.

Thus, an interview session was held with 11 qualified radiographers in an attempt to approximate the eventual size of the sample. It was apparent from the questionnaire that reporting of examinations does not happen often. However, it could be established that the approximate size of the sample could equal ± 20 patients per month during the normal work hours of a Monday to Friday week.

3.2.4 Inclusion and Exclusion of Patients in Sample

Inclusions

During the study period patients with lower cervical/upper thoracic vertebrae pathology, including trauma and post manipulation/instrumentation were included in the study. Also included were variants like patients with cervical

ribs, cervical vertebrae necrosis and acquired conditions like arthritis (Köhler & Zimmer, 1993: 502). Patients from any race or gender were included in this study. Patients had to be conscious; able to give consent. Patients had to understand the procedure as well as what was expected of them. Patients understood that there was no remuneration involved for participating in the current study.

Exclusions

Patients reliant on life support systems, and who were unconscious, were excluded from the study. Also excluded were pregnant female patients due to the possibility of irradiating the foetus, which could lead to abortion, deformation and a possible decrease in intellectual capability (Bushberg, 2002: 851). Patients with limited mental capability and patients younger than 16 years were excluded from the study. Some patients with associated extremity injuries were excluded after being evaluated by the radiographer, since these injuries will have a direct impact on the examination procedure and the acquisition of the two projections (Appendix4) compared in this study.

3.2.5 Consent

Informed consent was obtained from the patient by the radiographer examining the patient. Appendix 7 (catering for English, Se-Sotho and Afrikaans speaking patients) was completed and signed by patients after the procedure was explained to them by the examining radiographer using Appendix 8, the subject information sheet. The three different versions of Appendix 8 (A, B and C), reflects the cultural diversity of our region, namely: Se-Sotho, Afrikaans and English speaking groupings.

Follow-up discussions with radiographers and a letter (Appendix 12) with the guidelines on obtaining consent as stipulated by the Medical Research Council of South Africa (MRC, 2004: Online) were used to make participating radiographers aware of the correct way to obtain consent.

For informed consent to be valid it should be offered voluntarily and be based on adequate understanding of the procedure, with due regard to the patient's language and culture (MRC, 2004: Online).

3.2.6 Examination Procedure

Each member of the sample was examined using the cross table variation of the swimmer's method (Appendix 4). 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.

At the completion of the two projections, the radiographers completed Appendix 10 to indicate which film was performed with which technique. Appendix 10 also served as a record for remunerating radiographers. A collection box was used, where radiographers could deposit the films (hard copies) and appendixes. The researcher's constant visits and visibility in the department aided and encouraged the collection process. The researcher downloaded digital images and printed them from the central archive of the radiology department.

On a rotational basis all images and copies of the evaluation rubric (Appendix 9) were distributed to the three participating radiologists for evaluation of images.

3.2.7 Comparison of Diagnostic Quality

Apart from academic excellence, criteria such as years of experience, 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. Through verbal agreement the radiologists had committed themselves to be available and participate in the study. The use of three radiologists excluded possible bias.

The images were marked A & B, ensuring that the radiologists did not know the origin of the images (which was done using technique A/B) that they had to evaluate. In doing so, the validity of the results was ensured through image anonymity. Only the radiographer that performed the examination and the researcher had access to data from Appendix 10 which served as a record to identify which film (A or B) was done using the swimmer's or adapted swimmer's (where the orientation of the arms differed) technique.

A rubric (Appendix 9) with a specific set of criteria was used to ensure standardisation of the evaluation. As stated in section 2.7, the criteria was compiled to ensure optimal radiographic technique for the demonstration of anatomy. The radiologists received only the images and Appendix 9.

A scoring system, ranging from 4 to 1 was used (see table 3.1, with the translation of the scoring system presented in table 3.2).

Table 3.1 The scoring system

Qualifier	Interpretation
4	Excellent
3	Acceptable
2	Needs attention
1	Poor

Where:

Table 3.2 Translation of the scoring system

Excellent	Where maximum radiological detection has been achieved.
Acceptable	Where a good diagnosis is achievable.
Needs attention	Where possible diagnosis is achieved.
Poor	No diagnosis possible

The radiologists compared overall acceptability of films A & B by using the set criteria as indicated in Tables 3.1 & 3.2, as well as answering a deliberate question, namely:

“Which of the 2 views has the least radiological diagnostic quality: which has to be repeated, A or B?” (Appendix 9). Their expertise was invaluable in distinguishing which of the images (obtained using different techniques) delivered the desired diagnostic quality best.

3.2.8 Statistical Analysis

No analysis were done using the information in Appendix 10, since it was for recordkeeping purposes and not related to the objectives of this study. After the radiologists evaluated the images, data from Appendix 9 was collected, categorised and presented in a predetermined MS Excel spreadsheet format

to facilitate statistical analysis (Appendix 13). The department of Biostatistics, at the University of the Free State, analysed the data. Results were summarised by frequencies and percentages (categorical variables) and means, standard deviations and percentiles (numerical variables). The two techniques, as well as other subgroups, were compared using 95% confidence intervals for differences in percentage, mean and median.

3.3 SUMMARY

The methodology was presented in such a way as to facilitate duplication of the technique and so allow verification and improvement. Due to the patient's physical and mental condition (section 1.3), as well as the anatomical location of the cervicothoracic junction, it is challenging to ensure diagnostic images of C₇-T₁. The methodology was a combination of a variety of factors that had to fit like a puzzle to enable the visualisation of anatomical structures.

Central to the methodology is the fact that the only changing variable during the examination was the orientation of the patient's arms. Radiographers had to obtain two lateral projections of the cervical spine; the researcher collected the images and relevant appendixes, then distributed these to three radiologists on a rotational basis. The radiologists evaluated the films using a set of criteria; the results of these evaluations were analysed by a biostatistician and are presented in Chapter 4.

Chapter 4

RESULTS

4.1 INTRODUCTION

Keeping the aims and objectives in mind, the results should indicate (i) the effectiveness of the adapted swimmer's method in demonstrating the cervicothoracic junction and (ii) which of the two methods (if any) would be the better option.

The results based on each of the criteria will be presented as a function of the objectives to demonstrate articulation between criteria results and the objectives of the study.

To compare the different criteria, a frequency distribution of the 45-patient sample was performed by the department of Biostatistics, at the University of the Free State. The frequency distribution grouped the data into a 1+2 (unacceptable) and a 3+4 (acceptable) class interval instead of a 1 to 4 spread. Grouping the data will assist in descriptive analysis through percentages and averages (Daniel, 1999: 17). Table 3.2, Chapter 3, the translation of the scoring system indicated that a score of 3 means an acceptable film, where a good diagnosis is achievable while a 4 implies an excellent film, where maximum radiological detection has been achieved. Since the condensed results of class interval 3+4, for both the swimmer's and adapted swimmer's, can be regarded as an indication of diagnostic acceptability, the percentages of the two categories were used to compare the two methods. The results of the frequency distribution for the 3+4 class interval, the frequency distribution of the repeat rate and an association analysis of these values will be presented in section 4.2.

Analysis of the feedback from the radiologists also revealed that there were cases where the results for objective 3, the repeat rate, showed that both

methods yielded acceptable films. However, the instances where both images were acceptable varied amongst the three radiologists.

4.2 RESULTS PER OBJECTIVES (n= 45)

The frequency distribution per criteria of acceptable films (Appendix 14) for the class interval 3+4 will be presented. A column chart of the differences between the swimmer's and adapted swimmer's will provide visual clarity. The significance of the difference between the two methods for each criterion as evaluated by each radiologist will be indicated. The minimum (category 1) and maximum (category 4) values of the 1-4 spread (Appendix 15) will not be presented in this chapter, but will be discussed in Chapter 5.

4.2.1 Objective 1: Quality of Projections

4.2.1.1 Lateral Vertebrae C₇-T₁, not appreciably Rotated

Rotation of C₇-T₁ is when the coronal plane of C₇-T₁ is not perpendicular to the image receptor, with direct negative consequences on demonstration of bony structures, sharpness and contrast and density that fuses together in the evaluation of spatial resolution.

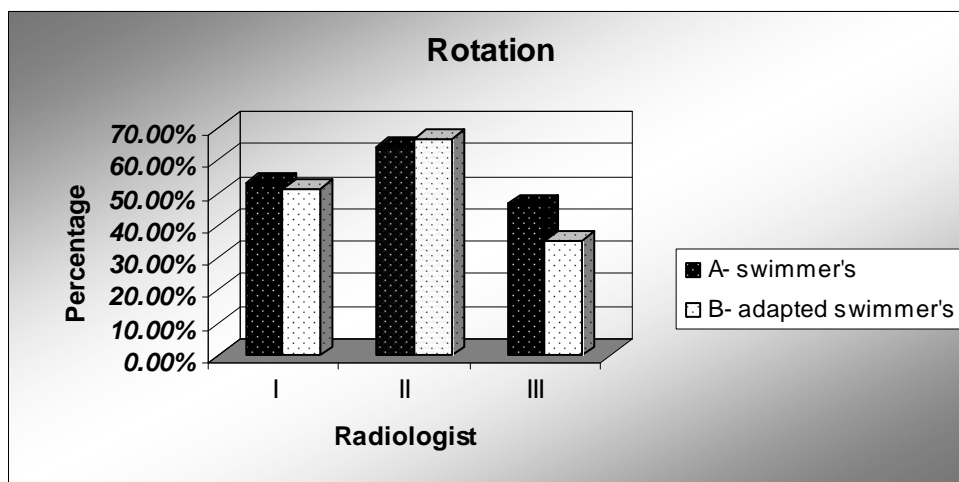


Figure 4.1 The percentage of acceptable films for rotation per radiologist for films A & B.

The frequency distribution for rotation is presented in figure 4.1, where acceptable films for the swimmer's projection (film A) equaled 53.3% and the frequency distribution for the adapted swimmer's (film B) equaled 51.1% for radiologist I. For radiologist II, the frequency distribution for the swimmer's

equaled 64.4% and the frequency distribution for the adapted swimmer's equaled 66.7%. The frequency distribution, according to radiologist III for the swimmer's equaled 46.7% and for the adapted swimmer's equaled 35.6%. For radiologist I the difference between films A and B for rotation have a p-value of 0.8415. Radiologist II's evaluation of rotation resulted in a p-value of 0.7963 and the p-value for radiologist III's evaluation equaled 0.5921. The high p-values indicate that the differences can be viewed as not significant.

4.2.1.2 Shoulder Separation from each other

Shoulder separation reflects the distribution of the bulk of the shoulder girdle and the consequent minimisation of the specific anatomical area (Wirth, 2006:1757; Kane, 2004: online). In order to visualise C₇-T₁, the amount of overlapping anatomy of the shoulder girdle is reduced by using either the swimmer's or adapted swimmers. In doing this radiographers are making better use of the exposure given with a consequent reduction in radiation dose.

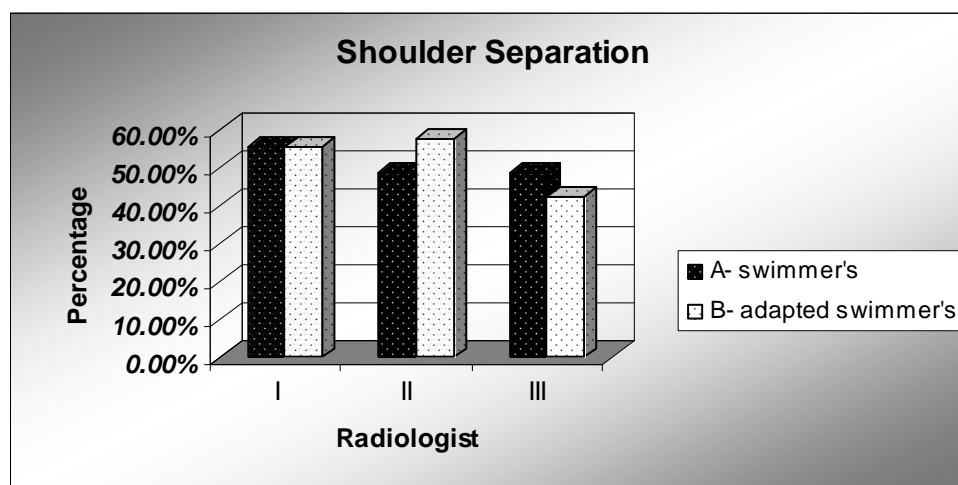


Figure 4.2 The percentage of acceptable films for shoulder separation per radiologist for films A & B.

For shoulder separation, the frequency distribution of acceptable films for the swimmer's projection (film A) equaled 55.6% and the frequency distribution for the adapted swimmer's (film B) equaled 55.6% for radiologist I. For radiologist II, the frequency distribution for the swimmer's equaled 48.9% and the frequency distribution for the adapted swimmer's equaled 57.8%. The frequency distribution, according to radiologist III, for the swimmer's equaled 48.9% and for the adapted swimmer's equaled 42.2% - see figure 4.2.

The p-value of the difference between films A and B for shoulder separation for radiologist I was 1.00, for radiologist II it was 0.4652 and the p-value for radiologist III's evaluation was equal to 0.3525. The p-values again indicate no significant evidence of superiority between the two methods.

4.2.1.3 X-ray Penetration of Shoulder Region C₇-T₁

X-ray penetration is the effectiveness of a given exposure to provide adequate transmission of x-rays in order to visualise anatomy. Figure 4.3 illustrates the difference in penetration between the two methods using the same exposure in both cases.

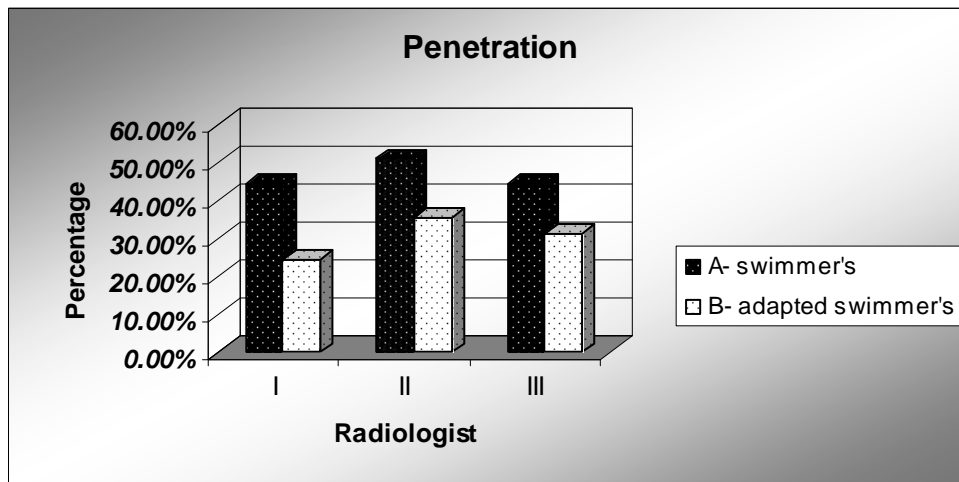


Figure 4.3 The percentage of acceptable films for penetration per radiologist for films A & B.

The frequency distribution of acceptable films related to penetration for the swimmer's projection (film A) equaled 44.4% and the for the adapted swimmer's (film B) equaled 24.4% for radiologist I. For radiologist II, the frequency distribution for the swimmer's equaled 51.1% and the frequency distribution for the adapted swimmer's equaled 35.6%. The frequency distribution according to radiologist III, for the swimmer's equaled 44.4% and for the adapted swimmer's equaled 31.1%.

The p-value of the difference between the penetration of films A and B for radiologist I was 0.0947, for radiologist II it was 0.1083 and the p-value for radiologist III's evaluation was equal to 0.4451. For this criteria radiologist I

showed close to significant evidence that the film A rendered better results. The p-values of the other two radiologists indicate no significance.

4.2.1.4 Contrast and Density C_7-T_1

Contrast and density takes exposures given and the size of the anatomy into consideration. It is also dependant on the influence of arm orientation and the grid used on scatter radiation.

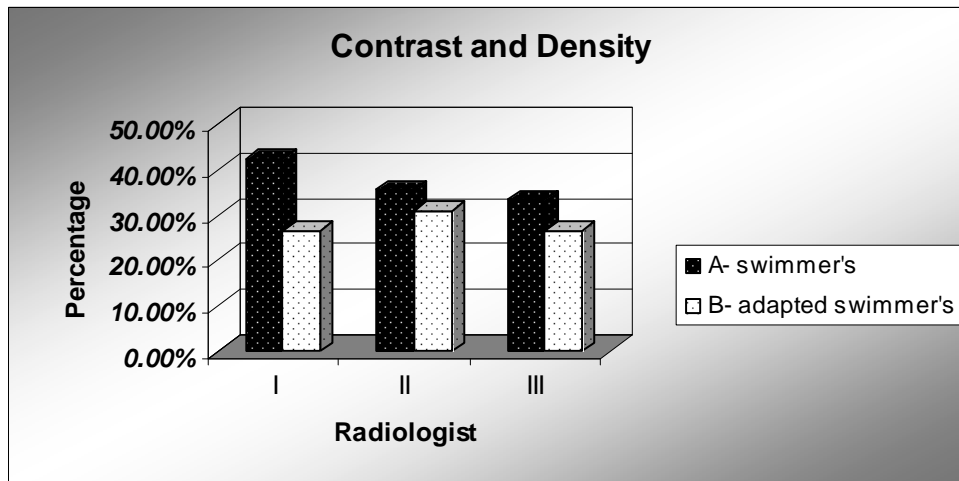


Figure 4.4 The percentage of acceptable films for contrast and density per radiologist for films A & B.

For contrast and density, the frequency distribution of acceptable films for the swimmer's projection (film A) equaled 42.2% and the frequency distribution for the adapted swimmer's (film B) equaled 26.7% for radiologist I. For radiologist II, the frequency distribution for the swimmer's equaled 35.6% and for the adapted swimmer's equaled 31.1%. The frequency distribution according to radiologist III, for the swimmer's equaled 33.3% and for the adapted swimmer's equaled 26.7%. The difference in contrast and density is given by figure 4.4.

For radiologist I, the p-value of the difference between films A and B for contrast and density was 0.1936, representing a close to significant difference. For radiologist II it was 0.6547 and the p-value for radiologist III's evaluation equals 0.4018, which points to no significant evidence of superiority.

4.2.1.5 Demonstration of the Bony Structures of the Cervicothoracic Vertebrae

An accurate idea regarding the anatomic arrangement of the internal structures with relation to an external landmark such as the jugular notch, aids materially in positioning of the patient for C₇-T₁. Wrong centering during positioning and incorrect alignment of the x-ray tube to C₇-T₁ causes image distortion.

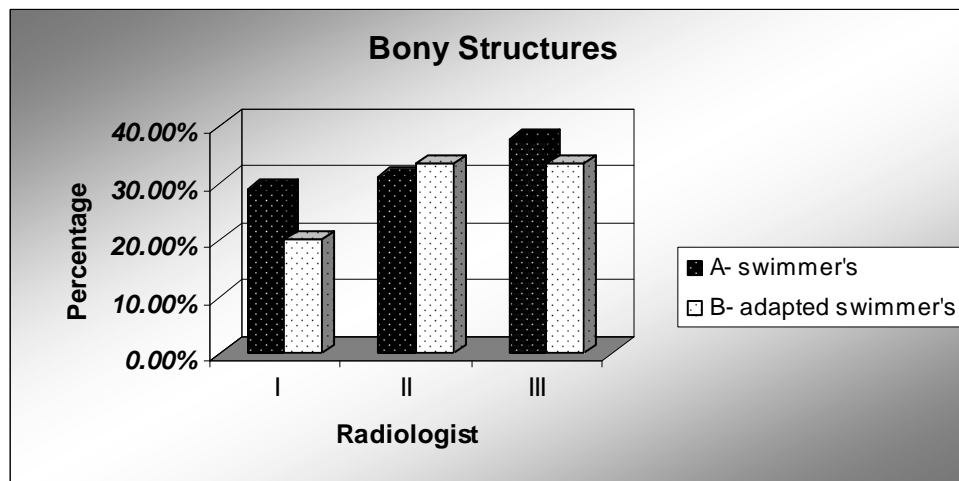


Figure 4.5 The percentage of acceptable films for bony structures per radiologist for films A & B.

