Patient related factors influencing the quality of paediatric chest radiographs

Eben Albert Strasheim

Student number: 952304

Masters in Medicine - Diagnostic Radiology

A research report submitted to the Faculty of Health Sciences, University of the Witwatersrand, Johannesburg, in partial fulfilment of the requirements for the degree of Master of Medicine in Diagnostic Radiology.

Johannesburg, 2017

Declaration

I, Eben Strasheim, declare that this research report is my own work. It is being submitted for the degree of MMed (RadD) at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at this or any other University.

Dr. Eben Albert Strasheim

On this 1st day of June 2017.

This study is dedicated to all the health care workers leaving their homes tonight to serve their communities.

Publications and presentations

This work has never been published as an abstract in the South African Journal of Radiology, May 2017.

This work has been presented as a poster at the South African Society of Paediatric Imaging congress, November 2016.

Abstract

INTRODUCTION: The chest radiograph is the most common radiographic examination performed worldwide due to its versatility. Improving the quality of chest radiographs and avoiding repeat radiographs can decrease the collective radiation dose to children.

AIM: To identify patient related factors that influence the quality of paediatric chest radiographs by assessing the quality of chest radiographs and to compare the quality of chest radiographs in "radiologically" sick patients to those of "radiologically" normal patients.

METHOD: A retrospective study was performed to determine the quality of paediatric chest radiographs forming part of an existing database. The sample size of 280 radiographs, included radiographs of children aged 3 days to 13 years. Radiographic errors were captured on an electronic tick-sheet, consisting of twelve specific radiographic errors commonly made in practice and included the presence or absence of respiratory pathology. Data was extracted with regards to each of the 12 errors, patient demographics and presence of respiratory pathology to identify associations.

RESULTS: The mean patient age was 52.95 months. The most common errors were, in descending order, "rotation", "under inspiration" and "trachea and bronchi not well seen." The most common respiratory pathologic finding was "Airspace opacification". There was a statistically significant, low correlation present between the radiographic error count and the presence of respiratory pathology ($p<0.001$). There was a statistically

significant difference in the quality of chest radiographs of children aged 0-18 months and those aged 37-156 months ($p<0.05$).

CONCLUSIONS: The results of this study have demonstrated that there is a correlation between the presence of respiratory disease on a paediatric chest radiograph and the quality of the chest radiograph. The numbers of errors detected were higher in patients with respiratory pathology on the chest radiograph.

Acknowledgements

I would like to thank my ever-loving wife, Liesl, for her continued support in everything that I do.

My supervisor, Dr. Linda Tebogo Hlabangana for her enthusiasm for research. Thank you for leading by example and for having confidence in me.

Dr. Jaishree Naidoo and Dr. Tanyia Pillay, the readers of the study, for slaving through my cases.

Prof. Herman Schoeman for his assistance with the statistical analysis.

Noleen Gordon for explaining the basics and the help with the administrative work surrounding the project. It will not be the same without you in the department.

Dr. Su Lucas for the good research advice during lunchtime at Chris Hani Baragwanath Academic Hospital.

Table of Contents

List of Tables

1. Chapter One: Introduction

The chest radiograph is most common radiographic examination performed worldwide due to its versatility(1). Radiographic quality is of extreme importance and when compromised can affect diagnostic accuracy(2, 3). Ionizing radiation exposure during childhood, can double the chances of contracting cancer later in life(4). The younger the paediatric patient is at exposure, the higher the risk of detrimental effects, thus it is of paramount importance to avoid unnecessary radiation(5, 6). By improving the quality of chest radiographs and avoiding repeat radiographs, the collective dose to children can be decreased(4). Radiographers and radiologists have been known to disagree about the quality of investigations and so performance assessment and quality assurance is crucial in any department(4, 7). The training of radiographers has been shown to be the vital component in protecting patients against unnecessary exposure(7). One of the pillars of radiological practice is to optimize radiation exposure during imaging with the goal of minimizing damage from ionizing radiation(5). By highlighting the factors that decrease the quality of radiographs, I hope to decrease repeat investigations and improve diagnostic quality of chest radiographs, thereby decreasing ionizing radiation and reducing its detrimental effects on children.

1.1. Background

Despite the adoption and widespread use of computed tomography (CT), magnetic resonance imaging (MRI) and ultrasound to investigate the paediatric thorax, the chest radiograph is still the most used radiological method of diagnosing pneumonia(1). The

chest radiograph remains to be the most cost effective, accessible and efficient in both time and radiation dose(1). Most paediatric patients will need serial investigations during their hospital stay and due to their relative sensitivity to ionizing radiation; the aim is to optimize the investigation to keep radiation exposure to a minimum(4). Pneumonia is a common illness in children, affecting 2% of children annually and often resulting in admission to a health care facility(8, 9). Due to its efficiency the chest radiograph remains important in classifying pneumonia(10). Patria et al studied the clinical severity of a child with suspected pneumonia correlating it with radiological severity. They found that bilateral lung, right hilar involvement, as well as radiological involvement of more than three sites, suggested severe pneumonia(9). Airspace opacification, pleural effusions, hilar lymphadenopathy and airway compression are radiographic signs of pneumonia and when present, indicate a radiologically severe or sick patient(11, 12). The absence of these findings will result in a normal radiological report, however that does not exclude pneumonia, which remains a clinical diagnosis.

1.2. Chest radiography in general

Radiographs are the most frequently performed radiologic investigation in the United States of America(7). "An estimated 324 million general radiographic studies were performed in the USA in 2006, including 129 million chest radiographs(7)". Even though the dose of a single radiograph is low compared to computed tomography, the widespread use of chest radiographs and the use of radiographs as a screening tool leads to a high collective dose(1). It has been shown that radiography is being performed more frequently on paediatric patients in recent times and that the effective dose to children is 30-60% more than adults(13, 14). Radiology is linked to technology and has shown the

rapid progress in the last 20 years. The formation of dose sparing guidelines, quality assurance and staff education has lagged behind the fast pace of digital radiographic technology development(7). Image quality is a very important consideration when assessing factors related to patient dose(15).

1.3. Patient related factors impacting the quality of chest radiographs

Image quality can be defined as the "characteristic of an image that measures the perceived image degradation (typically, compared to an ideal or perfect image)"(15). Minor changes in the quality of the paediatric chest radiograph can be challenging to identify, however Vetter et al described the image criteria of a frontal projection chest radiograph to include: The entire ribcage at the end of inspiration, the trachea and bronchi should be well visualized, all intravascular catheters should be visible and good visualization of the pulmonary vasculature(16). It is often difficult to quantify image quality and slight changes in technique will often go unnoticed and can be tedious to identify(10). To further complicate matters, children are notoriously difficult to image due to their inability to follow instructions and difference in anatomy when compared to adult patients. They demonstrate different problems to adults that can impact image quality(17). Normal age related paediatric development results in a large patient spectrum, often these patients are uncooperative and unable to stand by themselves(17). A challenge faced by radiographers is the great variability in patient dimensions, complicating not only the use of automatic exposure control but also imaging the relevant anatomic area(6, 17). Another problem encountered is movement artifacts resulting from children moving during exposure(6). Children exhibit normal anatomy not routinely found in adults, such as the thymus. In some cases important information may be

