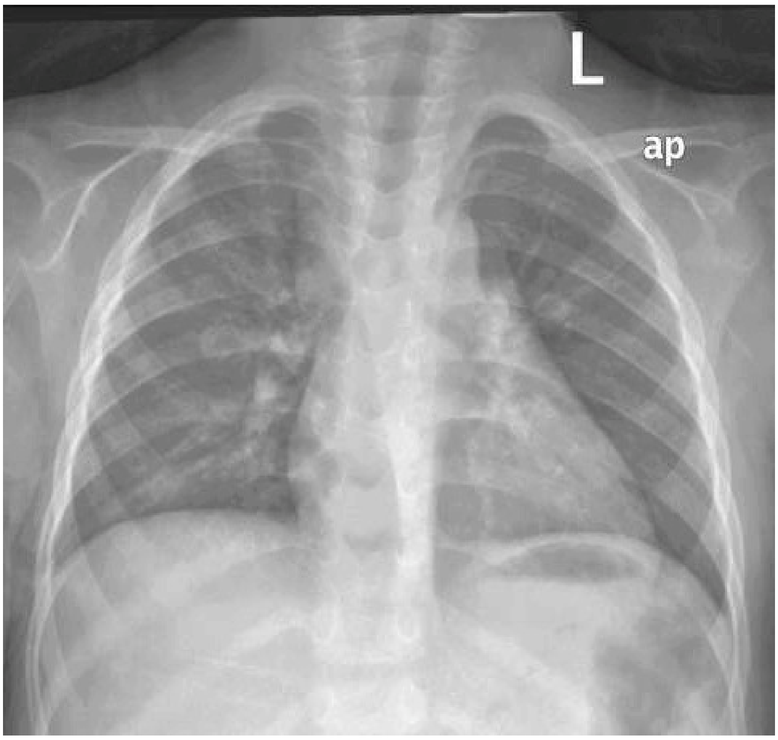
Introduction of a Pictorial Poster and a ‘Crash Course’ of Radiographic Errors for Improving the Quality of Paediatric Chest Radiographs in an Unsupervised Unit.



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A research report submitted to the Faculty of Health Sciences, University of the Witwatersrand in fulfillment for the degree

of

Masters of Medicine in the branch of Diagnostic Radiology

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DECLARATION

I, Linda Tebogo Hlabangana declare that this research report is my own work. It is being submitted for the degree of Master of Medicine in the branch of Diagnostic Radiology in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at this or any other university.

________________________ Signature

____________ Day of______________2012

DEDICATION

Thank you to my husband Abraham and our three beautiful princesses Lisakhanya, Mihlali and Amyoli for your constant love and support. To my parents, who have always cheered me on from the sidelines.

Abstract

Chest radiography is the most commonly performed diagnostic X-ray examination. Optimised image quality is important, particularly in children with radio-sensitive immature organs.

The aim of this study is to determine whether the introduction of an “intervention” comprising a crash course and poster, can sustainably decrease the number and rate of radiographic errors in an unsupervised department.

Method: A study with retrospective and prospective components was performed. The technical errors in frontal chest radiographs of one unsupervised paediatric radiology unit were assessed by QA analysis using a customised ticksheet. The QA was performed before and after an “intervention” which involved a ‘crash course’ of half an hour and a poster display in the department. Comparisons of the technical errors made before and after the “intervention” were made.

Results: There was statistically significant improvement in quality of radiographs immediately after the “intervention” ($p < 0.0001$) and decline in the review periods more than 2 months from the intervention.