Figure 4.5 represents the frequency distribution of acceptable films for demonstration of bony structures. For radiologist I the swimmer's projection (film A) equaled 28.9% and the frequency distribution for the adapted swimmer's (film B) equaled 20.0%. For radiologist II, the frequency distribution for the swimmer's equaled 31.1% and 33.3% for the adapted swimmer's. The frequency distribution according to radiologist III, for the swimmer's equaled 37.8% and for the adapted swimmer's equaled 33.3%.

For radiologist I, the p-value of the difference between films A and B for bony structures was 0.3938, for radiologist II it was 0.8273 and the p-value for radiologist III was equal to 0.1148. Radiologists I and II had p-values that indicated no significant difference between films A and B, while radiologist III's evaluation was close to significant.

4.2.1.6 Sharpness of the Cortical Outlines

Sharpness of the cortical outlines was influenced by the effect that the irradiated material (patient size: arm orientation) had on scatter radiation (Carlton & Adler, 2006: 228) as well as the influence of the longer OID and shorter SID on magnification and unsharpness (Carlton & Adler, 2006: 444; Ball & Price, 1995: 368).

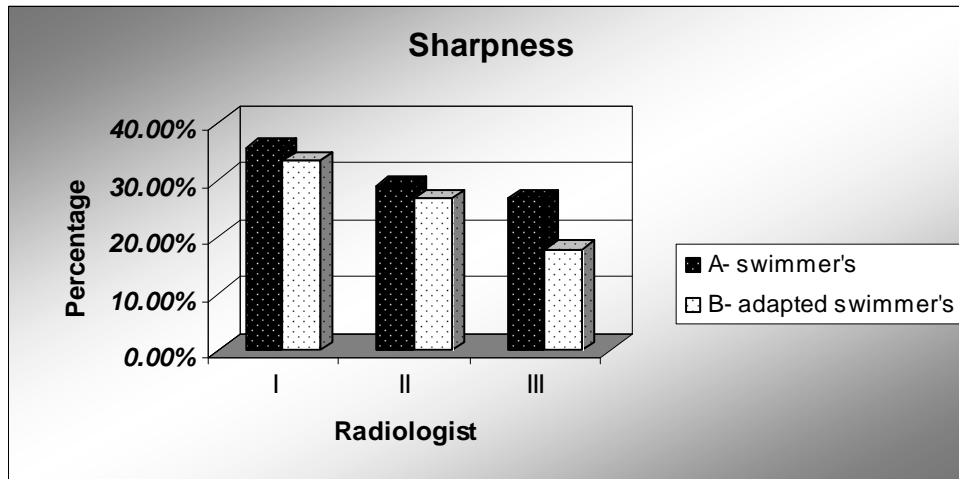


Figure 4.6 The percentage of acceptable films for sharpness per radiologist for films A & B.

The frequency distribution of acceptable films for sharpness (figure 4.6) of the swimmer's projection (film A) equaled 35.6% and the frequency distribution for the adapted swimmer's (film B) equaled 33.3% for radiologist I. For radiologist II, the frequency distribution for the swimmer's equaled 28.9% and 26.7% for the adapted swimmer's. The frequency distribution according to radiologist III, for the swimmer's equaled 26.7% and for the adapted swimmer's equaled 17.8%.

For radiologist I, the difference between films A and B for sharpness had a p-value of 0.8415. Radiologist II's evaluation of sharpness resulted in a p-value of 0.8185 and the p-value for radiologist III was equal to 0.2850. No significant difference between films A and B were found.

4.2.1.7 Spatial Resolution C₇-T₁

Spatial resolution is the ability to see small detail, meaning to distinguish between smaller objects in the image (Bushberg, 2002: 14); the term resolution is derived from the word resolve, which means *to distinguish*. For

the viewer, whether it is a radiologist or a novice, to be able to resolve and thereby define and interpret an x-ray image depends on all the criteria already discussed (see 4.2.1.1- 4.2.1.6).

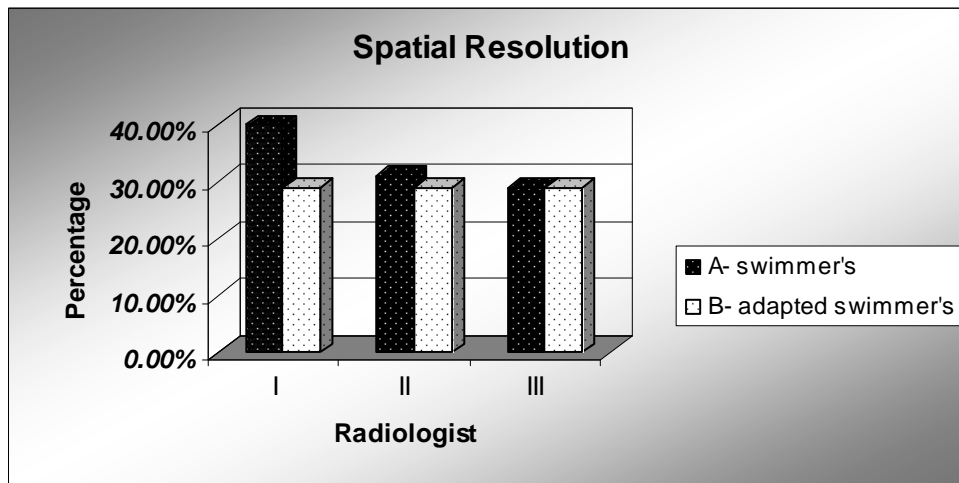


Figure 4.7 The percentage of acceptable films for spatial resolution per radiologist for films A & B.

For spatial resolution (figure 4.7) the frequency distribution of acceptable films for the swimmer's projection (film A) equaled 40.0% and the frequency distribution for the adapted swimmer's (film B) equaled 28.9% for radiologist I. For radiologist II, the frequency distribution for the swimmer's equaled 31.1% and 28.9% for the adapted swimmer's. The frequency distribution according to radiologist III, for both the swimmer's and the adapted swimmer's equaled 28.89%.

The p-values again showed no significance and are as follow. For radiologist I the p-value of the difference between films A and B for spatial resolution was 0.3173. Radiologist II's evaluation of spatial resolution resulted in a p-value of 0.8185 and the p-value for radiologist III equaled 1.00. All three radiologists' evaluation of the differences between films A and B showed no significant difference.

4.2.2 Objective 2: Diagnosis of Pathology

4.2.2.1 Demonstration of Pathology C₇-T₁ (where applicable)

Not all patients referred to the x-ray department for imaging after being clinically evaluated by a physician, have pathology. The function of medical imaging is to demonstrate possible pathology and/or confirm clinical

assessment. This is why the criterion specifies: where applicable. From the results there seems to be inconsistency amongst the radiologists with reference to the visibility of pathology. The first radiologist diagnosed pathology on 22 of the film sets, the second radiologist reported pathology on only 1 film set and the third radiologist on 2 film sets. This could be due to years experience or another reason can be that the first radiologist evaluated this criteria in view of ability to demonstrate possible pathology. Amongst the film sets evaluated, all three radiologists agreed that there was pathology on film set 41 and two of the three (radiologists I and III) also agreed that film set 11 had pathology. For film set 41, radiologist I assigned a 3 (acceptable) to film A and a 1 (poor) to film B. For radiologist II it was 4 (excellent) and 2 (needs attention) and for radiologist III it was 3 (acceptable) and 1 (poor). For film set 11, radiologist I assigned a 1 to film A and a 2 to film B. Radiologist III evaluated both films A and B equal to 1 for the demonstration of pathology on film set 11. Figure 4.8 illustrates the three radiologists' evaluation of pathology.

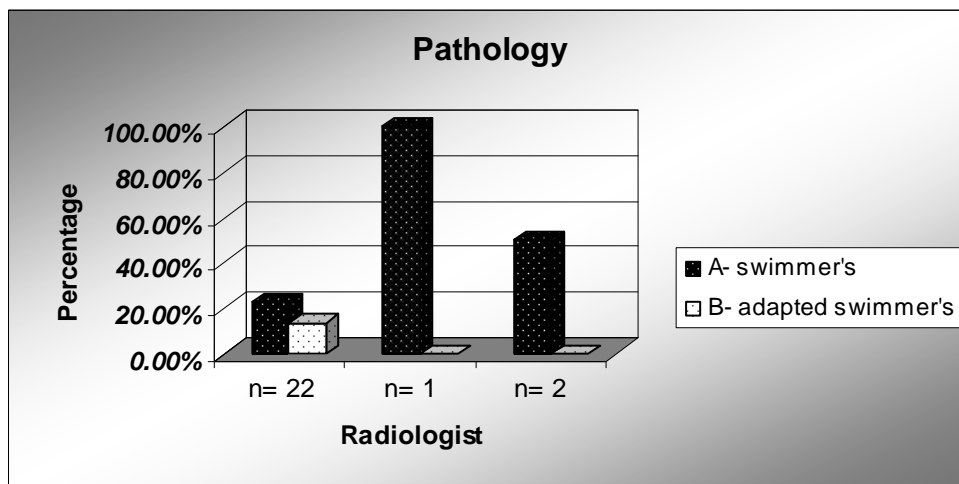


Figure 4.8 The percentage of acceptable films for pathology per radiologist for films A & B.

It should be noted that the frequency distribution for class interval 3+4 was used for the calculation and interpretation of results. For pathology (figure 4.8) the frequency distribution for the swimmer's projection (film A) equaled 22.7% (n=22) and the frequency distribution for the adapted swimmer's (film B) equaled 13.6% for radiologist I. For radiologist II, the frequency distribution for the swimmer's equaled 100% (n=1) and 0% for the adapted swimmer's. The frequency distribution according to radiologist III, for both the swimmer's was

50% (n=2, with the other 50% in class interval 1+2) and the adapted swimmer's equaled 0%.

4.2.3 Objective 3: Repeat Rate

Which of the 2 projections has the least radiological diagnostic quality: which has to be repeated?

Here the results did not provide a clear answer, since there were cases where neither film A nor B was acceptable. In other cases both methods were evaluated as acceptable without indicating which of the two had a higher diagnostic value.

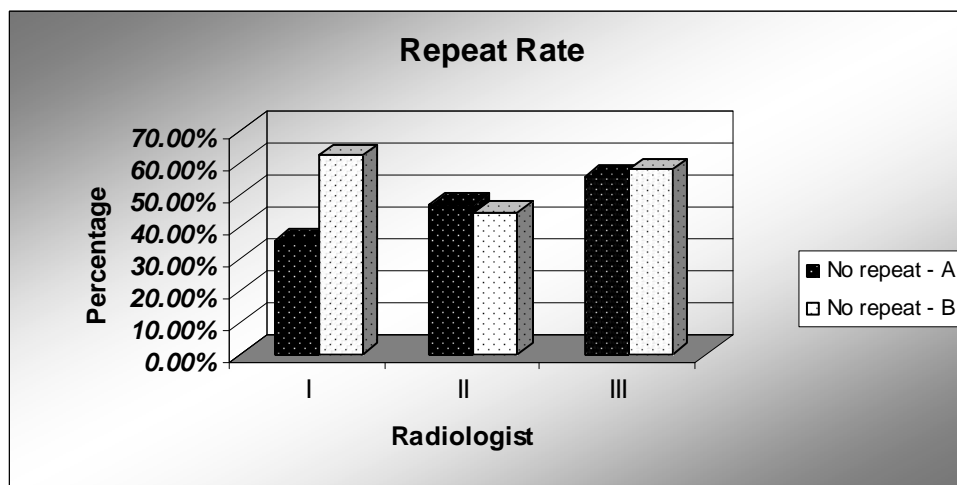


Figure 4.9 The percentage of the repeat films per radiologist for films A & B.

Figure 4.9 demonstrates the difference in frequency distribution for the repeat rate. 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 according to radiologist I. 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%. These percentages also represent the cases where both films were acceptable. Table 4.1 and figure 4.10 provide an alternative unpacking of the repeat rate for the three radiologists. The three radiologists' evaluation of films that needed to be repeated for both films A and B is presented as well as instances where both A and B could be passed* and instances where both films A and B needed to be repeated.

*A pass is equal to no repeat required.

Table 4.1 The overall ratio's of no repeat and repeat of all the films n=45

Category	Radiologist I	Radiologist II	Radiologist III
Film A pass	28	15	15
Film B pass	16	16	14
Both pass	1	9	5
Both repeat	0	5	11
Total (n)	45	45	45

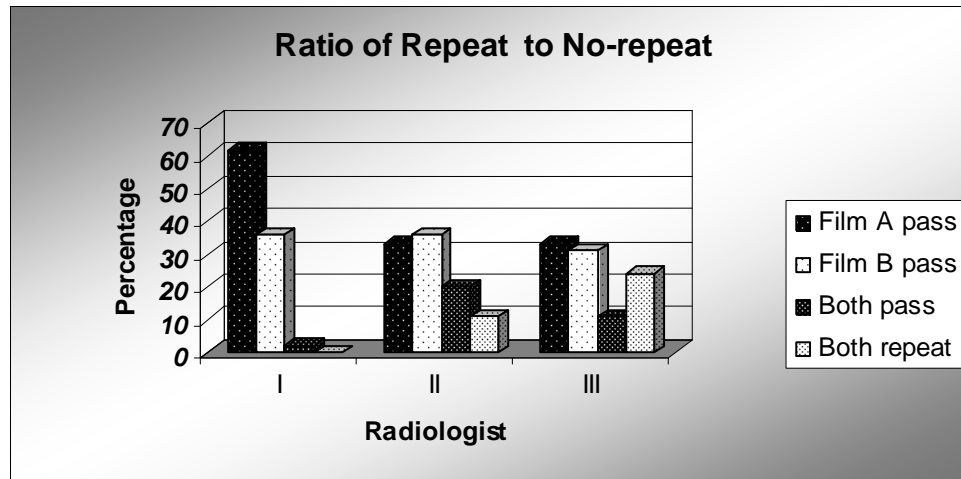


Figure 4.10 The percentage distribution of films passed and repeated for the three radiologists of all the films n= 45

Section 4.3 will examine the instances where all three radiologists evaluated both films A and B as acceptable. For radiologist I, the p-value of the difference between A and B for repeat rate was 0.0704, indicating close to significant evidence of film A being better. Radiologist II's evaluation of repeat rate resulted in a p-value of 0.8575 and the p-value for radiologist III was equal to 0.8527. The high p-values of radiologists II and III indicate no significant difference, meaning that both films A and B were reliable.

Table 4.2 Summary of the percentage distribution for class interval 3+4 for the different criteria evaluated by the three radiologists

Criteria	Radiologist I		Radiologist II		Radiologist III	
	Film A	Film B	Film A	Film B	Film A	Film B
Rotation	53.3%	51.1%	64.4%	66.7%	46.7%	35.6%
Separation	55.6%	55.6%	48.9%	57.8%	48.9%	42.2%
X-ray Penetration	44.4%	24.2%	51.1%	35.6%	44.4%	31.1%
Contrast and Density	42.2%	26.7%	35.6%	31.1%	33.3%	26.7%
Bony Structures	28.9%	20.0%	31.1%	33.3%	37.8%	33.3%
Sharpness	35.6%	33.3%	28.9%	26.7%	26.7%	17.8%
Spatial Resolution	40.0%	28.9%	31.1%	28.9%	28.9%	28.9%
Pathology	22.7%	13.6%	2.2%	0.0%	0.0%	0.0%
Repeat Rate	64.4%	37.8%	53.3%	55.6%	44.4%	42.2%

Table 4.2 gives a summary of the frequency distribution for class interval 3+4 for the different criteria evaluated by the three radiologists. Film A had the higher percentage in the majority of cases.

4.3 FREQUENCY DISTRIBUTION: BOTH IMAGES WERE ACCEPTABLE

The data of radiologist I's assessment will be presented using the scoring system. The percentage of the rating given by radiologist I (ranging from 1 to 4) was calculated in relation to the maximum achievable result, in this case 4. This was done because the frequency distribution could not be used due to the fact that there was only one case (n= 1) where both films were acceptable. Table 4.3 gives the percentages for each criteria for film set 1, where both films A and B were acceptable for radiologist I.

Table 4.3 Percentages frequency distribution per criteria where both films A & B were acceptable; n= 1 (radiologist I)

Criteria	Film A (swimmer's)	Film B (adapted swimmer's)
Rotation	100%	0%
Shoulder Separation	0%	100%
X-ray Penetration	0%	100%
Contrast and Density	0%	100%
Bony Structures	0%	100%
Pathology	100%	0%
Sharpness	100%	0%
Spatial Resolution	100%	0%

Looking at the one incident where both images were acceptable for radiologist I, it is clear that the number of criteria in favour of films A equals that of film B.

The results per criteria for radiologists II and III were condensed into a 3+4 class interval, as was the case in section 4.2. As stated before the instances where both films were acceptable, for radiologist II, n=9 and for radiologist III, n=5. On these films, where both were acceptable, the two radiologists did not see any pathology, hence no results will be presented for this criteria. Table 4.4 gives the averages per criteria for film sets 12, 22, 23, 25, 26, 27, 28, 33 and 43 (n=9) for radiologist II. Radiologist II gave rotation the highest percentage of 66.67%, where film A and film B are equal; the lowest percentage of 33.33% was allocated to film B for sharpness and spatial resolution.

Table 4.4 Summary of percentages per criteria where both films A & B were acceptable; n= 9 (radiologist II)

Criteria	Film A (swimmer's)	Film B (adapted swimmer's)
Rotation	66.67%	66.67%
Shoulder Separation	66.67%	55.56%
X-ray Penetration	55.56%	44.44%
Contrast and Density	55.56%	44.44%
Bony Structures	55.56%	44.44%
Sharpness	55.56%	33.33%
Spatial Resolution	55.56%	33.33%

The frequency distribution of six out of the seven criteria for the class interval 3+4, film A had better results. Rotation for both films was judged as equal by radiologist II.

Table 4.5 gives the averages per criteria for film sets 1, 25, 26, 28 and 42 (n=5), for both images being acceptable (radiologist III). Radiologist III gave the highest percentage of 100% to film A for x-ray penetration; the lowest percentage of 40% was allocated to film B for contrast and density and sharpness.

Table 4.5 Summary of percentages per criteria where both films A & B were acceptable; n= 5 (radiologist III)

Criteria	Film A (swimmer's)	Film B (adapted swimmer's)
Rotation	80%	60%
Shoulder Separation	80%	60%
X-ray Penetration	100%	80%
Contrast and Density	80%	40%
Bony Structures	80%	80%
Sharpness	60%	40%
Spatial Resolution	60%	60%

The frequency distribution of five out of the seven criteria for the class interval 3+4, film A had better results. Demonstration of bony structures and spatial resolution for both films was judged as equal by radiologist III.

4.4 AGREEMENT ANALYSIS

The frequency distribution for each radiologist per criteria for the class interval 3+4 was used to test association. All criteria except the demonstration of pathology were included. The weighted Kappa association test was done to compare agreement for categorical data (Kirkwood and Sterne, 2003: 434). Table 4.6 compares the relationship between the three radiologists' analysis of film A in relation to the criteria. Radiologist I was compared to radiologist II and to radiologist III; radiologist II was also compared to radiologist III.