obscured by normal anatomy, resulting in decreased diagnostic quality of chest radiographs(1). A study done to evaluate the quality of neonatal radiographs in the neonatal intensive care unit, found that important findings were hidden by artifact in 39% of cases(4). But it is not always the patient or environment that affects image quality. Technical factors related to the production of chest radiographs need to be studied as they often result in unwanted effects in children(2). The term ”dose-creep” has different connotations in different clinical disciplines. In the context of radiography, it refers to the tendency of radiographers to overexpose patients in hope of producing high quality images that are pleasing to radiologists(7, 17, 18). In a recent study by Hlabangana et al, the quality of paediatric chest radiographs were evaluated using a 12 point quality assurance tick-sheet identifying radiographic errors(2). 71% of the radiographs that were evaluated had more than 2 errors per image(2). International studies have shown that errors of collimation is the most common finding amongst paediatric cases, which was confirmed by Hlabangana et al in a South African study(2). A Nigerian multicenter quality assurance study, of rejected radiographs, reported a rejection rate of 1 in 5 (19), stating that the most common factors leading to rejection is equipment failure and technique errors(19). They furthermore found that movement artifact was most prominent feature which led to rejection in children(19). It was also commented that level of illness, body habitus and movement lead to rejection in only 10% of cases(19). Hlabangana et al however found that after poor collimation, patient positioning was the second commonest error reported(2). During a study of neonatal radiographs Russel et al commented that “a challenging patient population, time constraints, an incomplete understanding of the shielding provided by image coning and an absence of equipment” could all result in poor quality images(5). Poor communication between radiographers

and other health care workers also seems to play a role, however it has not been proven(5). Poorer quality investigations have been reported after hours when it is thought that less experienced radiographers and nurses are available(4). The question might be whether we are being too critical, that a decrease in image quality in paediatrics is not necessarily related to ability to diagnose and that the need for a perfect image should be weighed up against the extra radiation that a child will be exposed to(15).

1.4. Impact of quality assurance on radiology

Quality assurance is defined as actions and plans put in place to improve the quality of healthcare, which includes the assessment of standard of care, identifying factors leading to decreased delivery of care and developing tools to address any deficiencies(20). Quality assurance in radiology involves not only assessing the quality of equipment used to do investigations, but also assessing the quality of the investigations themselves(2). As quality assurance is a time consuming process it is important to know whether it is effective. A study that was done to assess the relevance of a quality assurance program reviewing chest radiographs in the emergency department found that 0.6% of reviews resulted in dramatic change of care and 3.1% resulted in altered care(21). Fleischer et al reported that by reviewing paediatric chest radiographs, one could expect a change in management in 1.2% of cases(21). A study that assessed the quality of chest radiographs before and after an educational intervention showed an initial improvement after radiographer education, but thereafter the quality again declined(2). The author therefore comments that the findings suggest that the education of staff needs to be done at least monthly to be effective(2). Radiologists are well aware of the stochastic risks of ionizing radiation in children and therefor quality assurance is essential to protect

paediatric patients from the effects of “dose creep”(6). Loovere et al found that quality assurance in the neonatal intensive care unit did not only result in better requests and improved image quality, but that it can be used as a tool to assess radiographic skill(4). Radiologists base their practice on the optimization of investigations and quality assurance is at the core of this optimization.

1.5 Study objectives

This study aims to identify patient related factors that influence the quality of paediatric chest radiographs by assessing the quality of chest radiographs in a group of paediatric patients and to score the quality of the chest radiographs, using a tick-sheet based point system. Then to compare the quality of chest radiographs in “radiologically” sick patients to chest radiographs of “radiologically” normal patients.

2. Chapter Two: Materials and Methods

The research design was a retrospective, observational, cross sectional study. Quality of paediatric chest radiographs was determined from stored images forming part of an existing database. The quality of chest radiographs in different groups was compared to determine associations.

2.1. Sample

The study population included radiographs of children ages 3 days to 13 years that form part of a larger study. These chest radiographs were performed at Chris Hani Baragwanath Academic Hospital from September 2014 to November 2014. Radiographs were performed on these children for clinical indications and were sourced independently and retrospectively. Radiographs were accessed from an existing database. Ethics approval was attained from the University of Witwatersrand Human Research Ethics Committee (Appendix A).

2.2. Inclusion and exclusion criteria

Children whom had a frontal chest radiograph performed was included in this study. Patient records with incomplete information were excluded. Rejected radiographs were not included in this study as they have not been stored in the database.

2.3 Materials and Methods

Radiographs were randomly selected from the above-mentioned database to represent normal demographics. The investigator of the existing database selected the cases. A pilot study was done that included 20 cases, which provided data to calculate the sample size. The blinded data included patient demographic details and a copy of the frontal projection chest radiograph. This was loaded onto compact discs. Two consultant radiologists, whom have completed diplomas in paediatric radiology, and the principal investigator, reviewed the chest radiographs. The principal investigator underwent training by a paediatric radiologist prior to reviewing the chest radiographs. The radiologists used Apple computers (Cupertino, California, USA), loaded with OsiriX software (Geneva, Switzerland). Radiographic errors were recorded using REDCap (Research Electronic Capture) (VanderBilt University, USA), an electronic data capturing application. REDCap is an internet-based tool that was developed as an online application that supports data capture of research studies with the necessary security and at no cost to the user(22, 23). The research team customizes the tool for optimal function(22). The data was exported to a Microsoft Excel (Redmond, USA) spread sheet for safe storage.

2.4 Data collection

Three people reviewed the radiographs, two consultant radiologists and the author. All 3 reviewers were fully blinded to the demographic groups and clinical data. Radiographic errors were captured on REDCap in a tick-sheet based electronic format to ensure uniformity and reliability without human error. The REDCap data sheet consisted of twelve specific radiographic errors commonly made in practice. The reviewers scrutinized

each radiograph individually and scored a positive (1) or negative (0) score to each of the 12 points. This will lead to a range of scores from 0 – 12 with a maximum of 12 and a minimum of 0. Errors included “poor collimation”, “scapulae in the way”, “cut off”, “inadequate inspiration”, “rotation”, “kyphotic or lordotic views”, “presence of artefacts”, “inability to visualize tracheobronchial tree”, “inability to visualize central vessels”, “inability to visualize peripheral vessels”, “vessels behind heart not well seen” and “absent or wrongly placed left or right markers”. The abovementioned forms part of a tick sheet that was developed and tested by Hlabangana et al(2). This tick-sheet was adapted into electronic form and the tick-sheet has been expanded to include the presence or absence of pathology. Scores were given to characterize severity of illness according to the presence of “airspace opacification”, “lymphadenopathy”, “pleural effusion” and “airway compression” (Appendix B). Each pathologic finding present resulted in a point allocated, resulting in a total score out of four. It was possible to extract data with regards to each of the 12 errors, patient demographics and presence of respiratory pathology to identify associations that was present.

2.5. Statistical analysis

Statistical analysis was performed on the data collected. A sample size of 280 radiographs analysed, resulted in a power of 85% to detect a difference in error means of 0.650 with a confidence level of 95%. A p-value of ≤ 0.05 was considered significant. Statistical analysis was performed on SAS (SAS Institute Inc, Carey, NY, USA), Release 9.3. Data was analysed using general linear model analysis for the comparison of means for error totals between the reviewers. The Fisher’s exact test and Chi – Squared test was used for comparison of total number of respiratory pathology counts between the

different reviewers. The Pearson Correlation coefficient was used to assess the correlations between the total number of radiographic errors and the presence of respiratory pathology on chest radiographs.