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INTRODUCTORY CHAPTER

1.1 Introduction

Chest radiography is the most commonly performed diagnostic X-ray examination. Although the radiation dose to the patient for this examination is relatively low, the contribution to the collective dose is considerable because of its frequent use.[1,2] Optimised image quality is important in children as not only does it allow for more accurate diagnosis but it also adheres to radiation protection guidelines. This should be prioritized, in children because of the increased radio-sensitivity of their immature organs. Due to the increased mobility of children, technical considerations such as rotation, poor collimation and under or over penetration of the film are more encountered in paediatric radiology.[1]A quality assurance (QA) study of paediatric chest X-rays was conducted in a sample of patients. The aim of this study was to determine whether the introduction of a poster with the images of the most common radiographic technical errors for paediatric frontal chest radiographs, accompanied by a 'crash course' would improve the quality of chest radiographs, in an unsupervised unit of a general hospital. The term "unsupervised unit" in this study is used to describe a radiology department that does not have additional paediatric radiological expertise (i.e. sub-specialised or 'dedicated' paediatric radiologist, paediatric trained radiographers and nursing personnel).[1,3]

1.2 Literature review

There are two limbs in Quality assurance (QA) for radiography; one that involves QA of the diagnostic X-ray equipment and the other that reviews the quality of the radiographs performed.[4,5] There are a number of levels in QA, each requiring a different type of scientific/technical surveillance.[5] In a field as large as Diagnostic Radiology no one individual group or scientific/professional society contains all of the skills or knowledge required to efficiently perform QA.[5]

Quality assurance is critical as a means of ensuring high image quality. Optimised image quality reinforces radiation protection and this should be actively persued.[3] To continuously improve image quality even very small variations in image quality need to be monitored.[6] Cook et al recommend that, "QA should ideally be performed on a daily and continuous basis so as to improve the quality of radiography in the department, which will also result in the decreased radiation dose to the patients and radiographers. There is usually a balance between dose and quality but good radiographic technique is the main factor in improving quality without the cost of increased dose." [1] Experienced and dedicated staff is the key to quality imaging[1] but these are often not available in a resource restricted setting particularly in a developing country such as South Africa.

The largest contributor by far to artificial radiation exposure is medical radiation. It is a well known and documented fact that radiation increases the risk of abnormal mutations and the development of fatal cancer in later life.[6,7] Children are more sensitive to the effects of radiation than adults and are at a much greater risk (2-fold greater) of developing delayed effects of radiation than adults for the same effective dose.[6,8] Departments that image children should therefore place particular emphasis on radiation protection measures, [1,9] and this should form an essential part of the QA process.

Children have a longer life expectancy, which allows carcinogenic effects more time to manifest.[1,10] Children also have a more widespread distribution of sensitive, pluripotential red bone marrow. This highlights the importance of collimation which excludes any body areas that are not of interest during an examination.[1,7] As children still have the potential for reproduction they have an increased risk of inducing genetic mutations in subsequent generations.[1] "It is therefore important for radiologists and radiographers to be aware of the lifetime risk of inducing a fatal cancer for various paediatric examinations."[1]

Despite recent advances in cross-sectional imaging of the thorax (e.g. Computational Tomography (CT) and Magnetic Resonance Imaging (MRI)), chest radiography remains a widely used modality for diagnosis of many pulmonary diseases. In most cases, it is the first—and often the only— imaging test performed in patients with a thoracic abnormality and in most counties throughout the world chest radiography remains the most commonly performed diagnostic imaging test overall.[3] Although the radiation dose to the patient is relatively low for chest radiographs, its frequent use contributes significantly to the collective dose.[1,2,6] Improvements in paediatric radiography are necessary[11] with "…the main goal being to improve diagnostic information and to reduce the patient dose to a minimum"- the As Low As Reasonably Achievable (ALARA) principle.[1,9] Such initiatives are currently being spear headed by the Alliance for Radiation Safety in Paediatric Imaging in campaigns such as the ‘Image Gently Campaign.’ But must reach the individual end-users i.e. the radiographers performing the studies.