Table 4.6 Agreement analysis of film subset A for result of class interval 3+4

Film A			
Criteria	Radiologist I vs. II	Radiologist I vs. III	Radiologist II vs. III
Rotation	0.1500	-0.0011	0.4524
Shoulder Separation	0.1389	0.2946	0.2230
X-ray Penetration	0.4600	0.4681	0.6630
Contrast and Density	0.3878	0.3447	0.6492
Bony Structures	0.6842	0.4272	0.5361
Sharpness	0.3360	0.2792	0.4102
Spatial Resolution	0.3208	0.3231	0.4775
Repeat Rate	0.5015	0.3541	0.2941

Figure 4.11 confirms the data presented in table 4.6 that shows the extent to which the three radiologists' evaluations move together. The comparison of radiologists I and III presented with the lowest weighted Kappa of -0.0011 for film A in relation to rotation. The highest weighted Kappa of 0.6842 was calculated for bony structures between radiologist I and II.

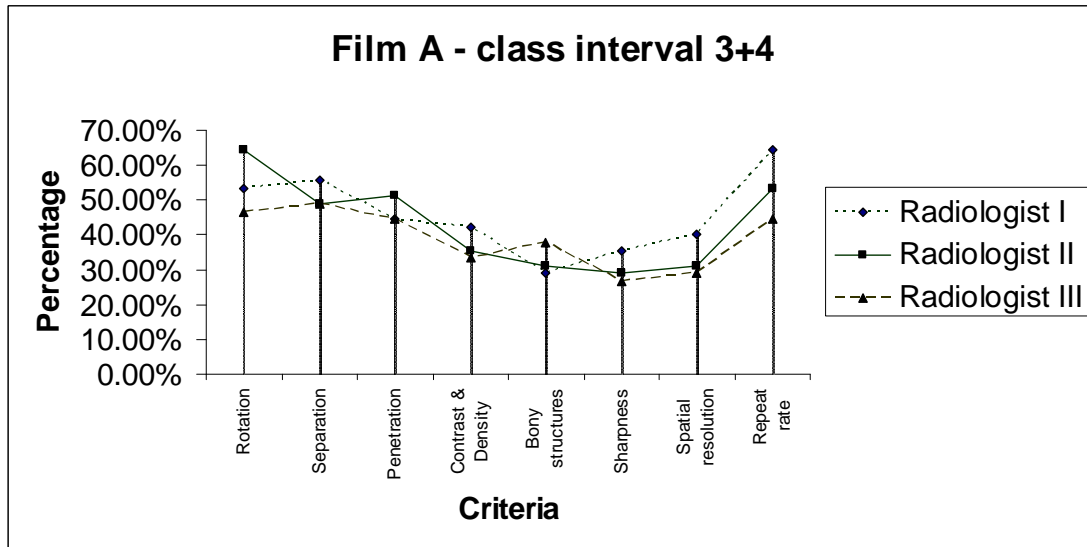


Figure 4.11 Association between the radiologists' analysis of film A for the frequency distribution of class interval 3+4.

Table 4.7 compares the relationship between the three radiologists' analysis of film B in relation to the criteria. The weighted Kappa of radiologists I and II presented with the lowest value of -0.0104 for film B in relation to rotation. The highest weighted Kappa of 0.7228 was calculated for repeat rate.

Table 4.7 Agreement analysis of film subset B for result of class interval 3+4

Film B			
Criteria	Radiologist I vs. II	Radiologist I vs. III	Radiologist II vs. III
Rotation	-0.0104	0.1778	0.0670
Shoulder Separation	0.2091	0.3417	0.4599
X-ray Penetration	0.3975	0.2571	0.3361
Contrast and Density	0.3210	0.3227	0.3993
Bony Structures	0.4180	0.2639	0.4375
Sharpness	0.3258	0.3163	0.3739
Spatial Resolution	0.1575	0.2102	0.4566
Repeat Rate	0.4808	0.7228	0.4757

A graphic representation of the relationship between the radiologists' analysis of film B is presented in figure 4.12. Figure 4.12 serves as confirmation of the data presented in table 4.7 that again shows the degree of association between the three radiologists' evaluation.

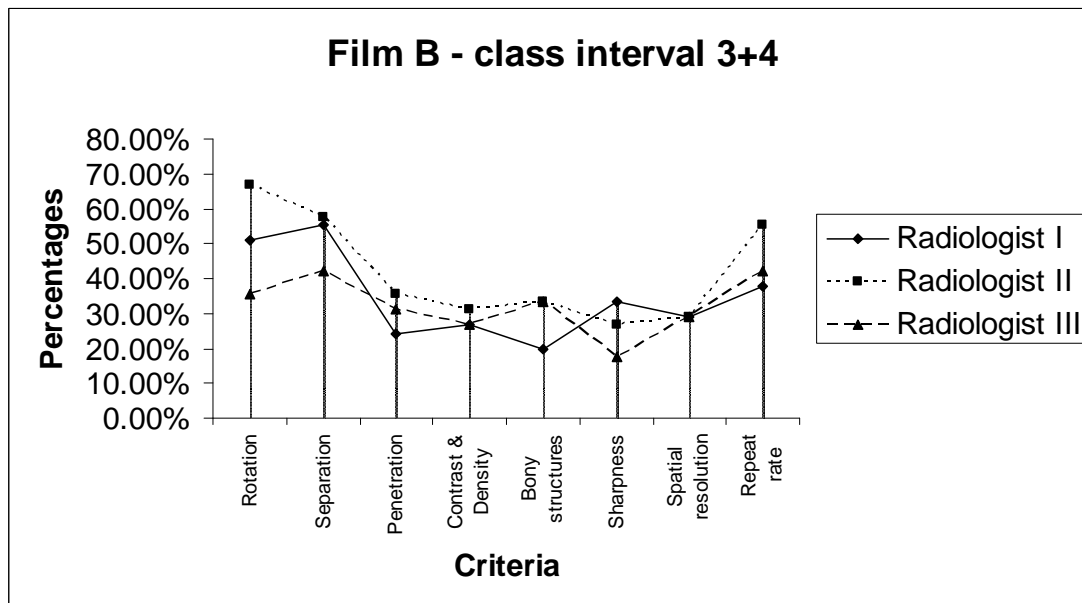


Figure 4.12 Correlation between radiologists' analysis of film B for the frequency distribution of class interval 3+4.

4.5 SUMMARY

The frequency distribution for the grouped data in class interval 3+4 was used to present the results. From the results, inconsistencies were discovered and presented in this chapter. The main findings will be summarised in the following paragraphs.

The difference for laterally viewed vertebrae C₇-T₁, not appreciably rotated between film A and film B for radiologist I and III was in film A's favour and radiologist II judged film B as better with a margin of 2.2%. There was no difference for shoulders separated from each other between films A and B for radiologist I (both equaled 55.6%). The difference for radiologist II and III was 7.8%, with film A being the highest. The difference for x-ray penetration of shoulder region C₇-T₁ between films A and B for the three radiologists was 16.3%, with A being the highest. The difference for contrast and density between films A and B was 8.2%, with A being the highest. The difference for demonstration of the bony structures of the cervicothoracic junction between films A and B was 5.2%, with film A being the highest. The difference for sharpness of the cortical outlines C₇-T₁ between films A and B was 4.5%, with A being the highest. The difference for spatial resolution between films A and

B for radiologist I and II was 6.7% and, for radiologist III, there was no difference.

For the repeat rate the frequency distribution, where no repeat was necessary for the swimmer's (film A), equaled 54.07% and the frequency distribution for the adapted swimmer's (film B) equaled 45.18%. The high p-value for two of the radiologists (0.8575 and 0.8527), indicates that the evidence is not convincing in favour of either film A or film B. Looking at the one incident where both images were acceptable, radiologist I evaluated films A and B as equally acceptable. Radiologist II and radiologist III evaluated in favour of film A.

The results for objective 1, image quality, was in favour of the swimmer's, with the adapted swimmer's having comparable results. In relation to objective 2, pathology, no valid conclusion was possible. The evaluation of repeat rate, objective 3, presented minimal difference between the two projections. All these aspects will be discussed in Chapter 5, where recommendations to future studies will also be addressed.

CHAPTER 5

DISCUSSION AND RECOMMENDATIONS

5.1 INTRODUCTION

In Chapter 4 the frequency procedure of the distribution of the 45-patient sample across the scoring system that ranges from 1 to 4 (Appendix 13 - the statistical analysis) per criteria, was presented. From Chapter 4 film A, the swimmer's projection consistently showed better results in the criteria of image quality. However, film B (the adapted swimmer's projection) also showed satisfactory results and there were also instances where the adapted swimmer's had better results. The high p-values for the different criteria, ranging from 0.1 to 1, were evidence of no statistical difference between the resultant images of the two techniques. The repeat rate of the adapted swimmer's compared well with that of the swimmer's projection. The results of the current study thus reiterate the difficulty to demonstrate and interpret radiography of C₇-T₁, since the anatomy of the shoulder girdle overlaps the junction. The problem is perpetuated by difficulties associated with patient positioning and patient condition. Images of the cervicothoracic junction should adhere to sound prescribed geometric principles (section 2.4).

The discussion chapter will first examine the results of the three objectives, image quality, demonstration of pathology and repeat rate (section 5.2). The results where both methods were acceptable and where no repeat was recommended will be discussed in section 5.3. The results where both methods were unacceptable will be discussed in section 5.4. This will be followed by the agreement analysis of the radiologists' evaluation and the limitations of the study. Analysis of the results pours over into inferring and reasoning that will lead to statistically sound conclusions and valid recommendations. This chapter seeks to interact with the results in a less structured (when compared to Chapter 4) but more condensed and interwoven way related to the objectives of the study.

5.2 COMPARISON OF DIAGNOSTIC QUALITY

The specific criteria used for the evaluation of the swimmer's and the adapted swimmer's projection in the present study (Appendix 9) were formulated from the evaluation criteria of the lateral cervical and the swimmer's projections (Bontrager, 2006: 311; Ballinger and Frank, 1999:415 and McQuillen-Martensen, 1993:326). The validity of the criteria was verified by consulting comparative studies by Ireland (1998: 151), Berquist, (1988: 669) and Templeton (1987:98). The criteria used has a more general application in medical imaging and is thus not discipline specific. The criteria affect pattern recognition and thus facilitate comparison of the two films. Differences in subjective analysis due to differences in interpretation and personal preferences of the radiologists who participated in the study had a profound influence on the results of the study to be discussed.

5.2.1 The Quality of Projections

One of the foundation rules of radiography states that the central x-ray beam and the anatomy being radiographed should be perpendicular to each other. Another collaborative rule is that the anatomy and the image receptor should be parallel to each other and relates to positioning in controlling the geometrical integrity of the recorded image. The orientation of the anatomy, central ray angle and centering are all alignment factors which influence rotation (Carroll, 1990: 222). Rotation of C₇-T₁ is when the coronal plane is not perpendicular to the image receptor, with direct negative consequences on all the other criteria umbrellaed by spatial resolution (section 4.2.1). In relation to rotation, two of the three radiologists agreed that the swimmer's projection had superior results. One radiologist evaluated the adapted swimmer's projection as the higher of the two methods. Radiologist I and III agreed that the swimmer's was better but there is a 8.9% difference in their frequency distribution. This large margin, as well as the fact that radiologist II evaluated the adapted swimmer's as being better, provided no clear trend. Taking this into account, an examination of the p-values also did not indicate or confirm the swimmer's projection's outright superiority.

Rotation or symmetrical positioning could have been influenced by the different arm orientations used during the study that relates to radiographer

familiarity. The different arm orientations were used to minimise the overlapping anatomical structures through shoulder separation (section 2.5.5). A smaller amount of anatomy to be penetrated through the shoulder girdle also means less scatter radiation degrading the overall image quality and more primary rays are used to improve overall image acceptability (Carlton & Adler, 2006: 229). If one examines the geometry of the diverging x-ray beam and the centering point, the depressed shoulder (for the swimmer's it is the shoulder further from the image receptor, for the adapted swimmer's it is the shoulder closest to the image receptor) would be projected lower (Carlton & Adler, 2006: 463). The same principle is also applicable in relation to the opposing shoulders in both cases - for the swimmer's the raised shoulder closest to the image receptor would be projected higher, for the adapted swimmer's it is the shoulder further away from the image receptor that would be projected higher.

For this study, one radiologist did not show a difference between the adapted swimmer's and swimmer's projections for shoulders separated from each other. The second radiologist evaluated the adapted swimmer's projection as better and the third radiologist evaluated in favour of the swimmer's projection. This means that the adapted swimmer's compared well with the swimmer's projection in terms of shoulder separation. Another indication that the adapted swimmer's compared well with the swimmer's projection in this study was that two different radiologists agreed that the swimmer's is better than the adapted swimmer's projection when compared with rotation. A third indication is that the difference of the frequency distribution for the swimmer's and the adapted swimmer's had high p-values. Yet another indication of good comparison is that the two other radiologists (II and III) evaluated either the swimmer's or the adapted swimmer's as the better option.

Radiologist III judged the swimmer's projection better for both rotation and shoulder separation, presenting evidence to the speculated link between the two criterion. On the other hand, the two other radiologists indicated no link between rotation and shoulder separation and the evidence is more suspect of incorrect positioning.

X-ray penetration refers to making effective use of exposures given in order to visualise anatomy. Since the exposures per patient remained constant and

the same image receptor was used for all the films, penetration was influenced by the size of the anatomy and the shoulder separation. The size of the anatomy and shoulder separation influenced the amount of scatter on the image and consequently the contrast and density, the sharpness and spatial resolution. All three radiologists in this study showed that, of the two techniques, the swimmer's projection had the better shoulder separation. The rather high percentages for the frequency distribution of the acceptable class interval represents a good correlation between the three radiologists' observation of penetration. The high percentages also showed moderate evidence that the swimmer's projection gives better results when compared to the adapted swimmer's projection.

One would assume that x-ray penetration should have been equal for the two projections compared in this study. Although the same exposure was used, the swimmer's projection presented with better shoulder separation demonstrated on the film. The CR machine used for this study at Pelonomi Hospital has a fixed SID of 115cm, since more than 95% of the images were obtained using this system, it posed a problem. Combining the SID with the increased OID of the humerus furthest from the image receptor (adapted swimmer's), it leads to magnification and decreased sharpness. A longer SID of 150cm would have combated the effect of the increased OID on image quality (Carlton & Adler, 2006: 444). The enlarged humerus along with the enlarged, superimpositioning corresponding clavicle not only influenced penetration but also the contrast and density over the area of C₇-T₁.

Contrast and density on the film is influenced by arm orientation and the influence thereof on scatter for the same exposure given. The amount of scatter reaching the image receptor is influenced by the grid used. The CR system at Pelonomi hospital employs a stationary grid, where a moving grid would have blurred out the stationary lead lines that decreases image quality (Carlton & Adler, 2006: 256). The air gap created when the patient is in the adapted swimmers position helped to decrease scatter and improved the contrast and density of the image. Again, all three radiologists judged the swimmer's projection as being better for contrast and density. The rather large difference in frequency distribution percentages amongst the

radiologists represents a big difference in observation that was also reflected by the high individual p-values.

Wrong centering during positioning and incorrect alignment of the x-ray tube to C₇- T₁ causes image distortion and unsharp images (Carroll, 1990: 222). Slight differences in positioning, when compared to the prescribed method (see Appendix 4), often influenced by patient condition, do not necessarily rule out the diagnostic value of the radiograph. Patient condition requires that a certain degree of latitude in positioning is permissible (Carroll, 1990: 234). In radiography the aforementioned is the norm rather than the exception and it also applies to this study where the neck of the patient could not be moved and associated injuries made positioning difficult. The effect that patient position (arm orientation) had on scatter radiation and the effect of the shorter SID on the magnification of the humerus, as discussed earlier, had an effect on the contrast and density of the image. For its part, contrast and density has an effect on visibility and the sharpness of the cortical outlines. Results for sharpness in this study presented a unanimous “yes” in favour of the swimmer’s projection. The significance of these differences diminished when viewing the high p-values for the three radiologists’ evaluations.

The swimmer’s projection had better results for rotation (two of the three radiologists agreed) and penetration (all three radiologists agreed); this represents a link between sharpness, rotation and penetration. The result for sharpness of the cortical outlines should also 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, penetration, 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? Or could it be a combination of factors that includes the aforementioned two? 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 (2006: 503) suggests that when consulting professionals to rate images, it is better not to ask which is the best. "... because when any group of professionals is asked to select the best image there will be difference of opinion, leaving no consensus as to which is the best image" (Carlton & Adler, 2006: 451).

Though spatial resolution was not part of the pilot study, it did tie-up all the other criteria to present an holistic evaluation of image quality. Spatial resolution can be viewed as the one criterion that incorporates all the other criteria. Being able to resolve the anterior longitudinal ligament is important in judging alignment and stability of the cervicothoracic vertebrae. The posterior longitudinal ligament, the laminospinal line, the interspinous and supraspinous ligaments posteriorly, the intertransverse ligament laterally, and the capsular ligaments and ligamentum flavum should also be resolved since they may demonstrate obvious pathology (Mirvis & Young, 1992: 292). The swimmer's projection had better results according to two radiologists, 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. As stated before, spatial resolution encompasses all the other criteria and the results of the present study discussed do not boast well for the general impression of the other criteria. The high p-value of 0.7120 for spatial resolution also indicated that the overall impression of the two films were equal.

In order to get a holistic view of the results it is important to investigate the outlying frequency distribution that is an indication of the minimum and maximum values (Appendix 15). The swimmer's projection had the higher frequency distribution in category 4 (excellent) for two radiologists and, according to all the radiologists had fewer incidences in category 1 (poor). The adapted swimmer's projection has the higher frequency distribution in the excellent category for the other radiologist. The differences in the frequency

distribution between the swimmer's and adapted swimmer's projections for the excellent category is represented by relatively small percentages. The frequency distribution of the minimum category (no diagnosis possible) was higher in comparison to the maximum category (maximum radiological detection achieved) for all three the radiologists. This could be an indication that the overall image quality for the sample of 45 films was poor.

5.2.2 Diagnosis of Pathology

Radiologist I diagnosed pathology on twenty-two image sets, radiologist II reported pathology on one image set and radiologist III on two image sets. Pathology was reported on film set 11 by two radiologist and all the radiologists agreed that film set 41 demonstrated pathology. The differences amongst the radiologists' evaluation of pathology indicated big differences in interpretation and made meaningful conclusions difficult. The aforementioned differences can be regarded as concerning since Murphy (2000: Online) claimed that the cross table lateral radiograph is 74% to 86% sensitive in detecting cervical spine injuries. On the other hand Blahd, Iserson and Bjelland (1985: 249) had a similar problem in their study to evaluate efficacy of the post-traumatic cross table lateral projection of the cervical spine. The physician in their study misdiagnosed 10 out of 33 cases where pathology was later confirmed by using CT. 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 frequency distribution of the acceptable class interval was used to compare demonstration of pathology. All three radiologists agreed that the swimmer's projection had better results. These results have to be contextualised. For two radiologists, the frequency distribution of the adapted swimmers projection was grouped under the "unacceptable" class interval. Here the frequency distribution for the "acceptable" class interval of the adapted swimmers projection for pathology was equal to 0%. The differences in samples size did not permit validation of the results as being commonly acceptable. The differences in sample size did not facilitate the calculation of p-values.

Most of the frequency distribution for demonstration of pathology was grouped in the minimum category (no diagnosis possible) of the 1 to 4 scoring system. This can be seen as an indication of the inherent difficulty of making a diagnosis from the swimmer's or adapted swimmer's projection. It can also be an indication of poor technique used during the examination procedure.

5.2.3 Repeat Rate

The repeat rate was unpacked with respect to which of the two films, the swimmer's or the adapted swimmers projection, had to be repeated most (see section 4.2.3, figure 4.9). According to one radiologist, the swimmer's projection had to be repeated in 16 of the 45 patients and the adapted swimmers projection had to be repeated in 28 cases. Another radiologist indicated that the swimmer's projection had to be repeated in 21 of 45 cases and for the adapted swimmers projection it was 20 of 45 cases. The corresponding values for the third radiologist for the swimmer's projection was 25 and for the adapted swimmers projection 26 of 45 cases.