3. Chapter Three: Results

A total number of 280 frontal chest radiographs were included in the study. Each radiograph was reviewed by 3 different readers, resulting in a total of (280x 3) 840 cases. The mean age was 52.95 months. The age ranged from 3 days to 13 years.

The total possible score for all 3 reviewers assuming a maximum of 12 errors is (12 x 280 x 3) 10080. A total number of 2033 (20.2%) errors were reported by the reviewers. The lowest score was 0, indicating an ideal radiograph and the highest score was 9, indicating a poor radiograph. The most common errors were, in descending order, "rotation", "under inspiration" and "trachea and bronchi not well seen." The least common errors were "incorrect marking", "parts cut off" and "artifacts."

Table 3.1. Summary of the prevalence of radiographic errors as percentages of the total number of errors, for the overall study population

Radiographic errors	Overall prevelance
Parts cutoff	0.5% (10/2033)
Under inspired	14.5% (295/2033)
Rotation	**21.3%** (433/2033)
Scapula in the way	7.8% (159/2033)
Kyphotic or lordotic	7.0% (142/2033)
Artifact	5.7% (115/2033)
Central vessels not well seen	7.8% (159/2033)
Peripheral vessels not well seen	7.6% (154/2033)
Poor collimation	7.5% (153/2033)
Trachea or bronchi not well seen	10.7% (217/2033)
Vessels behind heart not well seen	9.2% (188/2033)
Incorrect marking	**0.4%** (8/2033)

Radiographs were also scored according to the presence of respiratory pathology. The total cumulative score, assuming maximum respiratory pathology was (4 x 280 x 3) 3360.

The total cumulative prevalence of respiratory pathology findings was 16.4% (550/3360). Of the total number of 840 radiographs reviewed, 347 (41.3%) were identified as not having respiratory pathology. 493 (58.7%) radiographs were identified to have either 1 or more of the respiratory pathologies present. The most common respiratory pathologic finding was "Airspace opacification" and the least common was "Airway compression".

Table 3.2. Summary of the prevalence of radiographic respiratory pathology, as percentages of the total, for the overall study population

Respiratory pathology	Respiratory pathology postive	Overall prevalance
Airspace opacification	**86.7% (477/550)**	56.8% (477/840)
Lymphadenopathy	6.3% (35/550)	4.2% (35/840)
Pleural effusion	4.7% (26/550)	3.1% (26/840)
Airway compression	2.2% (12/550)	1.4% (12/840)

Statistical analysis was performed to determine correlation between the reviewer radiographic error count and the presence of pathology. There was a statistically significant, low correlation present between the radiographic error count and the presence of respiratory pathology that showed a linear relationship **(p<0.001)**. All correlation coefficients were low, but statistically significant due to the large sample size. Results of the statistical analysis are summarized in table 3.3.

Table 3.3. Correlation between radiographic error count and presence of pathology

	Pearson correlation coefficients	p-value	Spearman correlation coefficients	p-value
Reviewer 1	0.31	<0.0001	0.38	<0.0001
Reviewer 2	0.07	0.24	0.08	0.18
Reviewer 3	0.10	0.10	0.19	0.0016
Overall	0.15	<0.0001	0.20	<0.001

The 280 radiographs were reviewed by 3 readers to address inter observer variability. There was a statistically significant **(p<0.001),** low correlation present between readers in the assessment of radiographic errors (table 3.4 and table 3.5).

Table 3.4. General linear model analysis for comparison of reviewer means in the assessment of radiographic errors

	Reviewer 1	**Reviewer 2**	**Reviewer 3**
Reviewer 1	X	1.02 (p=0.3)	3.53 (p=0.0004)
Reviewer 2	1.02 (p=0.3)	X	2.51 (p=0.124)
Reviewer 3	3.53 (p=0.0004)	2.51 (p=0.124)	X

Table 3.5. Pearson correlation coefficients illustrating interobserver correlation in assessment of the quality of paediatric chest radiographs using a 12 point tick sheet

	Reviewer 1	**Reviewer 2**	**Reviewer 3**
Reviewer 1	1	0.70 (p<0.0001)	0.58 (p<0.0001)
Reviewer 2	0.70 (p<0.0001)	1	0.57 (p<0.0001)
Reviewer 3	0.58 (p<0.0001)	0.57 (p<0.0001)	1

There was a statistically significant inter observer correlation present (p<0.0001) in the assessment of presence of respiratory pathology. Results are summarized in table 3.6 and table 3.7.

Table 3.6. Comparison of reviewer totals to illustrate interobserver correlation in the indentification of respiratory pathology

Score	**Reviewer 1**	**Reviewer 2**	**Reviewer 3**	**Total**
0	37.5% (105/280)	65.7% (184/280)	20.7% (58/280)	41.3% (347/840)
1	51.8% (145/280)	30.7% (86/280)	76.4% (214/280)	53.0% (445/840)
2	9.7% (27/280)	2.9% (8/280)	1.43% (4/280)	4.6% (39/840)
3	1.1% (3/280)	0.7% (2/280)	1.4% (4/280)	1.1% (9/840)
4	0% (0/280)	0% (0/280)	0% (0/280)	0% (0/840)

Table 3.7. Pearson correlation coefficients in the identification of respiratory pathology

	Reviewer 1	Reviewer 2	Reviewer 3
Reviewer 1	1	0.49 (p<0.0001)	0.30 (p<0.0001)
Reviewer 2	0.49 (p<0.0001)	1	0.28 (p<0.0001)
Reviewer 3	0.30 (p<0.0001)	0.28 (p<0.0001)	1

A single reader reviewed 28 cases (10%) and repeated the process of scoring each radiograph using a 12 point tick sheet and assessing the presence of respiratory pathology to test the intra-reader variability. There was a statistically significant correlation between the first and second scores for both error scoring **(p=0.0064)** and the presence of respiratory pathology **(p=0.0093).** Results are summarized in Table 3.8.

Table 3.8. Correlation between first and second reading illustrating intrarater reliability.

	Radiographic errors		Respiratory pathology	
	Reading 1	**Reading 2**	**Reading 1**	**Reading 2**
Mean	2.57	2.93	0.89	0.82
Standard deviation	1.57	2.16	0.69	0.61
Median	2	2.5	1	1

The age of the patients was known in 65% of cases (182/280). Age groups were made according to well known radiographic age related protocols used and age related developmental milestones. There was a statistically significant difference in the means of children aged 0-18 months and those aged 37-156 months **(p<0.05)**. Results are summarized in table 3.9.