Radiographic factors affecting quality during paediatric chest radiography:

Patient positioning and immobilization

Small children are less likely to follow instructions to **keep still, keep straight and hold deep inspiration**. A child who is comfortable and relaxed, however, is far more likely to co-operate resulting in higher quality images and fewer repeat exposures.[1] Taking the time to provide reassurance to both the child and caregiver is a rewarding exercise. The use of simple restraining devices, with the help of attendants, is often successful in smaller children.[1,7]

Collimation

Good collimation, i.e. “**restricting the field-size to the area of interest only”**, is of great importance in paediatric radiolography.[7] The radiosensitive organs in the body lie closer together in children and are therefore more easily exposed to unnecessary radiation. Good collimation requires accurate positioning of the patient and for them to remain still, this can be difficult especially with children and excessive collimation can lead to **cut-off** of important parts, which is a significant radiographic error in itself. Good knowledge of paediatric surface anatomy and pathology is useful for accurate collimation. This is one of the main reasons why it is strongly recommended that only well trained, preferably dedicated, staff undertake paediatric radiography.[7] “Appropriate collimation is the most commonly reported radiographic error but it is important factor for improving image quality whilst also reducing dose.”[7,12] Optimum collimation also reduces scattered radiation, thus improving contrast resolution. Collimation should not be made relative to the size and shape of the cassette or performed as a post-processing function in digital radiography. Instead, the Light Beam Device (LBD) can be used to position the patient in advance of the exposure.[1,12]

Positioning

Tilted (lordotic/kyphotic views) or rotated films distort anatomy and should be avoided. Sick children, may not be cooperative with being positioned resulting in rotation on the radiograph. Assessment for **rotation** in children uses the length of anterior ribs and comparison the two sides.[1]

Patient identification and indicators of laterality

An important component of any QA analysis involves patient identification and checking the position of the **side marker (left or right)** against features such as the apex of the heart, position of the aortic knuckle and air bubble in the stomach.[1,12] This is not necessary a technical parameter but represents meticulous technique that is critical for both patient care and for medico-legal protection.

Lung volume

For standard anterior posterior (AP) radiographs the radiographer attempts 'to catch the picture at full **inspiration**'. This is even more difficult in children especially those with shortness of breath (tachypnea) and those crying inconsolably.[12] The lung volume of a chest radiograph is an important part of the search for pathology such as air-trapping or volume loss. This is done by counting down the anterior rib ends to see which one meets the middle of the left hemi-diaphragm - a good inspiratory film should have the anterior end of the fifth or sixth rib bisecting the middle of the hemi-diaphragm. More than six anterior ribs demonstrates over-inflation (hyperinflation) and fewer than five indicates an under-inflated, expiratory film.[12] Under-inspired radiographs may simulate disease with normal lungs appearing opaque and a normal heart appearing enlarged.[12]

Penetration

The duration of exposure and the power of the beam both affect penetration. **A poorly penetrated film looks diffusely light/white** and soft tissue structures, especially those behind the heart, are readily obscured. Features such as lung markings are poorly seen when a film is **over-penetrated** as the film looks **diffusely dark**.[12] The use of DR and CR (as opposed to analogue / hard copy) has modified the relationship of film blackness / lightness to dose. These advances in radiography allow more latitude for generating an adequate film and a greater margin of error (requiring less repeat radiographs), but have in the process, eliminated the penalty of a black radiograph as an outcome when giving a child too high a dose. [12]

Previous Reports of Quality Assurance in Children:

Alt et al demonstrated in a study of paediatric radiographs, that the quality of the centering of the X-rays/patient positioning and collimation was only moderate (average scale value: 2.4 and 2.8), while the quality of the exposure and sharpness was good and very good (average scale value: 1.9 and 1.5).[3] These authors reported that, "the quality of the chest X-rays in departments with additional pediatric radiological expertise (super-specialised radiologists, trained radiographers, sister) was better, mainly in the case of younger patients (younger than 5 years), than departments without additional pediatric radiological expertise."[1,3] They also concluded that in order to achieve a high quality standard daily quality QA is necessary for paediatric chest X-rays.[3]

Cook et al specify that: "the key is having a core group of staff with a clear if not exclusive commitment to paediatrics. It is preferable for general hospitals to dedicate certain staff, areas and lists specifically for paediatrics. Gaining a child's confidence is of the utmost importance in obtaining quality at an achievable dose without protracted investigation times and with minimum stress to the child, parents and staff."[1,7]

Both governments and equipment manufacturers are recognizing that radiation protection is an important issue in paediatric radiolography. With increased patient expectations, medico-legal issues become more important. It is important for all radiologists and radiographers that work with children to be fully aware of regulations and guidelines and there was statistically significant improvement in quality of radiographs immediately after the "intervention" and decline in the review periods that were more than 2 months from the intervention.