The difference in repeat rate for the first radiologist was 12 with the swimmer's projection requiring less repeats. According to another radiologist, the adapted swimmers projection had to be repeated less. The last radiologist evaluated less repeats for the swimmer's projection. Though the results were inconsistent, they also indicated that the adapted swimmer's projection was a comparable alternative to the swimmer's projection. The instances where both images were acceptable will be discussed in section 5.3 and the instances where both images were unacceptable will be discussed in section 5.4. The close evaluation of radiologists II and III for the repeat rate that was linked to diagnostic acceptability indicated that the adapted swimmers projection in the present study compared well with the swimmer's projection.

5.3 BOTH IMAGES RATED ACCEPTABLE

The instances where both images were acceptable varied amongst the three radiologists. One radiologist adjudged one image set as being acceptable for both methods. Five and nine sets of images were acceptable for the other two radiologists respectively.

Looking at the distribution of the data of the first radiologist's assessment (n= 1) for the criteria, both the swimmer's and the adapted swimmers projection were equally acceptable in demonstrating the cervicothoracic junction. This again indicated the possible use of the adapted swimmer's projection and the advantage of the alternative.

The other two radiologists did not identify any pathology; hence no results will be presented for pathology. The distribution difference between the swimmer's and the adapted swimmer's projection for the two radiologists was in favour of the swimmer's projection.

There were also film sets where the three radiologists agreed on film acceptability. Radiologist I and III agreed that both the swimmer's and the adapted swimmers projections of film set 1 were acceptable. Radiologist II and III agreed that the swimmer's and the adapted swimmers projections of film sets 25, 26 and 28 were acceptable. The radiologist did not provide any reasons for declaring both images acceptable.

5.4 BOTH IMAGES RATED UNACCEPTABLE

Only two of the three radiologists identified cases where both the swimmer's and adapted swimmer's projections needed to be repeated. One radiologist adjudged five image sets as unacceptable for both methods, for the other radiologist it was eleven sets.

The distribution difference between the swimmer's and the adapted swimmers projection of one radiologist (n= 5) was higher for the adapted swimmer's projection. This means that even though both images needed repeating, the adapted swimmers projection had better acceptability. In situations where $C_7 - T_1$ can not be demonstrated using the swimmer's projection, the adapted swimmer's can add value to the examination.

For the other radiologist (n= 11) the distribution difference between the swimmer's and the adapted swimmers projection was higher for the swimmer's projection. The swimmer's projection had better acceptability, though both images needed repeating. The two radiologists agreed that the swimmer's and the adapted swimmer's projections of film sets 30, 32 and 36 were unacceptable. Again no reasons why both images were unacceptable were available.

5.5 AGREEMENT ANALYSIS

For this study the weighted Kappa represents the individual films where there was agreement on acceptance. Radiologist I was compared to radiologist II and radiologist III; radiologist II was also compared to radiologist III. The instances where there was good agreement between the three radiologists had a higher frequency for the swimmer's projection than for the adapted swimmers projection. Steven Offerman (2006: 194) explains that the familiarity that their reviewing panel had with images produced using the swimmer's projection influenced interpretation and comparison with other less familiar projections. For the present study, one can only speculate on the influence of familiarity, since the study design and evidence gathered did not take this into account. There was good agreement between all the radiologists for x-ray penetration and demonstration of the bony structures for 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.

The study performed at Pelonomi Hospital on 45 patients has shown that the swimmer's projection had a higher frequency distribution per criteria in the "acceptable" class interval. No evidence of these results being significant could be found.

In Freemyer, Knopp and Piche's study (1989: 820) supine oblique projections did not improve detection of pathology when compared to the three projection series (see section 1.3). Turetsky *et al.* (1993: 689) states that supine oblique projections may detect fractures or ligamentous injury better than the three projection series. The two studies have contradictory results on the same topic. The studies indicate that the addition of supine oblique projections may or may not improve the detection of pathology. Similarly, Contractor (2002:550) showed no difference in visualising the vertebral bodies of C₇-T₁ junction between swimmer's or supine obliques. This also applies to Ireland

(1998: 151), who declared that the swimmer's projection and supine oblique projections show the alignment of the vertebral bodies with equal frequency.

The aforementioned studies compared the swimmer's projection to other methods of demonstrating C₇-T₁. The results of the mentioned studies show that other methods, such as supine oblique projections used to demonstrating C₇-T₁, have equal validity to that of the swimmer's (see section 2.6).

5.6 LIMITATIONS OF THE STUDY

Care was taken that all aspects of the study were executed as accurately as possible by taking the necessary quality factors into consideration. Limitations were, however, evident and will be contextualised under the following headings (5.6.1- 5.6.7):

5.6.1 Study Design

Quantitative research can be described as research that is more formulated; (i) images were obtained using a specified procedure (see section 5.6.5), (ii) the radiologists used a standardised set of criteria to evaluate two methods of demonstrating the cervicothoracic junction (see section 5.6.6), (iii) a biostatistician had to interpret the evaluation results obtained from participating radiologists. A qualitative approach is more explicitly controlled - through regular interaction and visibility of the researcher at Pelonomi Hospital as well as having the radiographers use a specific method of demonstrating the cervicothoracic junction. The researcher could unfortunately not be present on a more permanent basis and this had a negative effect on the control of the study process. It has a precisely defined range- related to a specific sample - section 5.6.3, projections - section 5.6.5 and timeframe - section 5.6.2 (Mouton & Marais, 1991: 159).

The research project was characterised by all the aforementioned quantitative research fundamentals. The sound basis on which the project was planned unfortunately did not include the human element in its equation. Challenges emanating from this miscalculation will be discussed in the following sections.

5.6.2 Preparation and Training Session

The researcher spent two weeks in the Pelonomi Regional Hospital Casualty Department familiarising himself with the setup and procedures of the department. This was also the launch period for the research project through several interventions. After two formal information and training sessions and after numerous informal discussions with radiographers assisting with the study, readjustments through evidence based practice were made. It seemed as if there was a genuine interest in the project and its aims and objectives from the radiography staff. The researcher was able to collect signed declaration forms (Appendix 6) from radiographers committed to the aims and objectives of the project during these sessions. The fact that the researcher could not be onsite for the full duration of the study could have influenced commitment. But more importantly, the study was conducted in the newly-opened emergency centre, where the first computed radiography system in the Free State province was installed. This meant that not only did radiographers have to do an additional projection - where the word additional is used deliberately - but they also had to do this in a new environment with new technology.

It was incorrect for the researcher to assume that two training sessions and informal discussions would be satisfactory. In section 2.5.3, Ireland (1998: 151) used a 12 week training period to ensure familiarity with the supine oblique projection that requires a complete change of machine orientation with a marked increase in time required to deliver desired results using an unfamiliar technique. In defence, it could also be argued that the project only involved qualified radiographers performing a familiar projection and an additional one with a slight adaptation that did not warrant a longer training period.

Thus, the groundwork laid for this study should have had more positive spin-offs especially related to the time of experimentation. It was planned that the project would be conducted over a period of 4 months at Pelonomi Hospital. Initially, the progress of the project was slow due to concerns about the correct way of obtaining consent. Additional information, on consent, were sourced from the Medical Research Council of South Africa's website (elaborated on in section 5.6.4). There were also concerns over protocol to follow in cases of multiple injuries, e.g. upper extremity injuries. For such

cases radiographers were advised to do swimmer's and adapted swimmer's projections where possible. This led to the experimentation period being extended to ensure a sample large enough to validate conclusions made.

5.6.3 Sampling

The sample of 45 film sets was acquired over 12 months at Pelonomi Hospital X-ray Department. Patients with multiple injuries not only made positioning challenging, but also had an adverse effect on the radiographers' commitment to obtaining additional images. Taking an extra projection increases the examination time and could have an adverse effect on the patient's general wellbeing.

On consultation with the head radiographer at a private casualty x-ray department in Bloemfontein, it was found that the average time for performing a trauma cervical spine examination is 20 minutes. On average it takes approximately 5 minutes per projection (anteroposterior, odontoid, lateral and swimmer's), with an additional 5 for the adapted swimmer's. Repeat films of the swimmer's projection increases examination time by another 5 minutes per repeat. The increase in examination time due to the addition of the adapted swimmer's projection was outweighed by the possible benefits associated with the study. The sample size was influenced by certain patient categories that were excluded from the study (see section 3.2.4).

This begs the question of the effect of a bigger sample. If it was possible to prolong the experimentation period, a bigger sample would have resulted. Ireland (1998: 151) included 53 patients in his study (see section 2.7), Freemyer, *et al.* (1989: 818) included 58 high risk patients in his sample. Wirth (2006:1757) compared three different arm-positioning strategies in 53 patients, while Kane (2004: Online) investigated the effectiveness of the swimmer's CT in ten patients. The sample of 45 is comparable to the mentioned studies but can not really be regarded as representative of the majority of cervicothoracic junction imaging cases being performed. The sample size and the 95% confidence intervals make other meaningful interpretations possible (Offerman, 2006: 194).

5.6.4 Consent

In some cases it was difficult to obtain written consent from all cervical injury patients in order to perform the additional projection. It can be argued that written consent is not necessarily more valuable than the verbal form as proof of consent. Verbal consent was used where written consent was impossible. The use of written consent in research projects with minimal risk or with significant discomfort is however, recommended by the Medical Research Council of South Africa (MRC, 2004: Online).

During the first month, the radiographers concerns related to projection procedure and consent were addressed by providing additional information through verbal and written communications (Appendix 12). Regardless of the aforementioned guidelines on obtaining consent, progress was still slow since obtaining consent was regarded as an add-on that prolonged the examination of patients that were traumatised and disorientated. Thus, obtaining consent was regarded as a hindrance to performing the additional projection.

5.6.5 Positioning

Radiography is an evidence based practice that requires critical thinking, analysis and adaptation of technique where required. As stated in section 5.2.1, slight differences in positioning do not necessarily rule out the diagnostic value of the radiograph. This philosophy is also underpinned by studies using the different arm orientation discussed in section 2.5.2. Different arm orientation also forms the basis of the comparison between the swimmer's and the adapted swimmer's projections. Most radiographers at Pelonomi Hospital were more familiar with the swimmer's projection than with the adapted swimmer's projection. Correct positioning could not be guaranteed in all cases of the less familiar adapted swimmer's. In other archived cases found during the study period, only the adapted swimmer's projection was performed, evidence to the validity of the alternative.

5.6.6 Inconsistencies in Film Evaluation

The results of this study (Chapter 4) as well as section 5.2 showed a number of inconsistencies amongst the radiologists regarding film acceptability affecting the results of the study. More specifically, the visibility of pathology (1, 2 and 22 instances for the three radiologists respectively out of 45 patients), the instances where both images were acceptable (1, 5 and 9 instances for the three radiologists respectively) and the cases of unacceptable images, did not facilitate valid conclusions. The level of experience of the different radiologist could also have played a role in interpretation. Another limitation of this study relates to repeat rate. If the radiologist were asked why repeats were necessary, it would have given more meaningful insight to positioning and image recording technique used. The feedback for objectives two and three of this study can not be seen as representative of a common trend amongst all cervicothoracic junction examinations.

5.6.7 Literature reviewed

A final shortcoming is the availability of more current literature on studies of the cervicothoracic junction. This can be attributed to the strides made in, and the availability of, CT. As stated in 2.2, search alerts that were registered on online databases, have as yet heralded few new publications or articles of projects related to the study. This would have enabled more in-depth comparison, engagement and abstract formulation.

5.7 RECOMMENDATIONS

In this section, recommendations to the shortcomings of this study (section 5.6) will be made. These recommendations are not only relevant to this study and future studies emanating from this study, but also to similar studies that compare the acceptability of images produced using two different techniques.

It will be wise to factor a degree of latitude for all aspects other individuals are directly or indirectly in control of, since it has an implication on the time frame. A more onsite presence of the researcher will permit better control of the research process and more timely assistance with problems. Contractor's study also advises better control, since nine of their films were lost during data collection that could have influenced the results obtained (Contractor, 2002:551). Written consent is the golden standard but verbal consent given after a verbal description of what is involved in research with less than minimal risk can also be regarded as currency. Verbal consent will speed up the research process, allow for patients with extremity injuries and illiterate patients to participate. The newly installed CR system was not only unfamiliar to radiographers but also had a fixed SID of 115cm; all examinations were to be done using this SID. The use of more familiar equipment would have eased the experimentation. The use of a SID of 150cm is recommended to deliver less magnification and increase sharpness.

The criteria that the three radiologists had to use to evaluate the images are available in Appendix 9. Each radiologist also received the study protocol and individual meetings were used to discuss the objectives of the study and evaluation process. From the inconsistencies in the results, I would recommend that a more consultative process should be followed for discussion, implication and application of the criteria in Appendix 9. The process should be facilitated by the researcher in a forum that includes radiographers as well as radiologists. It is recommended that the process starts by identifying the criteria and addressing any unclear issues through work-shopping. From the aforementioned contact sessions, the researcher assumed that all aspects of the project were clear, but a more communal approach would have relieved the radiographer's anxiety, eased the experimentation process and created ownership. The more systematic

approach to image critique proposed by Carlton and Adler (2006: 472) can give future studies a more holistic appeal. This alternative method starts by classifying the image as acceptable or not. It then focuses on image recording problems, examination procedural problems and equipment-associated problems. Using this image critique method will also allow more experienced radiographers to participate in the image evaluation process. Care should be taken when radiographers are included in image critiquing. Thorough training and establishing scope of relevance should lead this process.

Future studies should pilot the study in the same clinical environment as the more comprehensive study. Some of the limitations discussed in section 5.6 could have been identified earlier and remedial action could have been taken. This pilot should also include intensive image quality critiquing that will increase the overall image quality of the sample. As mentioned in section 5.6.3, the sample size of 45 and the fact that the two techniques were compared using 95% confidence intervals for differences in percentage make other meaningful interpretations possible. A larger sample size would minimise other possible conclusions (Offerman, 2006: 194) as this will increase the value and applicability of resultant conclusions.

All major patient categories (trauma and non-trauma) formed part of the sample; another recommendation would be to concentrate on one category, e.g. only trauma patients. Yet another recommendation would be to compare trauma to non-trauma patients.

5.8 AIMS AND OBJECTIVES ADDRESSED

The aim of this study (see section 1.6) was to compare the swimmer's and the adapted swimmer's projections of demonstrating the cervicothoracic junction (C₇-T₁). In view of the objectives, the results of the study did not clearly indicate if the swimmer's or the adapted swimmers projections, will demonstrate C₇-T₁ better. However, it was possible to identify a comparable alternative. The demonstration of pathology could not be satisfactorily addressed since there were big variations on the incidence of pathology amongst the radiologists. The overall diagnostic quality that relates to repeat rate again provided ambiguous results. One of the radiologists declared the

swimmer's projection better by a large margin. The other two radiologists were indecisive as to whether the swimmer's or the adapted swimmers projections were better. The difference between the swimmer's and the adapted swimmers projections for these two radiologists was 1 in both instances; this was in favour of either the swimmer's or the adapted swimmers projections.

5.9 CONCLUSIONS FROM RESULTS

Evidence based practice, as applied to radiography basically states that the foundational rules and procedures related to not only positioning but also imaging considerations are not cast in stone. The patient's clinical condition, as well as the clinical environment are the primary influences on evidence based practice. This form the backdrop of the relevance of the findings regarding this study.

In all the categories the swimmer's projection (film A) showed better results. However, there were also instances where the adapted swimmer's (film B) had better results (rotation, shoulder separation, demonstrating the bony structures and rotation). The differences in percentage were represented by p-values > 0.1 that indicated no significant difference between the swimmer's and the adapted swimmer's projections.

The difference in arm orientation or shoulder separations between the swimmer's and the adapted swimmer's projections should have allowed for more scatter to reach the image receptor in the case of the swimmer's projection. This would decrease the contrast on the film. Theoretically, the air gap provided by the adapted swimmer's should improve contrast. The short SID at Pelonomi Hospital and the larger OID of the humerus further from the image receptor causes enlargement, distortion and degraded contrast and density. The humerus cast a shadow over the anatomy of the shoulder girdle, influencing the evaluation of penetration that has a direct implication on spatial resolution.

The inconsistent frequency distribution amongst all the radiologists for pathology led to a statistical conundrum. The p-values for radiologist II and III

could not be calculated as there were no values for the adapted swimmers projection in the acceptable category. In relation to the second objective, a valid conclusion could not be made and it also raises the question of subjectivity as well as the clarity of the guidelines for evaluation (Appendix 9). The question, which one of the two films should be repeated, tries to get to the core of the matter in evaluating the swimmer's projection's superiority or the adapted swimmers projection's validity. The differences for two of the three radiologists regarding this objective were small with the adapted swimmers projection higher for radiologist II and the swimmer's projection better for radiologist III. Radiologist I indicated a larger difference in the favour of the swimmer's projection (Table 4.1). The biggest difference between the swimmer's and the adapted swimmers projections was 26.7%, with the adapted swimmer's projection being the higher, was evaluated by radiologist I in relation to repeat rate - meaning more repeats of the adapted swimmer's projection. This equates to the adapted swimmers projection being repeated in 28 cases with the swimmer's projection having 12 less. It also means that the adapted swimmer's delivering comparable results in 16 instances. In the cases where both projections were acceptable, the swimmer's projection for radiologist II was better in 1 of the 9 instances, whereas for radiologist III it was 1 of 5 instances, with the swimmer's projection faring better. The adapted swimmer's was equal to the swimmer's in 8 of 9 and 4 of the 5 instances.

For the images evaluated in this study at Pelonomi Hospital for 45 patients, the results of the present study have shown that the swimmer's projection delivers fractionally better results when compared to that of the adapted swimmer's, but no evidence of these results being significant could be found from the calculated p-values.

Similar to the studies done by Offerman (2006: 194), Turetsky *et al.* (1993: 689), Freemyer *et al.* (1989: 818), Bland *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. What this study and the aforementioned studies also have in common is that they have indicated the value of current methods of demonstrating cervical pathology. The studies mentioned have shown that other methods can be used advantageously in some instances.

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 (see section 3.2.8) implies that in 50 of 1000 examinations (Kirkwood and Sterne, 2003: 52), the adapted swimmer's can add value to the visualisation of C₇- T₁ and in 950 cases the results will be comparable.

REFERENCES

Agfa imaging [online]. [n.d.]. *Ortho CP-G plus*. Available from: <
http://www.agfa.com/en/he/products_services/all_products/ortho_cpg_plus.js
p > [Accessed on 25/02/2005]

Ahmad, N. 2003. auntminnie [online]. *Radiographic positioning techniques for the cervical spine*. Available from: <
<http://www.auntminnie.com/index.asp?sec=log&URL=%2Findex%2Easp%3FSec%3Dnws%26sub%3Drad%26pag%3Ddis%26ItemId%3D57734> >
[Accessed on 25/02/2004]

Albright, S.C. 1999. *Data analysis and decision making with Microsoft Excel*. London. Duxbury press. p. 442

Ball, J. & Price, T. 1995. *Chesney's Radiographic Imaging*. 6th edition. London. Blacwell Science. pp 24, 368

Ballinger, P. & Frank, E. 1999. *Merrill's atlas of Radiographic positions and Radiologic procedures*. Volume 1. 9th ed. St. Louis: Mosby. pp 415, 416

Bell, G. & Finlay, D. 1986. *Basic radiographic positioning and anatomy*. London: Baillière Tindall. p 152

Berquist, T.H. 1986. *Imaging of orthopedic trauma and surgery*. Philadelphia: Saunders.

Berquist, T.H. 1988. Imaging of adult cervical spine trauma. *RadioGraphics*, 8(4): 667- 694, July.

Berquist, T.H. 1992. *Imaging of sports injuries*. Maryland: Aspen Publications. pp 44, 669

Bettinger, B.I. & Eisenberg, R.L. 1995. Improved swimmer's lateral projection of the cervicothoracic region. *American Journal of Roentgenology*, 164(5):1303-1304, May.