Table 3.9. Mean score for different age groups found on assessment of the quality of the radiograph using a 12 point error based tick-sheet

Age group	Error score mean	Standard deviation	Sample size
0 - 6 months	2.99	1.68	84
7 - 18 months	2.56	1.56	120
19 - 36 months	1.95	1.45	105
3 - 7 years	2.00	1.25	96
8 - 12 years	1.75	1.08	117
13 - 17 years	1.50	0.5	24
Unknown	2.70	1.57	294

4. Chapter Four: Discussion

4.1. Results in context

From these results it can be deduced that there is a correlation between the presence of respiratory disease on a paediatric chest radiograph and the quality of the chest radiograph. There was a statistically significant correlation present between the radiographic error count and the presence of respiratory pathology. Correlation was low and the implication is that correlation will be present in large numbers, however the clinical relevance should be questioned in smaller groups. The presence of respiratory pathology was associated with an increased error count. The radiographic signs used in our study to represent respiratory pathology have been proven to indicate severe forms of clinical pneumonia(11, 12). We can extrapolate that these children would be severely ill and less cooperative. The most common errors were “rotation”, “under inspiration” and “trachea and bronchi not well seen”. Patient movement can cause rotation. This compares well to another African study that reported patient movement as the principle reason for film rejection in the paediatric population(19). Poor visualization of the tracheobronchial tree relates to the exposure of the radiograph which was reported as being the responsible for film rejection in 21.8% of cases(19). A recent study by Hlabangana et al used the same parameters to test the quality of paediatric chest radiographs in a different South African hospital; comparison of the findings of this study is made in table 4.1(2).

Table 4.1. The prevelance of radiographic errors, as percentages of the total number of possible errors, in camparison to Hlabangana et al.

Total possible errors (number of cases x 12)	Overall prevelance	Hlabangana et al (2012)
Parts cutoff	0.01% (10/10080)	**0.2%** (8/5256)
Under inspired	2.9% (295/10080)	2.3% (120/5256)
Rotation	**4.3%** (433/10080)	4.3% (228/5256)
Scapula in the way	1.6% (159/10080)	4.2% (223/5256)
Kyphotic or lordotic	1.4% (142/10080)	4.9% (259/5256)
Artifact	1.1% (115/10080)	2.3% (125/5256)
Central vessels not well seen	1.6% (159/10080)	1.6% (82/5256)
Peripheral vessels not well seen	1.5% (154/10080)	2.2% (114/5256)
Poor collimation	1.3% (153/10080)	**5.4%** (284/5256)
Trachea or bronchi not well seen	2.1% (217/10080)	2.6% (139/5256)
Vessels behind heart not well seen	1.9% (188/10080)	3.3% (175/5256)
Incorrect marking	**0.01%** (8/10080)	0.2% (10/5156)
Total	20.2% (2033/10080)	33.6 % (1766/5256)

Figures in bold indicate highest and lowest percentages

From this table it can be appreciated that there is correlation between these studies. In both studies the least common errors were “Incorrect marking” and “Parts cut off”.

It is well known that there is great inter observer variability present within the field of radiology(24). This was again proven in our study by the poor agreement between the three readers with regards to the presence of respiratory pathology and quality of the

chest radiograph, however there was a correlation. A recent Swedish study reported a superior interobserver correlation of 66%, in evaluating chest radiographs for the presence of pathology(25). It is suspected that due to time constraints and pressure the radiographs are not as diligently scrutinised by the readers as one would during general reporting for service delivery. There was no clinical history provided either and thus ambiguity remained where a radiologist would have made the logical conclusion when visualizing radiographic signs if the history was known. The findings of such variability between 2 consultant Radiologists and a registrar in radiology should however not be taken lightly and highlights the fact that more needs to be done to standardize reporting of paediatric chest radiographs. The incorrect reporting of "airspace opacification" would most likely lead to the administration of antibiotics as well as follow up imaging, impacting on the child's future health. Similarly, the mention of "lymphadenopathy" or "airway compression" would lead to further investigation and prolonged hospital stay resulting in further pressure on resources, in an already resource limited environment. Interestingly, the study found that there is good correlation when assessing the intra-reader variability. It can be deduced that the study is repeatable but will inevitably still demonstrate subjectivity.

There was a correlation between the age of the patients being examined and the quality of the chest radiograph. The quality of chest radiographs improved as the age of the patients increased. There was a statistically significant difference between the patients aged 0-6 months, 6-18 months and patients older than 36 months. It can be deduced that older children are more cooperative, which results in better quality radiographs.

4.2. Current applications

In a busy radiology unit, radiographers should be aware that the quality of images is poorer in children with severe pneumonia. Feedback of the results to radiographers will result in more attention given to these patients to ensure excellent image quality. Providing training to radiographers to illustrate to most common radiographic and patient related errors will result in improved radiographs and less repeat radiographs, improving patient care.

Radiographers working in a busy unit should be made aware of the image quality of the chest radiographs being produced and that the quality is directly related to the age of the patient. More time should be spent to ensure, within reasonable limits, that the quality of chest radiographs of children of younger ages is improved. The study provides evidence to support the use of patient immobilization devices in younger children.

Radiologists should be made aware that there is poor correlation between colleagues when assessing the quality of images and when interpreting radiographs for respiratory pathology. It should be noted that there is subjectivity involved in the assessment of radiographs, but that this subjectivity is repeatable. Standardization of chest radiograph reporting is crucial in addressing this variability. This will lead to less repeat investigation and ultimately reducing collective radiation dose.

4.3. Limitations of the current study

The study population is from a single training hospital involved in training radiographers of different levels of experience. Radiographs performed by unqualified personnel will skew results, however it is a reality in a training hospital. Rejected radiographs were not assessed as they were not saved on the picture archiving and communication system and therefore could not be accessed. These radiographs could have provided vital information. Many radiographs had pathology present other than respiratory in origin. There was ambiguity when assessing these cases. Airspace opacification caused by a cardiac disease for instance, could influence our results. The principal investigator is not a qualified radiologist. The substitution of the principal investigator with a more experienced radiologist could have resulted in more relevant results.

4.4. Future applications

The results from this study can be used as a training tool to inform radiographers of the most commonly made errors. This can result in an immediate improvement in quality of paediatric chest radiographs. Time should be spent to ensure that the quality of radiographs for patients younger than 18 months improve in our unit. Our study has proved that there is relatively poor correlation between radiologists when assessing paediatric chest radiographs and that interpretation should be standardized. It would be interesting to compare respiratory pathologic findings by a radiologist to that of paediatricians, whom are often the primary users of chest radiographs in our setting. Radiographers and nurses working at rural hospitals and clinics are in some cases expected to interpret the radiographs of patients. Our study can be used to assess the

ability of other health care workers to assess the presence or absence of pathology to prove or disprove correlation with radiologists.

5. Chapter Five: Conclusion

The results of this study have shown that there is a correlation between the presence of respiratory disease on a paediatric chest radiograph and the quality of the chest radiograph. The presence of respiratory pathology was associated with an increased error count and therefor a poorer quality chest radiograph. Clinical relevance will only be present in large numbers, as the correlation is low. We furthermore found a correlation between the age of the patients being examined and the quality of the chest radiograph, supporting the common thinking that the older a patient, the better the quality of the radiograph. This information can be used as an educational tool with the aim to improve paediatric chest radiographs and decrease radiation to children.

Appendix A: Ethics Clearance Certificate

R14/49 Dr Eben Albert Strasheim

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

CLEARANCE CERTIFICATE NO. M150127

NAME: (Principal Investigator)	Dr Eben Albert Strasheim
DEPARTMENT:	Diagnostic Radiology
PROJECT TITLE:	Patient Related Factors Influencing the Quality of Paediatric Chest Radiographs
DATE CONSIDERED:	30/01/2015
DECISION:	Approved unconditionally
CONDITIONS:	
SUPERVISOR:	Dr LT Hlabangana
APPROVED BY:	Professor P Cleaton-Jones, Chairperson, HREC (Medical)
DATE OF APPROVAL:	20/02/2015

This clearance certificate is valid for 5 years from date of approval. Extension may be applied for.