To be able to employ dose saving techniques all departments should have a dedicated group of staff devoted to paediatrics with direct responsibility and support for dealing with paediatric imaging requests, imaging children and ensuring that image quality is maintained at the lowest possible dose.[12]
With limited expert staff in paediatric imaging, developing countires must develop cost effective and simple strategies to maintain or improve image quality at low doses to children, that can be rolled out across a variety of service level platforms.

1.3 Aim

To determine whether the introduction of a poster of technical errors in paediatric radiography accompanied by a ‘crash course’ on common errors can sustainably decrease the number and rate of these in an unsupervised unit of a general hospital.

1.4 Objectives

1.4.1 To quantify and characterize predetermined radiographic errors made in a paediatric imaging unit by performing a QA analysis of clinical radiographs of the chest using an error score

1.4.2. To compare radiographic errors made in a paediatric imaging unit by performing a QA analysis of clinical radiographs of the chest using an error score before and after introduction of the pictorial poster and crash course to radiographers

1.4.3. To repeat the QA in the first month, second month and from the third month post intervention to determine sustainability of the “intervention”

1.4.4. To analyse the improvement or deterioration of scores over the monthly follow-up QA

1.4.5. To provide recommendations for repeating the intervention process as a routine QA function and improving the department to produce higher quality radiographs in children.

2.0 CENTRAL CHAPTER

2.1 Materials and Methods

2.1.1. A study with a retrospective and prospective component was performed at the Charlotte Maxeke Johannesburg Academic Hospital.

2.1.2. Predetermined technical errors in frontal chest radiographs performed in one unsupervised paediatric radiology unit were assessed by QA analysis.

2.1.3. The QA review was performed by a single qualified radiologist with regards to the technical aspects of the radiographs according to a developed QA tick-sheet (Figure A1). (The diagnostic component was not assessed). Each X-ray's errors were recorded on an individual tick sheet and this information was then captured on a Microsoft Excel spreadsheet. The tick-sheet was developed by the principal investigator and the supervisor and is currently in use in reporting over 1000 X-rays for the South African Tuberculosis Vaccine Initiative (SATVI) and for Medecins Sans Frontiers (MSF). It was compiled from a variety of sources including the European Commission guidelines for paediatric radiographs. The poster and tick-sheet were developed to represent the common general radiographic errors. The images used were collected from several locations. Images were incorporated into both the tick-sheet and poster so to be reflective of each other.

2.1.4. The images from the poster of common radiographic errors (Figure A2) were presented as a PowerPoint presentation and explained in a 30-minute talk ('Crash Course') to **the radiographers** working in the radiology department on the 5th of May 2012. The 'crash course' represented a 30-minute lecture given by a senior paediatric radiologist involved in the study (not the principle investigator). The lecture took place within the academic training environment of the research location. The lecture was advertised throughout the radiographer hierarchy and was well attended. There was a total number of 58 out of a possible 61 (95.1%) radiographers at the talk, this number included both qualified and student radiographers. The PowerPoint presentation included an introduction and pictorial demonstration of a variety of errors in paediatric frontal chest radiography including how these would impact on clinical diagnosis. It did not include radiographic technique, which is outside the scope of practice of the radiologist. The poster was then duplicated and placed at strategic locations in the X-ray department where paediatric X-rays are performed – in front of X-ray control panel areas and at X-ray review areas. This represented an intervention that is within acceptable QA functions of a department.

2.1.5. QA scores were calculated and types of error categorized for the pre poster and post poster period (during the first month post, second month post and from the third month onwards post intervention).

2.1.6. Comparisons of the technical errors before and after the "intervention" were made. Errors were sub-catorgorised by the researcher into 'perfect films' (no errors), 'not so bad films' (4 or less errors but not a perfect score) and 'bad films' (5 or more errors) - a classification produced in-house without international benchmarking.