Blackmore, C.C. 2003. Evidence-based imaging evaluation of the cervical spine in trauma. *Neuroimaging clinics of North America*, 13(2): 283-291, May.

Blahd, W.H. ; [Iserson, K.V.](#) & [Bjelland, J.C.](#) 1985. Efficacy of the post-traumatic cross table lateral view of the cervical spine. *Journal of Emergency Medicine*, 2(4): 243-249

Blickman, J. G. 1994. *Pediatric radiology: the requisites*. St. Louis: Mosby. p 62

Bontrager, K. 2006. *Textbook of Radiographic positioning and related Anatomy*. 6th ed. St. Louis: Mosby. pp 16, 17, 23, 289, 311

Botha, R.W. 2006. Demonstrating the cervicothoracic junction on plain film: an alternative to the Swimmers view. *Interim*, 5(1): 1- 10

Bushberg, J.T. 2002. *The essential physics for medical imaging*, 2nd ed. Philadelphia: Lippincott Williams and Wilkins. pp 10, 14, 59, 293, 296, 297, 851

Carlton, R.R. & Adler, A.M. 2006. *Principles of Radiographic Imaging - An art and a science*, 3rd ed. Albany, N.Y: Delmar Publishers. pp 6, 64, 88, 228, 229, 256, 320, 357, 444, 445, 450, 451, 458, 463, 472, 726.

Carroll, Q.B. 1990. *Fuch's principles of radiographic exposure, processing and quality control*. 4th ed. Springfield: Charles C. Thomas Publishers. pp 216, 222, 234

Contractor, N. 2002. Towards evidence based emergency medicine: best BETs from Manchester Royal Infirmary. Swimmers view or supine oblique views to visualise the cervicothoracic junction. *Emergency Medicine Journal: EMJ*, 19(6): 550-551, November.

Cullinan, A. M. 1992. *Optimizing radiographic positioning*. Philadelphia: J.B. Lippincott Company. p 134

Curry, T.S. ; Dowdey, J.E. & Murry, R.C. 1990. *Christensen's Physics of Diagnostic Radiology*. 4th ed. Philadelphia: Lea & Febiger. p 118

Daffner, R.H. 2000. *American Journal of Roentgenology* [online]. Available from: < <http://www.ajronline.org/cgi/content/full/175/5/1309> > [Accessed on 26/11/2004]

Daffner, S.D. 2002. Managing disorders of the cervicothoracic junction. *American Journal of Orthopaedics*, 31(6): 323-327, June.

Daniel, W.W. 1999. *Biostatistics: A foundation for analysis in the health sciences*. 7th ed. New York: John Wiley and Sons, Inc. pp 3, 17

De Vos, D. 1995. *Basic principles of radiographic exposure*. 2nd ed. Baltimore: Williams & Wilkins. p 37

Freemyer, B. ; Knopp, R. ; Piche, J. ; Wales, L & Williams, J. 1989. Comparison of five-view and three-view cervical spine series in the evaluation of patients with cervical trauma. *Annals of Emergency Medicine*, 18(8): 818-821, August

Gehweiler, J. J. ; Osborn, R. L. & Becker, F. G. 1980. *The radiology of vertebral trauma*. Philadelphia: Saunders.

Graber, M. & Kathol, M. 1999. *American Academy of Family Physicians* [online] Available from: < <http://www.aafp.org/afp/990115ap/331.html> > [Accessed on 25/03/2004]

Hagler, M. 1993. *The pocket rad tech*. Philadelphia: W. B. Saunders company. p 255

Harris, J.H. (junior), Harris, W.H & Novelline, R.A. 1993. *The radiology of Emergency Medicine*. 3rd ed. Baltimore: Williams & Wilkins. p 155

Ireland, A.J. 1998. Do supine oblique views provide better imaging of the cervicothoracic junction than swimmer's views? *Journal Of Accident & Emergency Medicine*, 15(3): 151-154, May.

Ivy, M. & Cohn, S. 1997. Addressing the myths of cervical spine injury management. *American Journal of Emergency Medicine*, 15(6): 591-595, October.

Jelly, L. 2000. Radiography versus Spiral CT in the Evaluation of Cervicothoracic Junction Injuries in Polytrauma Patients Who Have Undergone Intubation. *RadioGraphics*, 20:S251–S259, January.

Jenkins. 1999. Where do we go after the three standard cervical spine views in the conscious trauma patient? A survey. *Society For Emergency Medicine*, 6(3): 215-217, September.

Kane, A. 2004. Swimmer's CT: Improved Imaging of the Lower Neck and Thoracic Inlet. *American journal of neuroradiology* [online]. Available from: <
<http://www.ajnr.org/cgi/reprint/25/5/859?maxtoshow=&HITS=10&hits=10&RESULTFORMAT=&searchid=1&FIRSTINDEX=0&sortspec=relevance&volume=25&firstpage=859&resourcetype=HWCIT>
> [Accessed on 13/07/2007]

Katzenellenbogen, J.M. ; Joubert, G. & Abdool Karim, S.S. 1999. *Epidemiology, a manual for South Africa*. Cape Town: Oxford University Press Southern Africa. p 69

Kirkwood, B.R. & Sterne, J.A.C. 2003. *Essential Medical Statistics*. 2nd ed. Malden: Blacwell Science, Inc. pp 52, 434

Köhler, A & Zimmer, E.A. 1993. *Borderlands of normal and early pathological findings in skeletal radiography*. New York : Thieme Medical publishers. pp 498, 502

Kuhns, L.R. 1989. *Decision making in Imaging*. Chicago: Year book medical publishers, inc. p 4

McQuillen-Martensen, K. 1993. *Radiographic Critique*. Philadelphia: Saunders. pp 326, 338

MRC (Medical Research Council of South Africa) [online]. 2004. *Consent* . Available from:< <http://www.mrc.ac.za/ethics/consent.htm> > [Accessed on 23/11/2004]

Mirvis, S. & Young, J. 1992. *Imaging in trauma and critical care*. Baltimore: Williams & Wilkins. pp 291, 292

Mouton, J. & Marais, H.C. 1991. *Basiese begrippe: metodologie van die geesteswetenskappe*. Pretoria: RGN-uitgewers. p 159

Murphy, R.B. 2000. *Mindwheels* [online]. Available from: < <http://www.mindwheels.com/ED-WEB%20Web/c-spine%20imaging.htm> > [Accessed on 25/11/2004]

National Council of Radiation Protection and Measurements (NCRP) Report No. 48. 1989. *Radiation Protection for Medical and Allied Health Personnel*. p 13

Offerman, R. ; Holmes, J. ; Katzberg, R. & Richards, J. 2006. Utility of supine oblique radiographs in detecting cervical spine injury. *Journal of Emergency Medicine*, [30\(2\)](#): 189-195, February.

Ohioenoya, D. 1996. *Journal of Accident and Emergency Medicine* [online]. Available from: < <http://emj.bmj.com/cgi/content/abstract/13/3/175?maxtoshow=&HITS=10&hits=10&RESULTFORMAT=&andorexactfulltext=and&searchid=1&FIRSTINDEX=0&sortspec=relevance&volume=13&firstpage=175&resourcetype=HWCIT> > [Accessed on 13/07/2007]

Oxford English Dictionary [online]. Available from: < <http://www.oed.com/> > [Accessed on 13/07/2007]

Redman, H. 1993. *Emergency Radiology*. Philadelphia: Saunders. p 179

Road accident fund commission report 2002 *Volume 2*. [online] Available from: <

http://www.parliament.gov.za/pls/portal30/docs/FOLDER/PARLIAMENTARY_INFORMATION/PUBLICATIONS/ROAD/s12-29.pdf

[Accessed on 29/10/2004]

Sclafani, S. 1991. *Radiology of Trauma*. Philadelphia: J. B. Lippincott company. p 3.2

Singer, C. 1989. Exposure of emergency medical personnel to ionizing radiation during cervical spine radiography. *Annals of Emergency Medicine*, 18(8): 818-821, August.

South African Department of Health [online]. [n.d.]. Available from: <
<http://www.doh.gov.za/search/index.html> > [Accessed on 15 August, 2006]

Streitwieser, D. 1983. Accuracy of standard radiographic views in detecting cervical spine fractures. *Annals of emergency medicine* [online]. Available from: <

<http://www.annemergmed.com/article/PIIS0196064483802935/abstract>

> [Accessed on 13/07/2007]

Templeton, P. A. ; Young, J. W. R. ; Mirvis, S. E & Buddemeyer, E. U. 1987. Value of retropharyngeal soft tissue measurements in trauma of the adult cervical spine. *Skeletal Radiology*. 16(2): 98-104, February.

Turetsky, D. ; Vines, F. ; Clayman, D & Northup, H. 1993. Technique and use of supine oblique views in acute cervical spine trauma. *Annals of Emergency Medicine*, 22(4): 685-689, April.

Wirth, S. 2006. Comparison of different patient positioning strategies to minimize shoulder girdle artifacts in head and neck CT. *European radiology*, 16(8): 1757-1762, August.

Woodring, J.H. & Lee, C. 1992. The role and limitations of computed tomographic scanning in the evaluation of cervical trauma. *J Trauma*, 33:698-708, November.

APPENDICES

APPENDIX 1

Terminology

Air gap technique

By increasing the distance between the imaged anatomy and image receptor, the amount of scattered radiation reaching the receptor is reduced to an acceptable level. No effect on primary radiation (Ball and Price, 1995: 24)

Anterior

Refers to the front half of the patient, or that part seen when viewed from the front (Bontrager, 2006:16)

Biostatistics

When data analyzed are derived from the biological sciences and medicine. (Daniel, 1999:3)

Bucky

A tray that holds the cassette and radiographic grid (Carlton & Adler, 2006, 88)

Caudal vs. Cranial

Caudal means away from, whereas cranial means towards the head end of the body (Bontrager, 2006:23)

Compton scatter

An interaction between x-rays and matter. An incident x-ray photon interacts with a loosely bound electron, removes the x-ray photon from its position and it proceeds in a direction as a scattered photon (Carlton & Adler, 2006, 726)

Computed Radiography

Indirect digital radiography. The radiographer must move the detector between acquisition and display (Carlton & Adler, 2006, 726)

Computed Tomography

Images produced by passing x-rays through the human body at numerous angles by rotating the x-ray tube around the body. The detected transmissions can be reconstructed to form individual slices of imaged human anatomy (Carlton & Adler, 2006, 6)

Ethics committee

Ethics committee of the Faculty of Health Sciences of the University of the Free State.

Fluorescence

Light emitted within 10^{-8} seconds after stimulation of x-rays (Curry, 1990: 118). This implies that there is no afterglow.

Golden hour principle

A period within which treatment must be administered in order to avoid either loss of life or disablement in consequence of a particular injury. Failure to administer timeous treatment within this window of opportunity invariably results in higher levels of permanent disablement, which are ultimately significantly more costly to the compensatory system than a timeous medical intervention. – The Hospital Association of South Africa.

(Road accident fund Commission report, 2002 Volume 2)

Imaging plate

Light is trapped by the phosphor crystals (phosphorescence) after stimulation of x-rays. The crystals are called storage phosphors or imaging plates (Bushberg, 2002: 293).

Inclusion/ Exclusion criteria-

Inclusion - **noun 1** the action of including or the state of being included.

2 a person or thing that is included.

Exclusion - **noun** the process of excluding or state of being excluded (Oxford English dictionary, 2007: Online)

Kyphosis

Kyphosis describes the thoracic curvature where there is an increase in convexity in the thoracic area, when viewed from the lateral (Bontrager, 2006:289)

Lateral

Refers to the side of, or a side view (Bontrager, 2006:17)

Lordotic

Lordosis describes the anterior concavity of the lumbar and cervical spine, when viewed from the lateral (Bontrager, 2006:289)

Magnetic Resonance Imaging (MRI)

MRI is an imaging technique that produces tomographic slices of a patient, where each pixel or point information depends on the micromagnetic properties of that tissue (Bushberg, 2002, 10).

mRem

A measure of radiation and organ specific damage in humans (Bushberg, 2002, 59)

Nexus

Current and completed Research projects in South Africa (NRF).

Oblique

An angled body plane, where the anatomy is not perpendicular, nor parallel to the image receptor; *supine oblique projections* are done with a 30° angled x-ray beam (Ireland, 1998: 151).

Phosphorescence

Light emitted beyond 10^{-8} seconds after stimulation of x-rays (Curry, 1990: 118). This implies that there is an afterglow.

Posterior

Refers to the back half of the patient, or that part seen when viewed from the back (Bontrager, 2006:16)

Radiation control committee

The radiation control committee of the department of Medical Physics, Faculty of Health Sciences of the University of the Free State.

Sensitivity

The sensitivity of an imaging procedure is its ability to detect a disease in a patient who does have the disease (Blickman, 1994: 62)

Specificity

The specificity of an imaging procedure is its ability to discern that a patient is truly free of a disease, does not have that disease (Blickman, 1994: 62)

Statistics

p-value – is a significance test that assess the strength of the evidence

- ✓ $p\text{-value} < 0.01$ - convincing evidence indicating the superiority of the method (A or B) with the higher value for grouping 3 / 4.
- ✓ $p\text{-value} < 0.05$, but > 0.01 - represents strong evidence in reference to superiority
- ✓ $p\text{-value} < 0.1$, but > 0.05 - moderate evidence (Albright, 1999: 443)

weighted Kappa - The weighted Kappa association test compares agreement for categorical data. For this study the weighted Kappa represents the individual films where there was agreement on acceptance (class interval 3+4).

- ✓ A weighted Kappa < 0.4 , but > -1 shows poor agreement,
- ✓ A weighted Kappa < 0.75 , but > 0.4 indicates good agreement and
- ✓ A weighted Kappa > 0.75 shows excellent agreement (Kirkwood and Sterne, 2003: 434).

APPENDIX 2

Provisional approval

FREE STATE PROVINCE



RW Botha
Faculty health & Environmental studies
Private bag x 20539
Bloemfontein

Research project: Radiology

Your letter dated 24 February 2005 refer.

Provisional approval is granted to do the project subjected to:

1. Discussion of the project with the head of Radiology, Dr M Africa
2. Providing a signed copy of the Ethics committee approval to Dr Africa
3. Provide the department with a copy of your research results

I trust that you would find these arrangements appropriate.

MG SCHOON
Head: Clinical services
14 March 2005

cc Dr M Africa

APPENDIX 3
NEXUS Search



Current and Completed Research Projects in South Africa

1. It is compulsory to provide the information of the name of researcher, title of the project and the name of the institution
2. Click on the submit button at the end of form after completion
3. Nexus staff will update or include your information on the database

Researchers

1. Name of researcher:

(surname initials, eg. Smith IAB)

Botha RW

Name of institution: *(researcher located)*

Central University of technology, Free State

Telephone no.:

051-5073179

Race (Not compulsory):

Black
White

2. Name of researcher:

(surname initials, eg. Smith IAB)

NA

Name of institution: *(researcher located)*

Telephone no.:

Race (Not compulsory):

Black
White

3. Name of researcher:

(surname initials, eg. Smith IAB)

NA

Name of institution: *(researcher located)*

Title:

Mr.

Function of researcher:

Project Leader
Contact person
Student (M-degree/D-degree)

E-mail address:

rbotha@cut.ac.za

Fax no.:

051-5073354

Gender (Not compulsory):

Male
Female

Title:

Function of researcher:

Project Leader
Contact person
Student (M-degree/D-degree)

E-mail address:

Fax no.:

Gender (Not compulsory):

Male
Female

Title:

Function of researcher:

Project Leader
Contact person
Student (M-degree/D-degree)

E-mail address:

Telephone no.:

Fax no.:

Race (Not compulsory):

- Black
- White

Gender (Not compulsory):

- Male
- Female

4. Name of researcher:

(surname initials, eg. Smith IAB)

NA

Title:

Function of researcher:

- Project Leader
- Contact person
- Student (M-degree/D-degree)

Name of institution: (researcher located)

E-mail address:

Telephone no.:

Fax no.:

Race (Not compulsory):

- Black
- White

Gender (Not compulsory):

- Male
- Female

Project

5. Title of research project:

Demonstrating the cervicothoracic junction

6. Name of institution: (hosting of project)

CUT

7. Department:

Radiography

8. E-mail address of institution:

9. Telephone no. of institution:

10. Fax no. of institution:

051-5073199

051-5073911

11. Internet address (URL) of dept/institution:

12. Name of funding agency:

CUT Innovation fund

http://www.cut.ac.za

13. E-mail address of funding agency:

14. Telephone no. of funding agency:

15. Budget of project:

R14885.88

Methodology

16. In the case of quantitative/empirical research please indicate:

Sample size or Number of treatments

±100

Description of population or treatments

Conscious patient

Availability of datasets in a machine readable format (e.g. ASCII, SAS, SPSS, etc.)

None

Availability of questionnaires

Yes No

Conference paper

Discipline of project

17. Specific field of research e.g., Developmental psychology, Secondary education, Reptiles, Qualitative physics, etc.:

Radiography

18. Project description/abstract (problem statement and research methodologies) in approximately 200 words:

Please press the enter key to break the lines.

The single most important projection of a patient with suspected cervical spine trauma is the lateral view demonstrating the first cervical vertebrae and including the first thoracic vertebrae.
A study was conducted (as part of a B.Tech qualification) to ascertain which technique would result in the identification of injury at the level

Purpose

Click on the relevant box to indicate purpose of research project:

19. Degree/Diploma

Yes No

If yes, please specify (e.g. MA MTech, PhD):

M. Tech

20. Non-qualification

21. Status of project:

Current (1-4 years)

Indefinite (10- years)

Ongoing (5-10 years)

Completed

22. Duration in months

± 26

23. Year of commencement

2005

24. Year of completion

2007

Bibliographic details

25. Intended publication(s):

Report

Book

Article(s)

Thesis

Software

Video

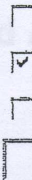
Database

APPENDIX 4

Conference paper

Tests

Other, please specify:



A large percentage of patients coming to the x-ray department for examinations of their cervical spine are trauma related patients and are therefore strapped to a trauma/fracture board.

Submit Clear

NRF home Nexus

- The patient is supine (See figure 1)
- 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 raised on the patient's head (not demonstrated below)
- The height of the cassette was adjusted so that it was centred at the level of C7-T1
- The patient's mid-sagittal plane adjusted parallel to the cassette and the midcoronal plane was perpendicular (Bontrager, 2000: 311).
- The patient's shoulder that is furthest from the cassette is depressed in the same orientation as the rest of the body as much as possible.
- The main beam (red arrow) is horizontal and perpendicular to the centre of the image receptor (green arrow).

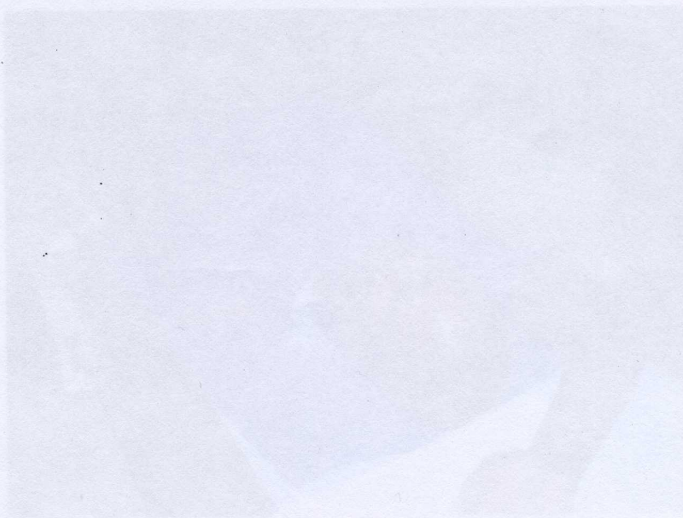


Figure 1: The Swimmers projection

APPENDIX 4

Positioning of the Swimmer's and Adapted Swimmer's projections

A large percentage of patients coming to the x-ray department for examinations of their cervical spine are trauma related patients and are therefore strapped to a trauma/ fracture board.