DECLARATION OF INVESTIGATORS

To be completed in duplicate and **ONE COPY** returned to the Secretary in Room 10004, 10th floor, Senate House, University.

I/we fully understand the conditions under which I am/we are authorized to carry out the above-mentioned research and I/we undertake to ensure compliance with these conditions. Should any departure be contemplated, from the research protocol as approved, I/we undertake to resubmit the application to the Committee. **I agree to submit a yearly progress report.**

Principal Investigator Signature

Date 2015/03/01

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

Appendix B: Reader information document

Instructions to readers

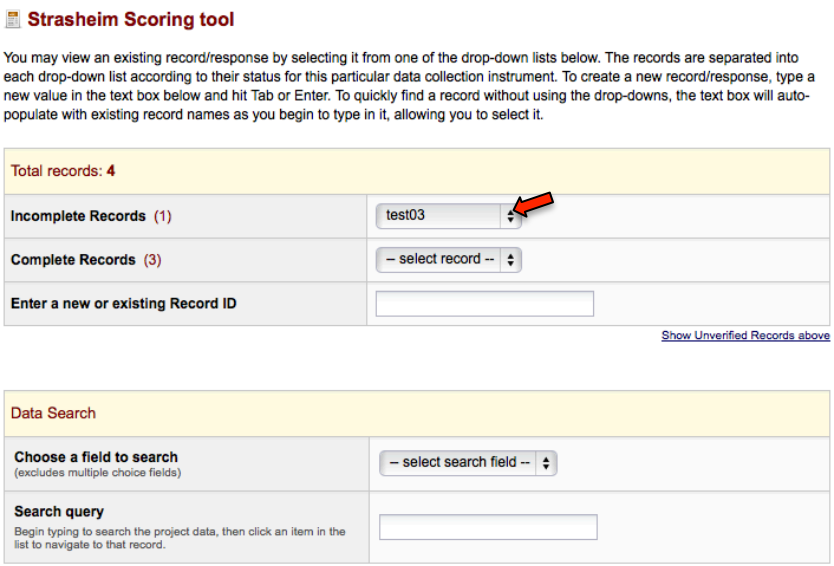
Thank you for participating in my research study.

Purpose:

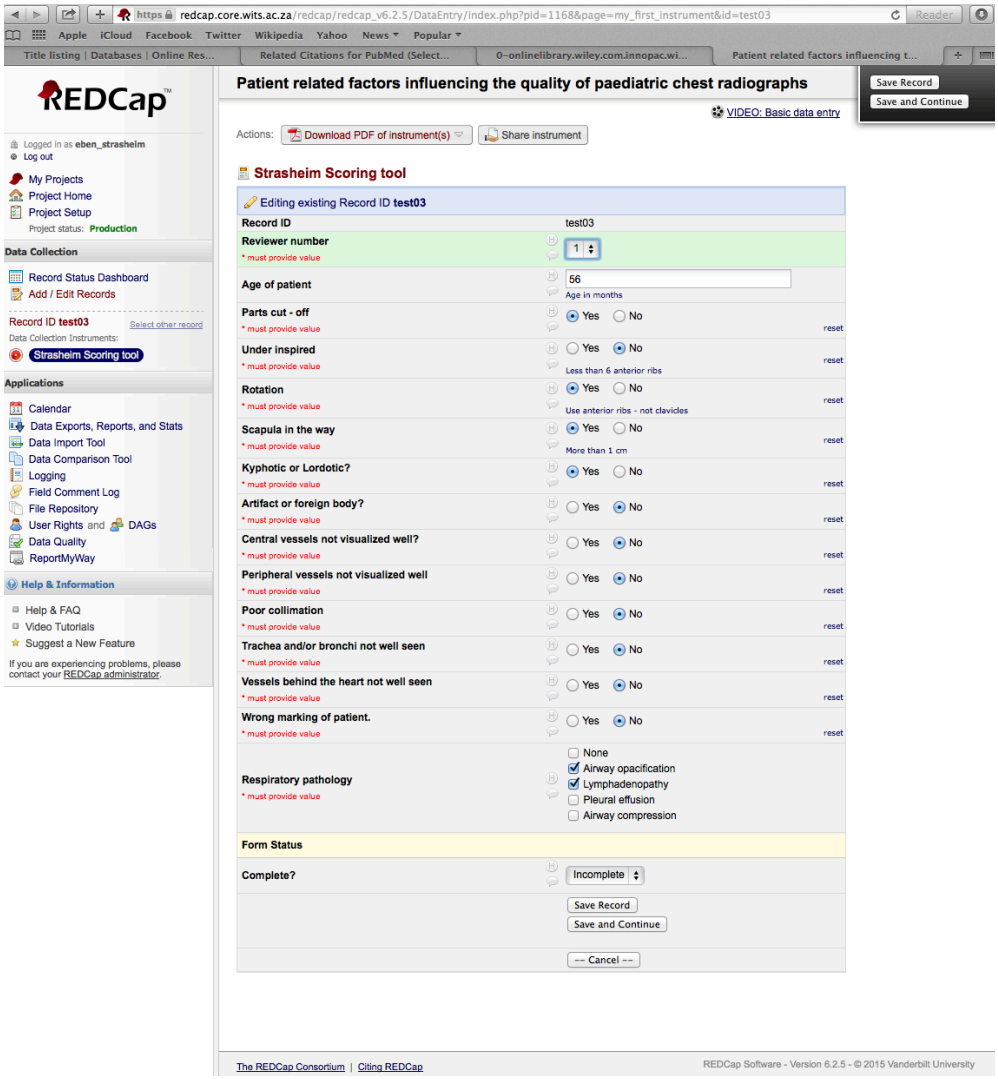
You will be assessing the quality of the radiographs produced during normal clinical practice at Chris Hani Baragwanath Hospital. A short tick-sheet based quality assurance tool will be used to assess the radiographs, resulting in a score reflecting the quality of the radiograph. Furthermore it has a short scoring method used to establish the illness severity "radiographically". The research is aimed at identifying patient related factors, in contrast to technical factors, that lead to decreased quality of radiographs.

Instructions:

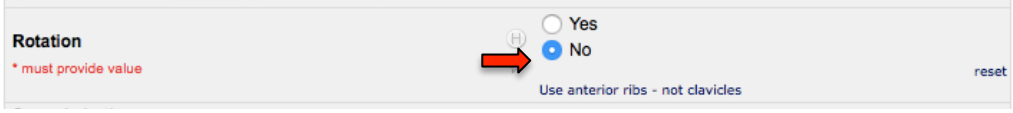
A compact disc containing the frontal chest radiographs of the sample cases will be handed over to you. Each radiograph has been coded. After logging into REDCap via the Internet, follow the links to the Data entering page. The number of the radiograph used for identification on the compact disc, is the number that will be filled in to the "Record ID" tab.



An electronic tick sheet will be available for each case.