2.2 Study Sample

X-rays were obtained from the filing room in the paediatric X-ray department and included a total of 438 radiographs performed over an eight month period. 138 radiographs were reviewed before the intervention (January- 4 May 2011), and a further 109 radiographs were reviewed during the first month after the intervention (5^{th} May- 6^{th} June 2011). A subsequent 100 radiographs and 92 radiographs were reviewed during the second month post (7^{th} June to 7th July 2011) and from the third month onwards post intervention respectively (8^{th} July-October 2011). The X-rays that were reviewed were all hard copy images.

2.3 Inclusion Criteria

2.3.1. Chest radiographs of children under the age of 5 years (dictated by the specific technique used for different age groups)

2.3.2. Ambulatory and non-ambulatory patients were included.

2.4 Exclusion Criteria

Portable X-rays were excluded (dictated by the specific technical differences in the performance of portable chest radiographs)

2.5 Statistical Analysis

A sample size of at least 92 X-rays per review group was analyzed for a power of 80% with a minimum difference of 15% in errors. A p-value of < 0.05 was considered significant. Statistical analysis was performed with the assistance of a statistician. The data was analyzed using:

- McNamara test- comparing the proportion of errors between baseline and those during the first month post, second month post and (from the) third month post intervention.
- Cochran-Mantel-Haenszel statistics to independently assess the errors at baseline, first month post, second month post and (from the) third month onwards post intervention.
- Kruskal and Wallis test to independently assess the errors between groups at baseline, first month post, second month post and (from the) third month onwards post intervention.
- Fischer Test for 2x2 analysis to compare the errors between groups at baseline, first month post, second month post and from the third month onwards post intervention.

2.6 Ethics

Radiographs performed and assessed were those requested and performed for clinical indications. No additional radiographs were performed even if errors were detected. No diagnostic evaluation was performed as the radiology report was not accessed. The recording of data according to a numbering code preserved patient anonymity. The code decipher was kept locked away and was only accessible to the primary author and supervisor. Ethics approval was obtained from the Human Research Ethics Committee of the University of the Witwatersrand. The Ethics Clearance certificate number is M10970. Permission to perform the study at the Charlotte Maxeke Johannesburg Academic hospital was obtained from the hospital CEO.

2.7 Results

There were a total of 438 radiographs included. The age mean overall was 10.4 months (range 1 month to 60 months). There were 171 males (39%) and 267 females (61%). The four groups were as follows:

Group 1 – Prior to any intervention: 137 radiographs (31.27%); mean age 14.0 months (SD 16.08); 52 Males (37.68%), 85 Females (61.59%)

Group 2 – Radiographs reviewed in the first month after the intervention: 109 radiographs (24.88%); mean age 8.8 months (SD 12.75); 42 Males (38.53%), 67 Females (61.47%)

Group 3- Radiographs reviewed during the second month after the intervention: 100 radiographs (22.83%); mean age 9.18 months (SD 14.55); 39 Males (39.0%), 61 Females (61.0%)

Group 4- Radiographs reviewed from the third month onwards after the intervention: 92 radiographs (21.00%); mean age 8.1 (SD 10.02); 38 Males (41.30%), 54 Females (58.70%)

The study demographics are summarized in table 2.1.

Table 2.1 Summary of study demographics

	Overall	Group 1	Group 2	Group 3	Group 4
Number of radiographs reviewed	438	137/438 (31.27%)	109/438 (24.88%)	100/438 (22.83%)	92438 (21.00%)
Male patients	171 (39.00%)	52 /137 (37.95%)	42/109 (38.53%)	39/100 (39.00%)	38/92 (41.30%)
Female patients	267 (61%)	85/137 (62.04%)	67/109 (61.46%)	61/100 (61.00%)	54/92 (58.70%)
Mean age (months)	10.4 Range 1-60months	14.0 SD 16.08	8.8 SD 12.75	9.18 SD 14.55	8.1 SD 10.02

Overall and group error prevalence under specific categories of error is summarized in table 2.2. The commonest errors were, in descending order, poor collimation [figures 2.1 and 2.2], kyphotic and lordotic view [figure 2.3] and rotation [figure 2.1 and 2.2]. The least common errors were cut-off, wrong/no left or right [figure 2.1] and central vessels not well seen [figure 2.3].