Position of part (swimmer's projection)

- ▶ The patient is supine (See figure 1)
- ▶ 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 (not demonstrated below)
- ▶ The height of the cassette was adjusted so that it was centred at the level of C₇-T₁
- ▶ The patient's mid-sagittal plane adjusted parallel to the cassette and the midcoronal plane was perpendicular (Bontrager, 2006: 311).
- ▶ 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 (red arrow) is horizontal and perpendicular to the centre of the image receptor (green arrow).



Figure 1: The Swimmers projection

Position of part (Adapted swimmer's projection)

- ▶ The patient is supine (See figure 2)
- ▶ 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-sagittal 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 (red arrow) is horizontal and perpendicular to the centre of the image receptor (green arrow).



Figure 2 The Adapted Swimmers projection

APPENDIX 5

UFS Ethics Committee Approval



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

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

E-mail address: gndkhs.md@mail.uovs.ac.za

Ms H Strauss

2006-03-17

MR RW BOTHA
SCHOOL OF HEALTH TECHNOLOGY
CENTRAL UNIVERSITY OF TECHNOLOGY, FREE STATE
BLOEMFONTEIN
9300

Dear Mr Botha

ETOVS NR 41/06
RESEARCHER: MR RW BOTHA
PROJECT TITLE: DEMONSTRATING THE CERVICOTHORACIC JUNCTION: A
COMPARISON OF TWO TECHNIQUES

You are hereby kindly informed that the Ethics Committee approved the above-mentioned study at their meeting held on 14 March 2006.

Your attention is kindly drawn to the following:

- A progress/final report have to be submitted after completion of the study or within a year after approval of the project
- That all extentions, amendments, serious adverse events, termination of a study etc have to be reported to the Ethics Committee
- These documents have been accepted as complying with the Ethics Standards for Clinical Research based on FDA, ICH GCP and Declaration of Helsinki guidelines as well as the Clinical Trials Guidelines 2000: Dept of Health RSA and MRC Guidelines on Ethics for Medical Research

Will you please quote the Etovs number as indicated above in subsequent correspondence to the secretariat.

Yours faithfully

DIRECTOR: FACULTY ADMINISTRATION

Researcher: RW Botha
Contact details: 051-5073179
0833819896

Study leader: Dr Africa
Contact details: 051-4051119



APPENDIX 6

Participating Radiographer Declaration

As part of an M-Tech study

Demonstrating the cervicothoracic junction: a comparison of two techniques.

I, hereby declare that:

I will conduct myself in an ethical and moral manner.

The information provided on Appendix 6 is correct and was obtained after explaining to the patient the procedure and using Appendix 8 where necessary.

I declare that I am participating of my own free will.

I also declare that I understand the consequences of providing wrong information.

Signature:.....

Date.....

Researcher: RW Botha
Contact details 051-5073179
0833819695

Study leader: Dr Africa
Contact details: 051- 4051119

APPENDIX 7

Consent form

As part of an M-Tech study
Demonstrating the cervicothoracic junction: a comparison of two techniques.

I, hereby give consent for an extra view to be taken of my neck.

I hereby declare the procedure has been explained to me byand that I understand what is going to happen.

I also declare that I am participating of my own free will.

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

If you agree to participate, you will be given a signed copy of this document as well as the participant information sheet, which is a written summary of the research project.

Nna....., ke fana ka tumello ya hore thuto e ka ntshetswa pele ho sebediswa molaleng wa ka ke hlaloseditswe KE.....

Ke a hlapanya hore ke ilwe ka hlaloeswa, ebile ke utlwisisa tsela eo mosebetsi o tlang ho etsahala.

Ke nka karolo ka ntle qobeletso.

O ka ikopanya le mongodi wa komiti ya melao ya botho ya le fapha la bophelo le mahlale, UFS-dinomorong tsena (051) 405 2812 e bang ona le dipotso ka ditokello tsa hao ebang o dumela ho nka karolo otlala fumana tumellano e ngodilweng ya pampiri e bontshang ka kgusofatso dintha tsa pupotso ya porojeke ena.

Hiermee gee ek....., toestemming vir die neem van 'n addisionele opname van my nek.

Ek verklaar hiermee dat die prosedure aan my verduidelik is deuren dat ek verstaan wat gaan gebeur.

Ek verklaar verder dat mydeelname uit vry wi isl.

U mag die Sekretariaat van die Etiese Komitee van die Fakultiet vir Gesondheidswetenskappe, UVS by telefoon nommer (051) 4052812, skakel as u enige vrae oor u regte as navorsings onderwerp het.

Indien u sou instem om deel te neem, sal u 'n ondertekende kopie van hierdie dokument sowel as die Onderwerp inligting blad, 'n opsomming van die navorsingsprojek, ontvang.

Signature:.....

Date:.....

Witness:.....

Date:.....

APPENDIX 8A

Information Sheet - English

Subject information Sheet

Research is just the process to learn the answer to a question. The question or purpose of this study is to find out which of two different methods will give the best diagnostic result in demonstrating the entire neck C₇-T₁. It is sometimes difficult for radiographers to do this successfully the first time. For this project we want to take one additional x-ray (projection) of your neck.

In patients with broad shoulders it is especially important to see C₇-T₁. In trauma, where time is of the essence, obtaining the desired results in the shortest time could be life saving (this is emphasized by the *Golden hour principle* which is a period within which treatment must be administered in order to avoid either loss of life or disablement in consequence of a particular injury). Thus an alternative method to the Twining method could reduce the repeat rate as well as the radiation dose and examination time.

In producing an x-ray we use radiation. Irradiation of humans in medical research can present certain risks. Such irradiation, when properly controlled by a qualified radiographer administering a small dose, carries a smaller risk to health than many chemicals, pharmaceuticals and other agents in common use. The doses used today falls below the dose threshold for cellular damage.

The success of this project relies on your participation.

Participation is voluntarily; you may decline participation or withdraw at any point during the procedure without fearing any repercussion.

Participants will not receive any compensation, no form of remuneration.

Efforts will be made to keep personal information confidential. Personal information may be disclosed if required by law.

Organizations that may inspect and/or copy your research records for quality assurance and data analysis include groups such as the Ethics Committee for Medical Research and the Medicines Control Council.

Any further queries should be forwarded to the following persons:

Researcher:
Contact details:

RW Botha
051-5073179
0833819695

Study leader:
Contact details:

Dr Africa
051- 4051119

Research Ethics Committee: (051) 4052812

APPENDIX 8B

Information Sheet - Sotho

Thuto pampiri ya tlhahiso leseding

Phuputso ke fela tsela ya ho ithuta karabo ho potso. Potso kapa sepheo sa thuto ena ke ho netefatsa hore na ke ofe mokgwa ho ena e mmedi o tla fana ka sephetho sa papiso ya molala kaofela, (C₇-T₁). Ka nako tse ding ho boima ho diradiographer ho etsa sena kgetho la pele ka kotleho. Ka baka lena porojeke ena re hloka ho nka pontshahatso ya molala wa hao ha ngwe(1) hape.

Ho bohlokwa haholo ho bona (C₇-T₁) bakuding ba mahetla a sephara. Ho tlameha ho ela hloko hore nakong ya mahlonoko, moo nako e leng bohlokwa, ho fumana diphetho tse batlehang nakong e kgutswane ho ka boloka bophelo(hona ho netefatswa ke *Golden hour principle*). Eo ke nako eo tswebetso etla mehlang ho etswa hore ho tle ho qobuwe lefu kapa fosahallo ya ditlamoraho tsa kotsi eitseng.

Ka hoo mokgwa o tshwang le Twining method o ka fokotsa pheta-pheto mmoho le bongata ba mahlasedi le nako ya tlhatlhobo.

Ho hlaliseng X-ray rehloka matla a letsatsi (radiation). Dipatlisiso tsa meriyana e ipapisitseng le irradiation ya batho eka tliša ditshoso tse mmalwa, mokgwa ona wa irradiation ha ole tlasa taolo e nepahetseng ya radiographer e loketseng ho fana ka kalo e nyane o ka fokotsa ditshoso bophelong ho feta dichemical, ditlhare le ding tse sebediswang ka tshwano. Dose e sebedisitsweng kajeno e wela ka tlase ho threshold dose bakeng ya di selle tse hlokofaditsweng, moo ho senang diphotoho tsa letho tse bonahalang.

Ho a tleha ha porojeke ea ho I tswethehile ka ho nka karolo ha hao. Ha ho motho ya qobellwang ho nka karolo o ka tlohela nako efe kapa efe haeba ose o sa rate. Ha hona mehato e tla nkuwa kgahlano le motho, ha hona moputso o fanwang ho batho ba nkang karolo. Boiteko bo tla etswa ho boloka ho nka karolo le ditaba sa hao di sireletsehile, tsireletso e re keke ra itlama ka yona. Ditaba tsa motho ho ka fanwa ka tsona ho ya ka molao

Mekgatlo eka fuposang kapa ho nka papiso\phuputso ya hao ya direkoto mabapi le hlahlobonetefatso le ditaba e kenyelesa ena Ethics Committee ya phuputso ya meriyana le meriyana taolo.

Ditlhakisetso mabapa le thuto ena di ka lebiswa ho ba lateleng:

Researcher:
Contact details:

RW Botha
051-5073179
0833819695

Study leader:
Contact details:

Dr Africa
051- 4051119

Research Ethics Committee: (051) 4052812

APPENDIX 8C

Information Sheet - Afrikaans

Onderwerp inligting blad

Navorsing is net die proses wat leer wat die antwoord is op 'n vraag. Die vraag of doel van die studie is om uit te vind watter een van die twee metodes sal die beste diagnostiese resultate gee in die demonstrering van die hele nek, C₇-T₁. Dit is soms moeilik vir die radiograawe om dit suksesvol te doen die eerste keer. Vir die projek wil ons graag 'n addisionele x-straal (projeksie) van u nek doen.

In pasiënte met breë skouers is dit in besonder belangrik om C₇-T₁ te sien. In trauma, waar tyd essensieël is, kan die verkryging van die verlangde resultate in die kortste moontlike tyd 'n lewe red (dit word beklemtoon deur die *Golden hour principle* wat 'n periode is waarin 'n sekere behadeling toegepas moet word om lewensverlies of 'n gebrek as gevolg van 'n sekere besering te voorkom). Dus kan 'n alternatiewe metode as die Twining metode, die herhaaltempo verminder, sowel as stralingsdosis en ondersoektyd.

In die produsering van x-strale gebruik ons bestraling. Bestraling van mense vir mediese navorsing het sekere berekende risiko's. Die bestraling, as reg gekontroleer deur 'n gekwalifiseerde radiograaf wat 'n klein dosis administreer, het 'n kleiner gesondheidsrisiko as baie chemikalië, medisyne en ander stowwe in algemene gebruik.

Die dosisse wat vandag gebruik word, val onder die drempeldosis vir sellulêre skade, waar geen merkwaardige veranderinge sigbaar is nie.

Die sukses van die projek hang af van u deelname.

Deelname is vrywillig: u kan weier om deel te neem of ontrek op enige stadium van die prosedure sonder om enige gevolge te vrees.

Deelnemers sal geen vergoeding ontvang nie, geen vorm van besoldiging

Voorsorgmaatreëls sal getref word om persoonlike informasie konfidensieël te hou.

Persoonlike inligting mag verskaf word indien verlang deur die wet.

Instansies wat die navorsings rekords mag inspekteer en/of kopieër vir kwaliteitskontrolle en data analise sluit groepe soos die Etiese komitee vir Mediese Navorsing en die Mediese Kontrole Raad.

Enige verdere navrae kan gerig word aan:

Navorser:

Kontak besonderhede:

Navorsing Etiese Komitee:

RW Botha

051-5073179

0833819695

(051) 4052812

Studieleier:

Kontak besonderhede:

Dr Africa

051- 4051119

APPENDIX 9

Film Evaluation Rubric

Evaluation rubric for assessment of C₇-T₁ in the study:

Demonstrating the cervicothoracic junction: a comparison of two techniques.

Film pair no.:

Please indicate the overall acceptability of the films by giving a value (1-4), WHERE

Qualifier	Interpretation
4	Excellent
3	Acceptable
2	Needs attention
1	Poor

This is to be done for each criterion in the table below.

Criteria	<u>Film a , Where 4 is the best and 1 is the lowest</u>	<u>Film b , Where 4 is the best and 1 is the lowest</u>
1. Lateral vertebrae C ₇ -T ₁ , not appreciably rotated		
2. Shoulders separated from each other		
3. X-ray penetration of shoulder region C ₇ -T ₁		
4. Contrast and density C ₇ -T ₁		
5. Demonstration of the bony structures of the cervicothoracic vertebrae		
6. Demonstration of pathology C ₇ -T ₁ (where applicable)		
7. Sharpness C ₇ -T ₁		
8. Spatial resolution C ₇ -T ₁		
<u>Total:</u>		

Which of the 2 projections has the least radiological diagnostic quality: which has to be repeated?

A
B

Note:

.....

Signature:

Qualification:

Researcher: RW Botha
Contact details: 051-5073179
 0833819695

Study leader: Dr Africa
Contact details: 051- 4051119

APPENDIX 10

Film Identification Sheet

Demonstrating the cervicothoracic junction: a comparison of two techniques.

Room:

Processor:

Radiographer:

VIEW	FILM IDENTIFICATION (A/ B)
SWIMMER'S	
ADAPTED SWIMMER'S	

Patient information:

Date	Shift	Patient no.	Ward	Clinical history
EG. 1/12/2005	7h30- 16h00	1234567	Ortho	Compression C ₇

Note:

.....
.....
.....

Signature:.....

Qualification:.....

Researcher: RW Botha
Contact details: 051-5073179
0833819695

Study leader: Dr Africa
Contact details: 051- 4051119

APPENDIX 11

Pilot study

DEMONSTRATING THE CERVICOTHORAXIC JUNCTION ON PLAIN FILM: AN ALTERNATIVE TO THE SWIMMERS.

R Botha

Abstract

This study was conducted to ascertain which of two techniques would result in more diagnostic films of patients with possible neck trauma. Twenty individuals were examined at the Radiology Department, Universitas hospital, Bloemfontein. Two exposures were done on each member of the sample: firstly the swimmers projection and secondly the orientation of the patient's arms was reversed. Using specific criteria to standardize evaluation, the films were evaluated by a radiologist. The adapted swimmers projection had better results in 50% of the categories. The swimmers projection was better in 33.3% of the categories. One category for both projections (16.7%) was equal.

Keywords:

Trauma
Swimmers projection
Orientation
Criteria

1. INTRODUCTION

The radiographic examination of a patient with suspected cervical spine trauma may be difficult and is usually limited to a few projections. The reasons for this are firstly that frequently the patient is unconscious and has associated injuries like pneumothorax/hemothorax, skull injuries as well as injuries of the extremities. Secondly unnecessary movement of such patients increases the risk of damage to the spinal cord (Ahmed, 2003: Online).

The single most important radiographic projection used under these conditions is that of the lateral projection, which includes the first cervical vertebrae (C₁), as well as the first thoracic vertebrae (T₁).

The lateral projection is always done first for all trauma patients because:

- the anatomy under investigation is not moved,

- pathology or possible problems are quickly identified,
- possible intervention can be planned

In essence, the cross-table lateral radiograph should serve only to assess obvious signs of instability and to detect gross fractures and dislocations. It is therefore of the utmost importance that not only the C₇ be visualized, but also to allow us to evaluate the relationship of the transitional architecture between C₇-T₁ vertebrae. The lateral projection (including T₁), may demonstrate obvious pathology or influence further positioning techniques to obtain the rest of the projections: anteroposterior, odontoid and obliques.

In a retrospective study of 740 patients (Davis, 2000: Online), the diagnosis of a cervical spine injury on plain radiographs was delayed or missed in 34 cases. In 10 of those 34 patients, permanent neurological sequelae developed that might have been avoided had the diagnosis been established at the outset.

In radiography, some projections are technically more challenging to perform. The demonstration of the cervicothoracic junction (C₇-T₁), using the swimmers method, heads this list. Daffner (2000: Online) also reported that the swimmer's projection needed to be repeated in 41% of all their patients. Of their study group 34% of the patients required three repeated radiographs and one patient each (2% of the study group) required four, and five repeated radiographs, respectively (Daffner, 2000: Online). In the demanding environment of a trauma department, having to do repeats, is not only stressful for the radiographer, but also life-threatening to the patient, costly and leads to an increase in radiation dose to the patient.

In this study, the researcher sought to ascertain which of the two techniques would result in optimum diagnosis of the cervicothoracic junction more frequently, thereby also increasing diagnosis and minimizing examination time and patient radiation dose.

This study should thus be viewed as an introductory study where the probability of an alternative to the generally accepted way of visualizing the lower cervical spine is of importance.

2. PURPOSE OF THE STUDY

The purpose of this study was to ascertain which of two different techniques [swimmers, adapted swimmers] will allow radiographers and radiologists to obtain the best diagnostic result in the shortest period of time of what is known as “the most commonly overlooked site of injury” (Ahmed, 2003: Online).

3. MATERIALS AND METHODS

B-room at the Universitas Hospital, is equipped with a functional x-ray machine (Siemens Vertix E), x-ray cassettes (Agfa), x-ray films (Agfa-CPG plus) as well as an operational x-ray processor. The x-ray machine was operated at 80% of its capacity. The reliance of the equipment’s performance was underscored by the fact that the machine had a newly installed generator.

To help reduce radiation, 400 speed screens were used. For radiation protection, it was sometimes necessary to use more than 1 wrap-around to ensure that every part of the anatomy was covered. Sensitometry was done to ensure that the processor function does not have an influence on image quality.

The sample that were used consists of 20 individuals. This is a very specific sample: the problem of demonstrating this junction occurs predominantly in patients with broad shoulders. A one cm interval caliper was used for the measurements. Measurements were made in the swimmers position at the level of C₇, just above the jugular notch. Each member of the sample was x-rayed twice:

- A. Using the Twinning method of performing the swimmers
- B. Reversing the orientation of the arms as was used in (A)

The caliper and standardized exposure chart was used to determine exposure factors. The same exposure factors will be used for both A & B, according to the measurement obtained per individual.

3.1 Positioning

The exposures were done with patient seated, in front of the vertical Bucky grid.

3.1.1 Position of part (swimmers)

- ▶ The midcoronal plane of the body was centered to the midline of the grid.
- ▶ The patient was moved close enough to the vertical Bucky so that the shoulders can rest firmly against the grid for support.
- ▶ The arm that is *closest* to the grid was elevated to a vertical position, the elbow flexed, and the forearm rested on the patient's head
- ▶ The height of the cassette was adjusted so that it was centered at the level of C₇-T₁
- ▶ The patient's mid-sagittal plane adjusted parallel to the cassette and the midcoronal plane was perpendicular
- ▶ The patient's shoulder that was *farthest from* the cassette was depressed as much as possible (Bontrager, 2005: 311).