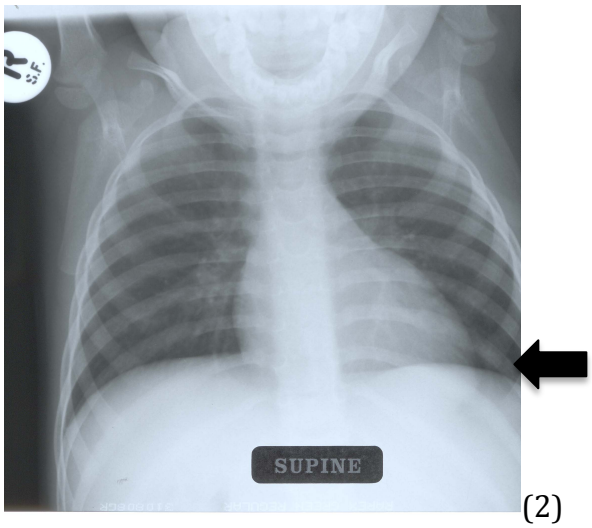


Tick “Yes” if relevant error is present and “No” if it is absent.



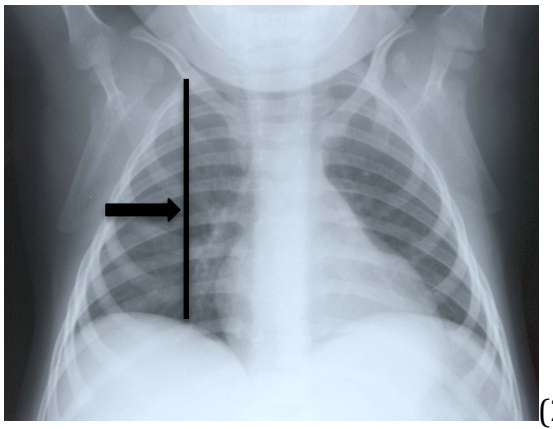
Please use the following examples as guide to assess the quality of each chest radiograph:

1. Parts cut-off

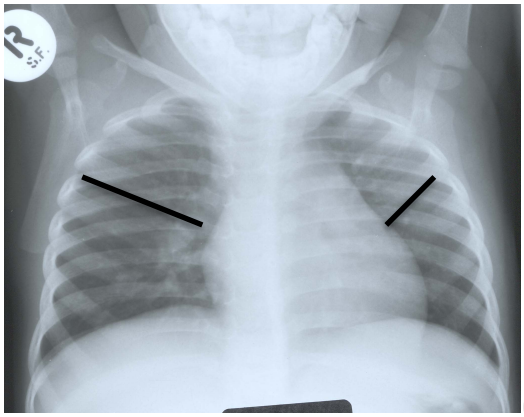


(2)

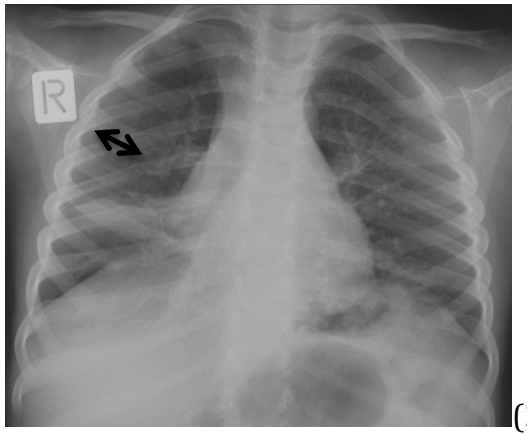
2. Under inspired (<6 anterior ribs visible in midclavicular line)


(2)

3. Rotated (Use length of anterior ribs not clavicles)

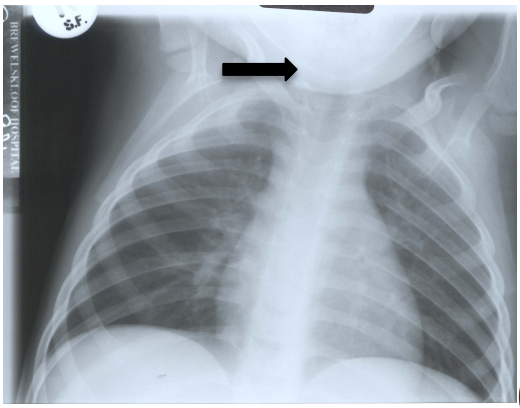

(2)

4. Scapula in the way (>1cm)

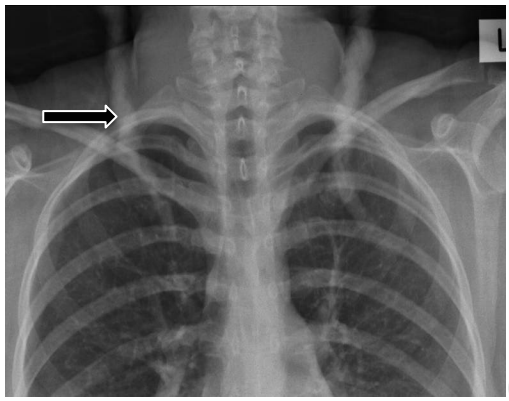


(2)

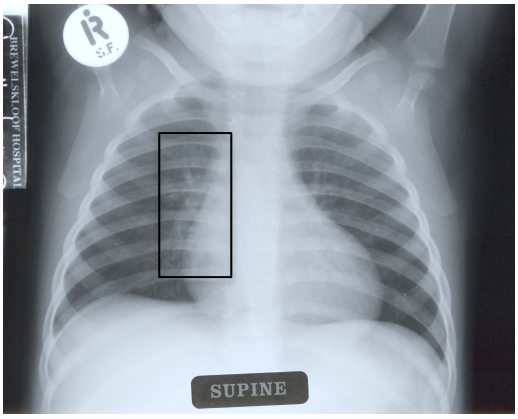
5. Kyphotic or lordotic


(2)

6. Foreign body/Artifact

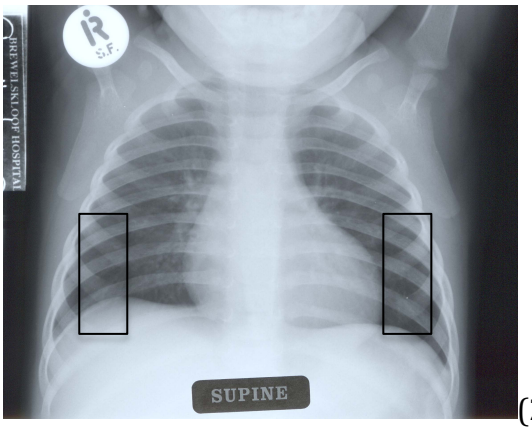

(2)

7. Central vessels not well visualised.



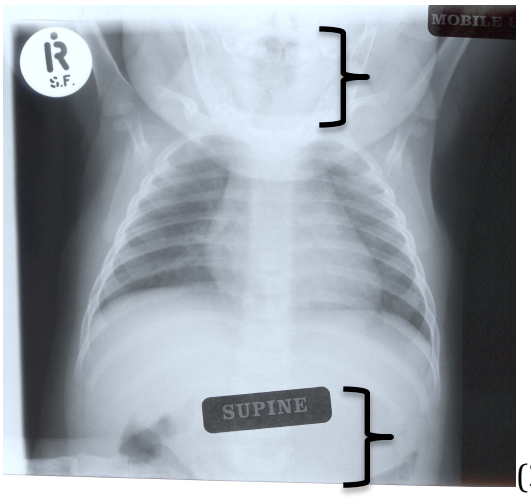
(2)