3.1.2 Position of part (adapted view)

- ▶ The midcoronal plane of the body was centered to the midline of the grid.
- ▶ The patient was moved close enough to the vertical Bucky so that the shoulders can rest firmly against the grid for support.
- ▶ The arm that is *farther from* the grid was elevated to a vertical position, the elbow flexed, and the forearm rested on the patient's head
- ▶ The height of the cassette was adjusted so that it was centered at the level of C₇-T₁
- ▶ The patient's mid-sagittal plane adjusted parallel to the cassette and the midcoronal plane was perpendicular
- ▶ The patient's shoulder that was *closest to* the cassette was depressed

3.1.3 The following is applicable to both methods

i) Central ray

Directed to the interspace between C₇ and T₁ at an angle of 3 to 5 degrees caudal, depending on the mobility of the shoulder closest to the image receptor (Ballinger & Frank, 1999: 416)

ii) Evaluation criteria

- ✓ Lateral vertebrae, not appreciably rotated
- ✓ Shoulders separated from each other
- ✓ X-ray penetration of shoulder region

iii) Radiographic criteria

- ✓ Vertebral bodies, intravertebral disk spaces, and zygapophyseal joints C4-T3 are shown
- ✓ The humeral head and arm furthest away from the Image recorder is magnified and should appear distal to T₄ or T₅ (if visible) (Bontrager, 2005: 297)
- ✓ Contrast and density are adequate to demonstrate the bony structures of the cervicothoracic vertebrae (McQuillen-Martensen, 1996: 338)

3.2 Important image recording principles for demonstrating C₇-T₁

3.2.1 Object-to-image distance (IOD) Objects that are further from the image receptor will be magnified. The OID is also a critical distance in both magnification and resolution. First, when objects within a structure are at different levels, they will be projected onto the image as different sizes. To decrease magnification and to improve sharpness, the source to image distance was increased to 180cm.

3.2.2 Air Gap The modified technique involves placing the patient at a greater object image receptor distance (OID), thus creating an air gap between the anatomy of interest and the film. By having the anatomy away from the

film, the amount of scatter reaching the film will be reduced (Carlton, 2001: 276)

3.3.3 Alignment Shape distortion can be caused or avoided by careful alignment of the central ray with the anatomical part and the image receptor. Proper positioning is achieved when the central ray is at right angles to the anatomical part and to the image receptor. This means the part and the image receptor should be parallel (Carlton, 2001: 420)

3.3.4 Anatomical Part

The long axis of the anatomical part, or object, is intended to be positioned perpendicular to the central ray and parallel to the image receptor (Carlton, 2001: 422)

3.3.5 Film/Screen Combination

- The specifications of the film used are as follow:

The film ensures a high contrast in the low densities of the image. This permits the use of Ortho CP-G Plus film in applications such as angiography, where it gives sharp and detailed images of even the smallest blood vessels as well as of bone structures. Even small differences in absorption between soft tissue and air become visible by the varying density levels, thanks to the high conversion efficiency. The Ortho CP-G Plus film is ideal for the imaging of bone structures, allowing even the detection of hairline fractures. The film is also suitable for orthopedics where it will give the finest details of bony structures, yet keeping the soft tissue visible. It is used to detect calcification, early signs of lung cancer and metastasis (Agfa Medical Imaging: Online).

- The specifications of the screens used are as follow:

CP-G 400, 400 speed screens will be used.

This means that the amount of phosphor crystals and crystal sizes are high. This also reduces geometric unsharpness (Ball & Price, 2000: 29)

The green light emission of the screens that we are going to use is based upon the GadoliniumOxySulphide phosphor.

The use of the latest technology enables an optimal compromise to be reached between speed and definition, thus ensuring high image quality and a low noise level when used with green-sensitive films (Agfa Medical Imaging: Online).

3.2.6 Motion

- To avoid machine motion during exposure, make sure that all machine-locks are operating optimally.
- Correct immobilization of the anatomical part was employed.

3.3 Comparison of diagnostic quality

The images obtained were given to a doctor (radiologist) for reporting. To exclude possible bias the films were only marked a or b, meaning the doctor did not know the origin of the films. A rubric was used with specific guidelines as to ensure standardization of the evaluation.

A scoring system ranged from 4 to 1 was used:

Table 1 The scoring system

Qualifier	Interpretation
4	Excellent Where maximum radiological detection has been achieved.
3	Acceptable Where a good diagnosis is achievable
2	Needs attention Where possible diagnosis is achieved
1	Poor Where a good diagnosis is achievable.

Table 3 Film evaluation rubric

<u>CRITERIA</u>	<u>FILM A</u>	<u>FILM B</u>
Lateral vertebrae, not appreciably rotated		
Shoulders separated from each other		
X-ray penetration of shoulder region		
Contrast and density		
Demonstration of the bony structures of the cervicothoracic vertebrae		
Sharpness		
<u>Total:</u>		

In using the set criteria, the radiologists will compare overall acceptability of the newly proposed technique.

3.4. Statistical analysis

The results from each criterion were tabled. These results were analyzed using Microsoft Excel's Data analysis tool. Descriptive statistics allowed the researcher to evaluate which of the two techniques gave better results. The validity of the hypothesis was also investigated.

4. RESULTS

4.1 Imaging considerations

4.1.1 Measurements

The average measurement of the sample as measured at the centring point, was 32.2cm; median was 32cm and the mode 31cm

4.1.2 Exposures given

The average exposure given for the two views, keeping in mind that the same exposure was given for both, was 75.7kV and 105mAs. The exposure given to the smallest candidate was 75kV and 80mAs and for the biggest one the exposure was 77kV and 125mAs. It must be kept in mind that 400speed screens were used.

4.1.3 Sensitometry

The values obtained for sensitometry, when compared to the values desired (target), were equal to the target values in 3 of the 5 criteria. The variations were all found to be within acceptable limits; for average speed, an acceptable variation is plus or minus 0.15. The same applies to the contrast. (WHO, Quality assurance workbook, 2001: 115)

4.2 Criteria results

4.2.1 Rotation of the vertebrae

For rotation the mean for the swimmers was 2.45 and the mean for the adapted swimmers was 1.8. This can be viewed as less significant – the upper vertebrae was rotated in most cases. Remember that C₁-C₆ should already have been demonstrated on the lateral view.

4.2.2 Shoulder separation

The difference between the shoulder separation with the mean for the swimmers was 2.7 and the mean for the adapted swimmers was 2.4, equals 0.3. If one examines the geometry of the diverging x-ray beam and the centering point, the depressed shoulder (swimmers) would be projected even lower.

4.2.3 Penetration of the C₇-T₁ junction

X-ray penetration was mostly influenced by superimposition of the clavicle and humerus. If one examines the geometry and the centering point again, the raised shoulder (adapted swimmers) would be projected higher. Here the results obtained were better for the adapted swimmers: mean adapted swimmers was 3.35 mean swimmers was 2.15.

4.2.4 Contrast and density

Contrast and density for the adapted swimmers was better then for the swimmers. Keep in mind that these values are mostly subjective; it depends on a wide range of variables including ambient lighting.

4.2.5 Demonstrating C₇-T₁

The difference in visualization of C₇/T₁ was only 0.05 units. This difference translates into 1.25%. In a clinical setting, this percentage, small as it may seem, could mean the difference between making a positive diagnosis of pathology and permanent neurological problems associated with misdiagnosis.

4.2.6 Sharpness of the cortical outlines

Keeping in mind that the same exposures were given for both projections, it was actually very surprising to that the sharpness of the cortical outlines, were evaluated as being equal by the doctor.

4.3 Hypothesis testing

The p-value of the rows and columns, the actual probability of making a Type I error, is larger then 0.1-this protects the researcher from making a serious Type I error (Albright, 1999: 443). The following clarification of p-values is in order:

- ✓ p-value < 0.01 – convincing evidence that the alternative hypotheses (H₁): Reversing the orientation of the arms in the swimmer's view does not increases the diagnosis of abnormalities at C7-T1 transition, is true

- ✓ p-value < 0.05, but > 0.01 – strong evidence that the alternative hypotheses (H_1), is true
- ✓ p-value < 0.1, but > 0.05 – moderate evidence that the alternative hypotheses (H_1), is true

The correlation matrix analysis allows us to investigate the relationships between datasets; that is whether they move together.

- A negative correlation means that small values of one dataset are associated with large values from the other dataset
- A positive correlation means that large (small) values of one dataset are associated with large (small) values from the other dataset
- A correlation of near 0 means that the datasets are unrelated (Albright, 1999: 92).

There are no extreme values that may otherwise have had an influence on the results obtained. This also means that, even if better results were obtained when the orientation of the arms were reversed, the swimmers method still has a justified place in diagnostic radiography.

5. DISCUSSION AND CONCLUSION

The aim of this exercise as stated in the purpose was to ascertain which of two different techniques would allow radiographers to obtain the best diagnostic result in the shortest period of time of the cervicothoracic junction.

The respective performances of the two techniques where the advantage of the one method over the other is given by the actual difference and as a percentage (%) were as follow:

ADAPTED SWIMMERS was better in 50% of categories:

Penetration	= 0.2	5%
Contrast & Density	= 0.25	6.25%
C ₇ / T ₁	= 0.05	1.25%

The SWIMMERS was better in 33.3% of categories:

Rotation	= 0.65	16.25%
Shoulder separation	= 0.3	7.5%

During Hypothesis testing, the p-value for both rows and columns were greater than 0.1. Thus the probability is very high that, reversing the orientation of the arms in the Swimmer's view increases the diagnosis of abnormalities at C₇-T₁ transition.

It was also found that in raising the arm farthest from the film, there was a certain amount of enlargement. The arm acts as a natural filter because the humeri were projected more posterior, it was also more enlarged. It can sometimes be very testing on a radiographer to produce good quality films that are of diagnostic value. Knowing that there is an alternative method to visualising the C₇/T₁ junction could be beneficial not only to radiography, but also to patients.

ADAPTED SWIMMERS should thus not be seen as a substitute for the SWIMMERS, but as a way to help minimize repeat films and radiation exposure where the swimmers is not optimal.

6. REFERENCES

Agfaimaging (online), [n.d.] Available from: <
http://www.agfa.com/en/he/products_services/all_products/ortho_cpg_plus.jsp>
[Accessed on 25/02/2005]

Ahmad, N. 2003. **auntminnie** (online). Available from: <
<http://www.auntminnie.com/print.asp?Sec=sup&Sub=xra&Pag=dis&ItemId=57734>> [Accessed on 25/02/2004]

Albright SC, **Data analysis and decision making with Microsoft Excel**,
Duxbury press, 1999

Ball, J. & Price, T. 2000. **Chesney's Radiographic Imaging**, 6th edition, Boston.
Blackwell Science Ltd, pp 29

Ballinger, P.& Frank, E. 1999. **Merrill's atlas of Radiographic positions and Radiologic procedures, Volume 1**, 9th edition. St Loise. Mosby, pp 416

Bontrager, K. 2005. **Textbook of Radiographic positioning and related Anatomy**, 6th edition, Mosby, pp 311

Carlton, R.R. & Adler, A.M. 2001. **Principles of Radiographic Imaging- An art and a science**, 3rd edition, Albany, N.Y., Delmar Publishers, pp 404,416-420, 422

Daffner. 2000. **AJR** (online). Available from: <
<http://www.ajronline.org/cgi/content/full/175/5/1309> >
[Accessed on 26/11/2004]

Davis, N. 2000. **auntminnie** (online).Available from: <
<http://www.auntminnie.com/print.asp?Sec=sup&Sub=xra&Pag=dis> > [Accessed
on 22/03/2004]

McQuillen-Martensen. 1996 . **Radiographic Critique**, Philadelphia : Saunders,
pp 338

WHO, 2001. **Quality Assurance workbook for Radiographers and radiological technologists**, Geneva, pp 115.

APPENDIX 12

Consent Written Communication

Radiography Staff
Pelonomi Regional Hospital
Private Bag X205814
Bloemfontein
9300

Dear Participant

Demonstrating the cervicothoracic junction: a comparison of two techniques.

One of the problems raised during consultation relates to obtaining consent another to the fact that some patients have associated extremity pathology.

Unfortunately we can not do anything about the second reason, but for the first, I was able to get the following information from the Medical Research Council of South Africa's website:

It can be argued that written consent is not necessarily more valuable than the verbal form as proof of consent. Nevertheless, the use of written consent in research projects associated with minimal or more than minimal risk or with significant discomfort is recommended. Witnessed consent is useful for the aged and for those who have intellectual or cultural difficulties in speech or understanding, but who are deemed capable of giving consent. An independent person, e.g. a nurse, signs a document stating that the witness was present when the investigator explained the project to the potential subject, and that in the witness's opinion consent was given freely and with understanding.

It can be proper for research involving less than minimal risk and which is easily comprehended to proceed on the basis of oral consent given after an oral description of what is involved. It can be argued that written consent is not necessarily more valuable than the verbal form as proof of consent. Nevertheless, the use of written consent in research projects associated with minimal or more than minimal risk or with significant discomfort is recommended.

Follow-up information sessions will be scheduled to discuss this and other possible queries.

Yours truly,

.....
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APPENDIX 13 A

MS Excel Spreadsheet – Radiologist I

	Lateral vertebrae C7-T1, not appreciably rotated		Shoulders separated from each other		X-ray penetration of shoulder region C7-T1		Contrast and density C7-T1		Demonstration of the bony structures of the cervicothoracic		Demonstration of pathology C7-T1 (where applicable)		Sharpness C7-T1		Spatial resolution C7-T1		REPEAT=R, NO REPEAT=N	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Filmset 1	4	2	1	3	2	3	2	3	2	3	4	3	4	3	4	3	N	N
Filmset 2	3	4	4	2	4	1	1	3	3	1	3	1	3	4	3	4	N	R
Filmset 3	3	3	4	1	3	1	2	2	2	1	2	1	2	3	2	3	N	R
Filmset 4	3	3	3	3	1	2	3	2	1	2	2	2	3	2	3	2	N	R
Filmset 5	2	4	4	3	2	2	3	2	2	1	2	2	3	2	3	2	N	R
Filmset 6	4	4	1	2	1	2	3	2	1	2	2	2	2	3	2	3	R	N
Filmset 7	3	2	2	4	1	3	2	3	1	2	3	2	2	3	2	3	R	N
Filmset 8	4	3	4	3	1	3	2	2	1	2	2	2	3	2	3	2	N	R
Filmset 9	4	3	4	1	4	1	3	2	3	2	2	2	3	4	3	4	N	R
Filmset 10	4	3	3	4	2	3	2	3	2	3	2	2	2	3	2	3	R	N
Filmset 11	4	2	2	3	1	2	2	3	1	2	2	2	2	3	2	3	R	N
Filmset 12	4	2	2	3	4	2	3	2	4	2	2	2	3	2	3	2	N	R
Filmset 13	3	3	3	3	2	2	2	2	2	3	2	2	2	2	1	2	R	N
Filmset 14	2	2	2	3	3	2	2	3	2	3	2	3	1	1	1	1	R	N
Filmset 15	3	3	2	3	3	2	3	2	3	2	2	1	3	1	2	1	N	R
Filmset 16	2	2	1	4	1	3	1	2	1	2	1	2	1	2	1	2	R	N
Filmset 17	3	2	2	3	1	2	1	1	1	1	1	1	1	1	1	1	R	N

Filmset 18	3	2	2	3	2	3	2	3	2	3	2	3	2	3	2	3	R	N
Filmset 19	2	2	4	3	3	2	3	2	3	2	3	1	2	2	3	2	N	R
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Filmset 36	2	3	3	2	2	1	2	1	1	1	0	0	1	1	2	1	N	R
Filmset 37	2	2	3	2	3	2	3	1	2	1	0	0	2	1	2	1	N	R

Filmset 38	3	2	2	2	3	1	3	1	2	1	0	0	2	1	1	2	N	R
Filmset 39	3	2	3	2	3	2	3	1	3	1	0	0	3	2	3	1	N	R
Filmset 40	3	4	2	2	3	2	3	2	3	2	0	0	3	2	3	2	N	R
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Filmset 44	2	3	2	3	1	2	1	2	1	2	0	0	2	3	2	3	N	R
Filmset 45	2	3	3	2	2	3	2	3	2	3	0	0	2	3	2	2	R	N

APPENDIX 13 B

MS Excel Spreadsheet – Radiologist II

	Lateral vertebrae C7-T1, not appreciably rotated		Shoulders separated from each other		X-ray penetration of shoulder region C7-T1		Contrast and density C7-T1		Demonstration of the bony structures of the cervicothoracic		Demonstration of pathology C7-T1 (where applicable)		Sharpness C7-T1		Spatial resolution C7-T1		REPEAT=R, NO REPEAT=N	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Filmset 1	3	3	2	3	3	3	2	3	2	3	0	0	3	2	2	2	R	N
Filmset 2	3	3	3	1	3	2	3	2	3	2	0	0	3	2	3	2	N	R
Filmset 3	3	3	4	1	3	1	2	1	2	1	0	0	2	1	2	1	N	R
Filmset 4	3	3	2	2	2	2	2	2	2	2	0	0	1	2	1	2	R	R
Filmset 5	3	3	3	2	3	2	3	2	2	2	0	0	2	1	3	2	N	R
Filmset 6	3	3	1	2	1	1	1	1	1	2	0	0	1	2	1	2	R	R
Filmset 7	1	3	1	2	1	3	1	2	1	3	0	0	1	2	1	2	R	N
Filmset 8	1	3	1	3	1	3	1	3	1	3	0	0	1	3	1	3	R	N
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Filmset 13	3	4	4	4	3	4	2	3	2	3	0	0	2	3	2	3	R	N
Filmset 14	3	3	2	2	3	2	3	2	3	2	0	0	2	2	3	3	N	R
Filmset 15	3	3	3	3	3	2	2	2	3	2	0	0	3	1	3	1	N	R
Filmset 16	1	3	1	4	1	3	1	3	1	3	0	0	1	3	1	3	R	N
Filmset 17	1	2	1	4	1	2	1	2	1	1	0	0	1	1	1	1	R	N

Filmset 18	2	3	1	4	3	3	3	3	2	3	0	0	2	3	2	3	R	N
Filmset 19	3	2	1	4	3	2	3	2	3	2	0	0	2	2	2	1	N	R
Filmset 20	1	2	4	4	1	2	1	2	1	2	0	0	1	2	1	2	R	N
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Filmset 23	2	2	3	2	1	2	1	1	1	1	0	0	1	1	1	1	N	N
Filmset 24	3	2	4	2	3	1	3	1	3	1	0	0	3	1	3	1	N	R
Filmset 25	3	3	4	3	3	3	3	3	3	3	0	0	4	3	3	3	N	N
Filmset 26	3	3	3	2	3	3	3	3	3	3	0	0	4	2	3	2	N	N
Filmset 27	2	1	1	4	2	1	2	1	2	1	0	0	2	1	2	1	N	N
Filmset 28	2	3	2	4	3	2	3	2	3	2	0	0	3	2	3	2	N	N
Filmset 29	2	4	2	4	2	3	1	3	1	4	0	0	1	3	1	3	R	N
Filmset 30	1	1	1	4	1	1	1	1	1	1	0	0	1	1	1	1	R	R
Filmset 31	2	3	1	4	2	2	2	2	2	2	0	0	2	2	2	2	R	N
Filmset 32	3	3	3	2	1	2	1	1	2	1	0	0	2	1	1	1	R	R
Filmset 33	4	4	4	4	3	4	3	3	3	3	0	0	3	3	3	3	N	N
Filmset 34	3	3	4	2	3	3	3	1	2	1	0	0	2	1	2	1	N	R
Filmset 35	2	1	2	3	3	1	2	1	2	1	0	0	2	1	2	1	N	R
Filmset 36	2	2	1	3	2	1	2	1	1	1	0	0	2	1	1	1	R	R
Filmset 37	3	1	4	1	2	1	2	1	2	1	0	0	2	1	2	1	N	R

Filmset 38	3	1	1	1	2	1	2	1	2	1	0	0	1	1	1	1	N	R
Filmset 39	3	3	2	3	2	3	2	3	2	3	0	0	2	3	2	3	R	N
Filmset 40	3	2	3	2	3	1	3	1	3	1	0	0	3	1	3	1	N	R
Filmset 41	3	3	4	1	4	1	4	1	4	1	4	2	4	1	4	1	N	R
Filmset 42	3	4	4	4	2	3	2	3	2	3	0	0	2	3	2	3	R	N
Filmset 43	3	3	4	1	2	2	2	2	2	2	0	0	2	2	2	2	N	N
Filmset 44	2	2	1	4	1	2	1	2	1	2	0	0	1	1	1	1	R	N
Filmset 45	3	4	4	3	3	4	2	4	2	3	0	0	2	3	2	3	R	N