8. Peripheral vessels not well visualised.



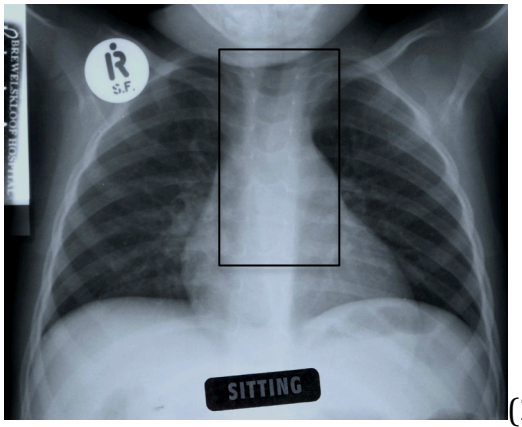
(2)

9. Poor collimation



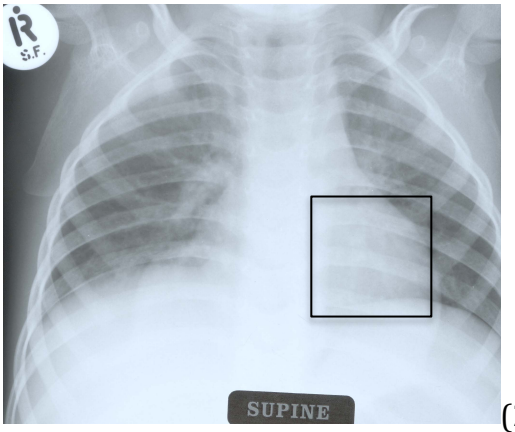
(2)

10. Trachea/Bronchi not clearly seen



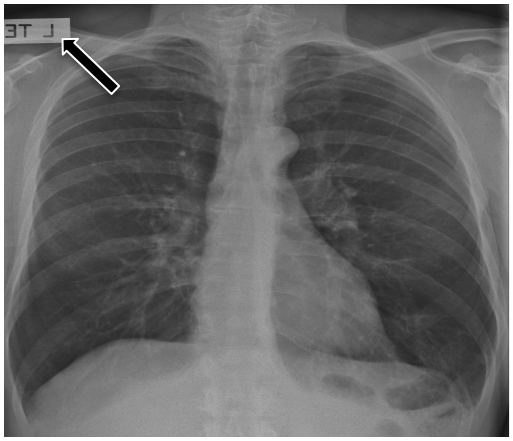
(2)

11. Vessels behind heart not well seen

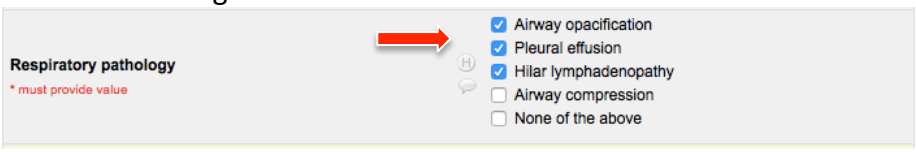


(2)

12. Wrong or no right/left marker

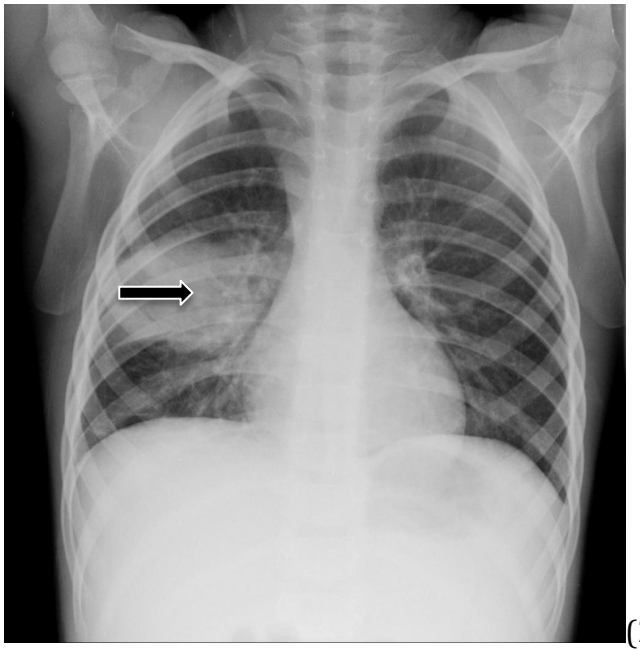

(2)

The tick sheet has been expanded to identify respiratory pathology. Please tick the box next to the relevant finding:

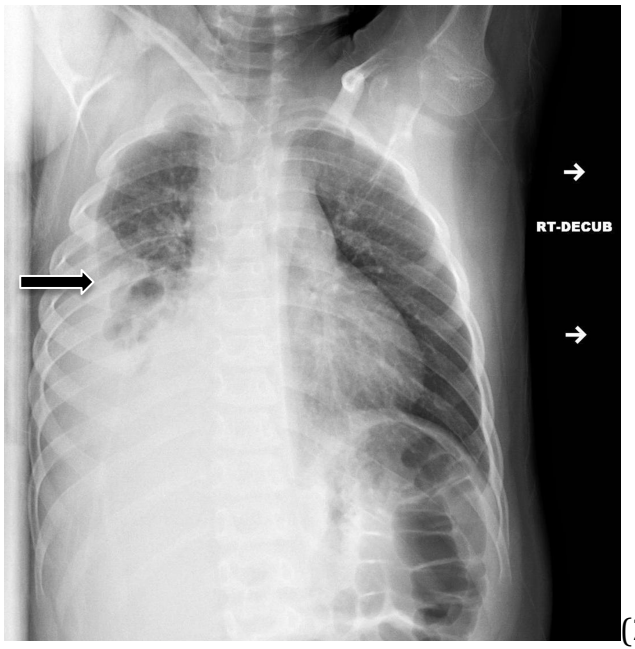


Use the following images as a guide:

1. Airway opacification

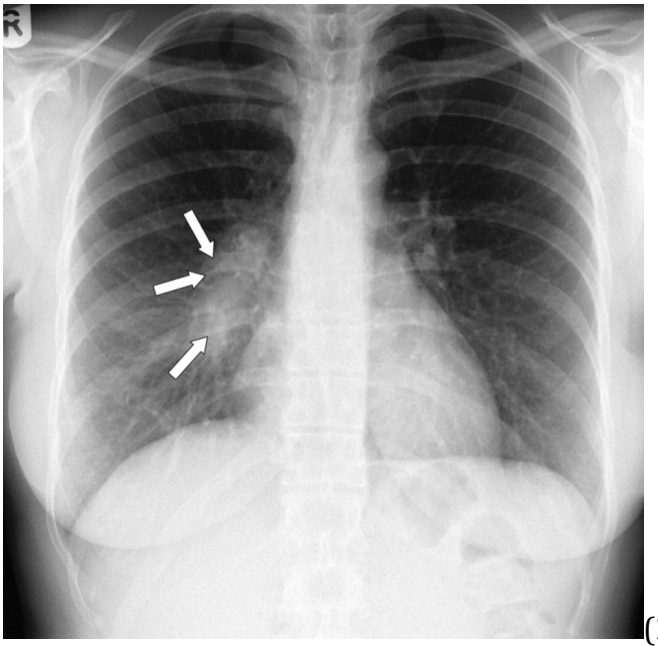

(26)