APPENDIX 13 C

MS Excel Spreadsheet – Radiologist III

	Lateral vertebrae C7-T1, not appreciably rotated		Shoulders separated from each other		X-ray penetration of shoulder region C7-T1		Contrast and density C7-T1		Demonstration of the bony structures of the cervicothoracic		Demonstration of pathology C7-T1 (where applicable)		Sharpness C7-T1		Spatial resolution C7-T1		REPEAT=R, NO REPEAT=N	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Filmset 1	3	2	1	1	3	3	3	3	3	3	0	0	3	3	3	3	N	N
Filmset 2	3	3	3	2	3	2	3	3	3	2	0	0	2	2	3	2	N	R
Filmset 3	3	2	3	1	3	2	3	2	3	2	0	0	3	2	3	1	N	R
Filmset 4	2	1	2	1	2	2	2	1	2	1	0	0	2	1	2	2	N	R
Filmset 5	3	2	4	1	3	2	3	2	3	2	0	0	3	2	3	2	N	R
Filmset 6	1	1	1	1	2	2	2	2	2	2	0	0	2	2	2	2	R	N
Filmset 7	1	2	1	2	1	2	1	2	1	3	0	0	1	2	1	2	R	N
Filmset 8	1	2	1	3	1	2	1	3	1	3	0	0	1	2	1	3	N	R
Filmset 9	3	3	4	1	4	2	3	2	3	2	0	0	3	2	3	1	N	R
Filmset 10	3	3	3	4	3	2	3	2	3	2	0	0	2	3	3	3	R	N
Filmset 11	1	3	1	3	1	3	1	2	1	2	1	1	1	2	1	1	R	N
Filmset 12	4	1	1	4	3	2	3	2	3	1	0	0	3	1	3	1	N	R
Filmset 13	3	3	1	3	1	3	2	2	2	3	0	0	2	3	1	2	R	N
Filmset 14	3	2	2	1	3	1	2	1	2	1	0	0	2	1	1	1	R	N
Filmset 15	2	4	4	2	3	3	2	3	2	3	0	0	2	2	2	3	N	R
Filmset 16	1	2	1	4	1	3	1	3	1	3	0	0	1	2	1	3	R	N
Filmset 17	1	2	1	3	1	2	1	2	1	2	0	0	1	2	1	2	R	N

Filmset 18	2	3	2	3	3	4	3	3	2	4	0	0	2	3	2	3	R	N
Filmset 19	2	2	4	4	2	2	2	1	2	1	0	0	2	1	2	1	N	R
Filmset 20	1	3	3	4	1	3	1	3	1	2	0	0	1	2	1	2	R	N
Filmset 21	3	3	4	4	4	4	3	4	4	4	0	0	3	3	3	3	N	R
Filmset 22	3	4	1	1	2	1	2	1	2	1	0	0	2	1	2	1	R	R
Filmset 23	3	1	1	1	1	1	1	1	1	1	0	0	2	1	2	1	R	R
Filmset 24	3	3	4	2	4	2	3	2	3	2	0	0	3	2	3	2	N	R
Filmset 25	3	3	4	3	3	3	3	3	3	3	0	0	2	2	2	3	N	N
Filmset 26	3	3	4	2	3	3	3	2	4	2	0	0	3	3	3	3	N	N
Filmset 27	3	3	3	3	2	2	2	2	2	2	0	0	2	2	2	2	R	R
Filmset 28	4	3	4	4	3	2	3	2	3	3	0	0	3	2	3	2	N	N
Filmset 29	2	2	3	2	2	3	2	3	2	3	0	0	2	3	1	3	R	N
Filmset 30	2	1	3	1	2	1	2	1	2	1	0	0	1	1	1	1	R	R
Filmset 31	2	2	3	3	2	2	2	2	3	2	0	0	3	2	2	1	N	R
Filmset 32	2	2	1	3	1	1	1	1	1	1	0	0	1	1	1	1	R	R
Filmset 33	2	2	3	3	3	3	2	3	2	3	0	0	2	3	2	3	R	N
Filmset 34	3	2	3	2	3	2	2	2	3	2	0	0	2	1	2	1	N	R
Filmset 35	3	2	1	2	2	1	2	1	2	1	0	0	1	1	1	1	R	R
Filmset 36	2	2	2	2	1	1	1	1	1	1	0	0	1	1	1	1	R	R
Filmset 37	2	2	2	2	1	1	2	1	2	1	0	0	2	1	2	1	R	R

Filmset 38	2	1	1	1	2	1	2	1	2	1	0	0	1	1	1	1	R	R
Filmset 39	3	2	3	2	3	2	3	2	3	1	0	0	3	1	3	1	N	R
Filmset 40	2	2	1	1	2	3	2	3	2	3	0	0	1	2	2	3	R	N
Filmset 41	4	2	4	1	4	2	4	1	4	2	3	1	3	2	3	1	N	R
Filmset 42	2	2	3	3	3	3	2	2	2	3	0	0	2	2	2	2	N	N
Filmset 43	2	2	2	1	2	2	2	2	3	2	0	0	2	2	2	1	R	R
Filmset 44	1	2	1	3	1	2	1	2	1	2	0	0	1	1	1	1	R	R
Filmset 45	2	3	2	2	2	2	2	2	2	3	0	0	2	2	1	3	R	N

APPENDIX 14 A

Statistical analysis and Frequency Distribution – Radiologist I

		Frequency Procedure			Cumulative Percent 3/4	% difference
	Frequency	Percent	Cumulative Percent 1/2			
Lateral vertebrae C7-T1, not appreciably rotated - A						
1	2	4.44%				
2	19	42.22%	46.67%			
3	17	37.78%				
4	7	15.56%		53.33%		
					-6.67%	
Lateral vertebrae C7-T1, not appreciably rotated - B						
1	3	6.67%				
2	19	42.22%	48.89%			
3	19	42.22%				
4	4	8.89%		51.11%		
					-2.22%	
Shoulders separated from each other - A						
1	3	6.67%				
2	17	37.78%	44.44%			
3	17	37.78%				
4	8	17.78%		55.56%		
					-11.11%	
Shoulders separated from each other - B						
1	3	6.67%				
2	17	37.78%	44.44%			
3	22	48.89%				
4	3	6.67%		55.56%		
					-11.11%	
X-ray penetration of shoulder region C7-T1 - A						
1	10	22.22%				
2	15	33.33%	55.56%			
3	15	33.33%				
4	5	11.11%		44.44%		
					11.11%	
X-ray penetration of shoulder region C7-T1 - B						
1	11	24.44%				
2	23	51.11%	75.56%			
3	11	24.44%				
4	0	0.00%		24.44%		
					51.11%	
Contrast and density C7-T1- A						
Frequency	Percent	Cumulative Percent 1/2	Cumulative Percent 3/4	% difference		

	1	6	13.33%			
	2	20	44.44%	57.78%		
	3	18	40.00%			
	4	1	2.22%		42.22%	
						15.56%
Contrast and density C₇-T₁-B	Frequency	Percent	Cumulative Percent 1/ 2	Cumulative Percent 3/ 4		% difference
	1	11	24.44%			
	2	22	48.89%	73.33%		
	3	12	26.67%			
	4	0	0.00%		26.67%	
						46.67%
Demonstration of the bony structures of the cervicothoracic - A	Frequency	Percent	Cumulative Percent 1/ 2	Cumulative Percent 3/ 4		% difference
	1	11	24.44%			
	2	21	46.67%	71.11%		
	3	12	26.67%			
	4	1	2.22%		28.89%	
						42.22%
Demonstration of the bony structures of the cervicothoracic - B	Frequency	Percent	Cumulative Percent 1/ 2	Cumulative Percent 3/ 4		% difference
	1	17	37.78%			
	2	19	42.22%	80.00%		
	3	9	20.00%			
	4	0	0.00%		20.00%	
						60.00%
Pathology C₇-T₁- A	Frequency	Percent	Cumulative Percent 1/ 2	Cumulative Percent 3/ 4		% difference
	1	3	13.64%			
	2	14	63.64%	77.27%		
	3	4	18.18%			
	4	1	4.55%		22.73%	
						54.55%
Pathology C₇-T₁- B	Frequency	Percent	Cumulative Percent 1/ 2	Cumulative Percent 3/ 4		% difference
	1	6	27.27%			
	2	13	59.09%	86.36%		
	3	3	13.64%			
	4	0	0.00%		13.64%	
						72.73%
Sharpness C₇-T₁- A	Frequency	Percent	Cumulative Percent 1/ 2	Cumulative Percent 3/ 4		% difference
	1	6	13.33%			
	2	23	51.11%	64.44%		
	3	15	33.33%			
	4	1	2.22%		35.56%	
						28.89%
Sharpness C₇-T₁- B	Frequency	Percent	Cumulative Percent 1/ 2	Cumulative Percent 3/ 4		% difference
	1	15	33.33%			
	2	15	33.33%	66.67%		

	Frequency	Percent	Cumulative Percent 1/ 2	Cumulative Percent 3/ 4	% difference
	3	13	28.89%		
	4	2	4.44%	33.33%	33.33%
Spatial resolution C₇-T₁ - A					
	1	6	13.33%		
	2	21	46.67%	60.00%	
	3	17	37.78%		
	4	1	2.22%	40.00%	20.00%
Spatial resolution C₇-T₁ - B					
	1	12	26.67%		
	2	20	44.44%	71.11%	
	3	11	24.44%		
	4	2	4.44%	28.89%	42.22%

Repeat rate- A	Frequency	Percent
No repeat required	29	64.44%
Repeat required	16	35.56%

Repeat rate- B	Frequency	Percent
No repeat required	17	37.78%
Repeat required	28	62.22%

APPENDIX 14 B

Statistical analysis and Frequency Distribution – Radiologist

II

		Frequency Procedure		Cumulative Percent 1/ 2	Cumulative Percent 3/ 4	% difference
Lateral vertebrae C7-T1, not appreciably rotated - A		Frequency	Percent			
	1	7	15.56%			
	2	9	20.00%	35.56%		
	3	27	60.00%			
	4	2	4.44%		64.44%	
						-28.89%
Lateral vertebrae C7-T1, not appreciably rotated - B		Frequency	Percent	Cumulative Percent 1/ 2	Cumulative Percent 3/ 4	% difference
	1	5	11.11%			
	2	10	22.22%	33.33%		
	3	24	53.33%			
	4	6	13.33%		66.67%	
						-33.33%
Shoulders separated from each other - A		Frequency	Percent	Cumulative Percent 1/ 2	Cumulative Percent 3/ 4	% difference
	1	14	31.11%			
	2	9	20.00%	51.11%		
	3	10	22.22%			
	4	12	26.67%		48.89%	
						2.22%
Shoulders separated from each other - B		Frequency	Percent	Cumulative Percent 1/ 2	Cumulative Percent 3/ 4	% difference
	1	8	17.78%			
	2	11	24.44%	42.22%		
	3	11	24.44%			
	4	15	33.33%		57.78%	
						-15.56%
X-ray penetration of shoulder region C7-T1 - A		Frequency	Percent	Cumulative Percent 1/ 2	Cumulative Percent 3/ 4	% difference
	1	11	24.44%			
	2	11	24.44%	48.89%		
	3	22	48.89%			
	4	1	2.22%		51.11%	
						-2.22%
X-ray penetration of shoulder region C7-T1 - B		Frequency	Percent	Cumulative Percent 1/ 2	Cumulative Percent 3/ 4	% difference
	1	14	31.11%			
	2	15	33.33%	64.44%		
	3	13	28.89%			
	4	3	6.67%		35.56%	
						28.89%

Contrast and density C₇-T₁-A			Cumulative Percent 1/2	Cumulative Percent 3/4	% difference
Frequency	Percent				
1	12	26.67%			
2	17	37.78%	64.44%		
3	14	31.11%			
4	2	4.44%		35.56%	
					28.89%
Contrast and density C₇-T₁-B			Cumulative Percent 1/2	Cumulative Percent 3/4	% difference
Frequency	Percent				
1	16	35.56%			
2	15	33.33%	68.89%		
3	13	28.89%			
4	1	2.22%		31.11%	
					37.78%
Demonstration of the bony structures of the cervicothoracic - A			Cumulative Percent 1/2	Cumulative Percent 3/4	% difference
Frequency	Percent				
1	12	26.67%			
2	19	42.22%	68.89%		
3	13	28.89%			
4	1	2.22%		31.11%	
					37.78%
Demonstration of the bony structures of the cervicothoracic - B			Cumulative Percent 1/2	Cumulative Percent 3/4	% difference
Frequency	Percent				
1	16	35.56%			
2	14	31.11%	66.67%		
3	14	31.11%			
4	1	2.22%		33.33%	
					33.33%
Pathology C₇-T₁-A			Cumulative Percent 1/2	Cumulative Percent 3/4	% difference
Frequency	Percent				
1		0.00%			
2		0.00%	0.00%		
3		0.00%			
4	1	100.00%		100.00%	
					-100.00%
Pathology C₇-T₁-B			Cumulative Percent 1/2	Cumulative Percent 3/4	% difference
Frequency	Percent				
1		0.00%			
2	1	100.00%	100.00%		
3		0.00%			
4		0.00%		0.00%	
					100.00%
Sharpness C₇-T₁-A			Cumulative Percent 1/2	Cumulative Percent 3/4	% difference
Frequency	Percent				
1	13	28.89%			
2	19	42.22%	71.11%		
3	10	22.22%			
4	3	6.67%		28.89%	
					42.22%
Sharpness C₇-T₁-B			Cumulative Percent 1/2	Cumulative Percent 3/4	% difference
Frequency	Percent				

	Frequency	Percent	Cumulative Percent 1/2	Cumulative Percent 3/4	% difference
1	18	40.00%	2		
2	15	33.33%	73.33%		
3	12	26.67%			
4	0	0.00%		26.67%	
					46.67%

Spatial resolution C ₇ -T ₁ - A	Frequency	Percent	Cumulative Percent 1/2	Cumulative Percent 3/4	% difference
1	15	33.33%	2		
2	16	35.56%	68.89%		
3	13	28.89%			
4	1	2.22%		31.11%	
					37.78%

Spatial resolution C ₇ -T ₁ - A	Frequency	Percent	Cumulative Percent 1/2	Cumulative Percent 3/4	% difference
1	18	40.00%	2		
2	14	31.11%	71.11%		
3	13	28.89%			
4	0	0.00%		28.89%	
					42.22%

Repeat rate- A	Frequency	Percent
No repeat required	24	53.33%
Repeat required	21	46.67%

Repeat rate- B	Frequency	Percent
No repeat required	25	55.56%
Repeat required	20	44.44%

APPENDIX 14 C

Statistical analysis and Frequency Distribution – Radiologist

III

Frequency Procedure					
	Frequency	Percent	Cumulative Percent 1/2	Cumulative Percent 3/4	% difference
Lateral vertebrae C7-T1, not appreciably rotated - A	1	8	17.78%		
	2	16	35.56%	53.33%	
	3	18	40.00%		
	4	3	6.67%		46.67%
Lateral vertebrae C ₇ -T ₁ , not appreciably rotated - B	1	6	13.33%		
	2	23	51.11%	64.44%	
	3	14	31.11%		
	4	2	4.44%		35.56%
Shoulders separated from each other - A	1	16	35.56%		
	2	7	15.56%	51.11%	
	3	12	26.67%		
	4	10	22.22%		48.89%
Shoulders separated from each other - B	1	14	31.11%		
	2	12	26.67%	57.78%	
	3	12	26.67%		
	4	7	15.56%		42.22%
X-ray penetration of shoulder region C ₇ -T ₁ - A	1	12	26.67%		
	2	13	28.89%	55.56%	
	3	16	35.56%		
	4	4	8.89%		44.44%
X-ray penetration of shoulder region C ₇ -T ₁ - B	1	9	20.00%		
	2	22	48.89%	68.89%	
	3	12	26.67%		
	4	2	4.44%		31.11%
Contrast and density C ₇ -T ₁ -A	Frequency	Percent	Cumulative Percent 1/2	Cumulative Percent 3/4	% difference

				2		
	1	10	22.22%			
	2	20	44.44%	66.67%		
	3	14	31.11%			
	4	1	2.22%		33.33%	
						33.33%
Contrast and density C₇-T₁-B				Cumulative Percent 1/2	Cumulative Percent 3/4	% difference
	1	12	26.67%			
	2	21	46.67%	73.33%		
	3	11	24.44%			
	4	1	2.22%		26.67%	
						46.67%
Demonstration of the bony structures of the cervicothoracic - A				Cumulative Percent 1/2	Cumulative Percent 3/4	% difference
	1	10	22.22%			
	2	18	40.00%	62.22%		
	3	14	31.11%			
	4	3	6.67%		37.78%	
						24.44%
Demonstration of the bony structures of the cervicothoracic - B				Cumulative Percent 1/2	Cumulative Percent 3/4	% difference
	1	13	28.89%			
	2	17	37.78%	66.67%		
	3	13	28.89%			
	4	2	4.44%		33.33%	
						33.33%
Pathology C₇-T₁-A				Cumulative Percent 1/2	Cumulative Percent 3/4	% difference
	1	1	50.00%			
	2	0	0.00%	50.00%		
	3	1	50.00%			
	4	0	0.00%		50.00%	
						0.00%
Pathology C₇-T₁-B				Cumulative Percent 1/2	Cumulative Percent 3/4	% difference
	1	2	100.00%			
	2	0	0.00%	100.00%		
	3	0	0.00%			
	4	0	0.00%		0.00%	
						100.00%
Sharpness C₇-T₁-A				Cumulative Percent 1/2	Cumulative Percent 3/4	% difference
	1	13	28.89%			
	2	20	44.44%	73.33%		
	3	12	26.67%			
	4	0	0.00%		26.67%	
						46.67%
Sharpness C₇-T₁-B				Cumulative Percent 1/2	Cumulative Percent 3/4	% difference
	1	15	33.33%	82.22%		

2	22	48.89%			
3	8	17.78%			
4	0	0.00%		17.78%	
					64.44%

Spatial resolution C ₇ -T ₁ - A			Cumulative Percent 1/ 2	Cumulative Percent 3/ 4	% difference
1	16	35.56%			
2	16	35.56%	71.11%		
3	13	28.89%			
4	0	0.00%		28.89%	
					42.22%

Spatial resolution C ₇ -T ₁ - A			Cumulative Percent 1/ 2	Cumulative Percent 3/ 4	% difference
1	20	44.44%			
2	12	26.67%	71.11%		
3	13	28.89%			
4	0	0.00%		28.89%	
					42.22%

Repeat rate- A	Frequency	Percent
No repeat required	20	44.44%
Repeat required	25	55.56%

Repeat rate- B	Frequency	Percent
No repeat required	19	42.22%
Repeat required	26	57.78%

APPENDIX 15

Minimum and Maximum Values

Criteria	Radiologist I				Radiologist I				Radiologist III			
	A		B		A		B		A		B	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Rotation	4.4	15.6	6.6	8.9	15.6	4.4	11.1	13.3	17.8	6.7	13.3	4.4
Separation	6.7	17.8	6.7	6.7	31.1	26.7	17.8	33.3	35.6	22.2	31.1	15.6
X-ray Penetration	22.2	11.1	24.4	0	24.4	2.2	31.1	6.7	26.7	8.9	20	4.4
Contrast & Density	13.3	2.2	24.2	0	26.7	4.4	35.6	2.2	22.2	2.2	26.7	2.2
Bony Structures	24.4	2.2	37.8	0	26.7	2.2	35.6	2.2	22.2	6.7	28.9	4.4
Sharpness	13.3	2.2	33.3	4.4	28.9	6.7	40	0	28.9	0	33.3	0
Spatial Resolution	13.3	2.2	26.7	4.4	33.3	2.2	40	0	35.6	0	44.4	0