2. Pleural effusion



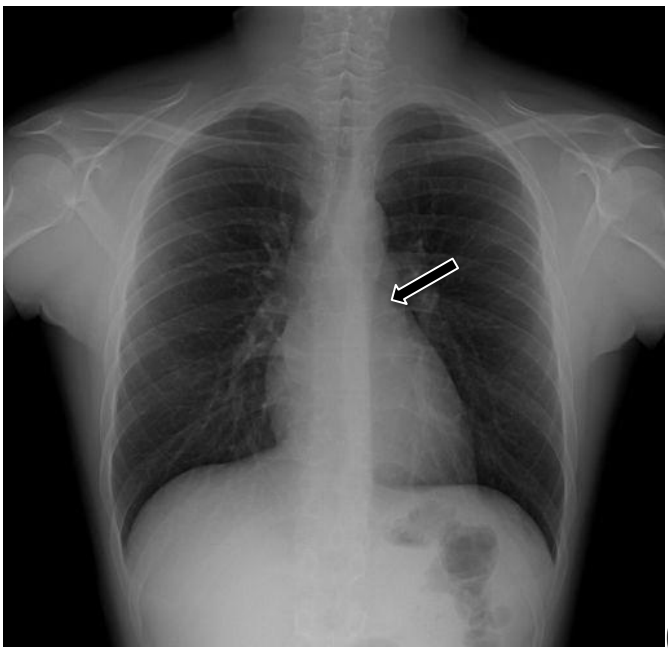
(27)

3. Hilar lymphadenopathy



(28)

4. Airway compression


(29)

It is possible to have more than one pathological finding per image, so please tick as many boxes as necessary. If none of the descriptions fit the pathology visualized on the image, please select “none of the above”. REDCap will automatically calculate the total scores, so there is no need to do it manually.

My contact details are provided below please feel free to contact me at anytime should you have any problems or queries.

Dr. Eben Strasheim
Principal investigator
Tel: 0824607065
E-mail: eben@thepub.co.za

6. Chapter Six: References

(1) Veldkamp WJ, Kroft LJ, Geleijns J. Dose and perceived image quality in chest radiography. Eur J Radiol. 2009 Nov;72(2):209-17.

(2) Hlabangana LT, Andronikou S. Short-term impact of pictorial posters and a crash course on radiographic errors for improving the quality of paediatric chest radiographs in an unsupervised unit - a pilot study for quality-assurance outreach. Pediatric radiology. 2014 Aug 17;45:158-65.

(3) Hlabangana LT. Quality-assurance interventions for Africa utilising social media. Pediatric radiology. 2014 Jun;44(6):705-6.

(4) Loovere L, Boyle EM, Blatz S, et al. Quality improvement in radiography in a neonatal intensive care unit. Can Assoc Radiol J. 2008 Oct;59(4):197-202.

(5) Russell J, Burbridge BE, Duncan MD, et al. Adult fingers visualized on neonatal intensive care unit chest radiographs: what you don't see. Can Assoc Radiol J. 2013 Aug;64(3):236-9.

(6) Goske MJ, Charkot E, Herrmann T, et al. Image Gently: challenges for radiologic technologists when performing digital radiography in children. Pediatric radiology. 2011 May;41(5):611-9.

(7) Don S, Goske MJ, John S, et al. Image Gently pediatric digital radiography summit: executive summary. Pediatric radiology. 2011 May;41(5):562-5.

(8) Newman RE, Hedican EB, Herigon JC, et al. Impact of a guideline on management of children hospitalized with community-acquired pneumonia. Pediatrics. 2012 Mar;129(3):e597-604.

(9) Patria MF, Longhi B, Lelii M, et al. Association between radiological findings and severity of community-acquired pneumonia in children. Ital J Pediatr. 2013;39:56.

(10) Elemraid MA, Muller M, Spencer DA, et al. Accuracy of the interpretation of chest radiographs for the diagnosis of paediatric pneumonia. PLoS One. 2014;9(8):e106051.

(11) Cherian T, Mulholland EK, Carlin JB, et al. Standardized interpretation of paediatric chest radiographs for the diagnosis of pneumonia in epidemiological studies. Bull World Health Organ. 2005 May;83(5):353-9.

(12) Hazir T, Nisar YB, Qazi SA, et al. Chest radiography in children aged 2-59 months diagnosed with non-severe pneumonia as defined by World Health Organization: descriptive multicentre study in Pakistan. BMJ. 2006 Sep 23;333(7569):629.

(13) Karimian A, Yazdani S, Askari MA. Reducing the absorbed dose in analogue radiography of infant chest images by improving the image quality, using image processing techniques. Radiat Prot Dosimetry. 2011 Sep;147(1-2):176-9.

(14) Sulieman A, Vlychou M, Tsougos I, et al. Radiation doses to paediatric patients and comforters undergoing chest X rays. Radiat Prot Dosimetry. 2011 Sep;147(1-2):171-5.

(15) Shet N, Chen J, Siegel EL. Continuing challenges in defining image quality. Pediatric radiology. 2011 May;41(5):582-7.

(16) Vetter S, Strecker EP. Clinical aspects of quality criteria in digital radiography. Radiat Prot Dosimetry. 2001;94(1-2):33-6.

(17) Willis CE. Optimizing digital radiography of children. Eur J Radiol. 2009 Nov;72(2):266-73.

(18) Williams MB, Krupinski EA, Strauss KJ, et al. Digital radiography image quality: image acquisition. J Am Coll Radiol. 2007 Jun;4(6):371-88.

(19) Victor EI OO, Nicholas IK, Livinus AC, Rasheed AA, Gbolahan AO, Cletus EU, Oselumenosen OD. Common Factors Affecting Radiographic Diagnostic Quality in X-Ray Facilities in Lagos. Journal of Medical Imaging and Radiation Sciences. 2012(43):108-11.

(20) NCBI; "Quality assurance, health care." 1980. <http://www.ncbi.nlm.nih.gov/mesh/68011785> [Accessed on 19/11/2014].

(21) Shirm SW, Graham CJ, Seibert JJ, et al. Clinical effect of a quality assurance system for radiographs in a pediatric emergency department. Pediatr Emerg Care. 1995 Dec;11(6):351-4.

(22) Harvard-Catalyst; <http://catalyst.harvard.edu/services/redcap/> [Accessed on 2015/02/23].

(23) Harris PA, Taylor R, Thielke R, et al. Research electronic data capture (REDCap)--a metadata-driven methodology and workflow process for providing translational research informatics support. J Biomed Inform. 2009 Apr;42(2):377-81.

(24) Andronikou S, Brauer B, Galpin J, et al. Interobserver variability in the detection of mediastinal and hilar lymph nodes on CT in children with suspected pulmonary tuberculosis. Pediatric radiology. 2005 Apr;35(4):425-8.

(25) Hirvonen-Kari M, Sormaala MJ, Luoma K, et al. Quality of chest radiograph reports. Acta radiologica. 2014 Oct;55(8):926-31.

(26) Medscape; <http://emedicine.medscape.com/article/1926980-overview> [Accessed on 2015/02/22].

(27) Pics R; 2015. <https://radiologypics.files.wordpress.com/2013/03/unknown-23.png> [Accessed on 2015/02/22].

(28) img.com; 2015. <http://imgkid.com/hilum.shtml> [Accessed on 2015/02/22].

(29) EuroRAD; <http://eurorad.org/eurorad/case.php?id=9756> [Accessed on 2015/02/22].