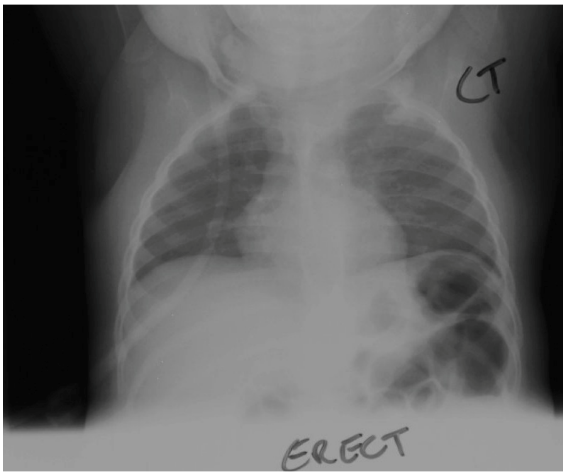


Figure 2.1 Frontal radiograph demonstrating rotation, under inspiration, poor collimation and a foreign body on film (tubing)

Figure 2.2 AP Chest radiograph demonstrating poor collimation, rotation, and inability to visualize the vessels behind the heart and the tracheobronchial tree and no left or right marker on film.

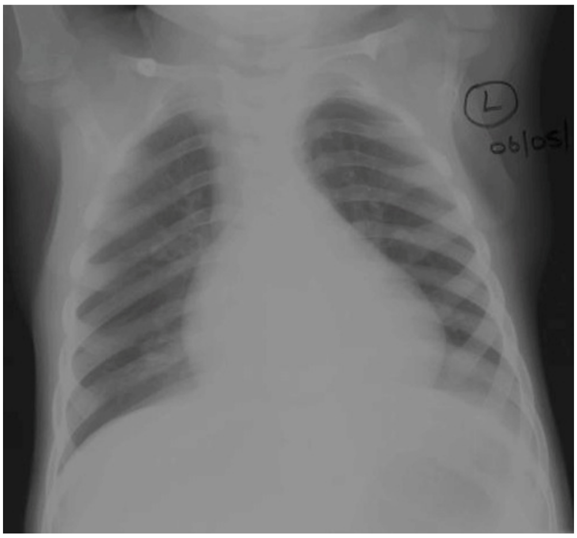


Figure 2.3 AP chest radiograph demonstrating a kyphotic view and the inability to visualize the tracheobronchial tree, the vessels behind the heart or the peripheral vessels.

Table 2.2 Summary of the prevalence of radiographic errors as percentages of the total, for the overall study population as well as subgroups

Total Possible Errors (Number of radiographs x 12 possible errors)	**Overall** 438 x 12 = 5256	**Group 1** 137 x 12 = 1644	**Group 2** 109x 12 = 1308	**Group 3** 100 x 12 = 1200	**Group 4** 92 x 12 = 1104
Cutoff	0.2% (8/5256)	0.2% (4/1644)	0.2% (3/1308)	0% (0/1200)	0.1% (1/1104)
Under inspiration	2.3% (120/5256)	2% (33/1644)	2.7% (35/1308)	2.5% (30/1200)	2% (22/1104)
Rotation	4.3% (228/5256)	3.6% (59/1644)	3.8% (49/1308)	5.2% (62/1200)	5.3% (58/1104)
Scapula In The Way	4.2% (223/5256)	4.7% (78/1644)	3.4% (45/1308)	3.9% (47/1200)	4.8% (53/1104)
Kyphotic / Lordotic view	4.9% (259/5256)	4.3% (71/1644)	5% (65/1308)	5.3% (64/1200)	5.3% (59/1104)
Artifact / Foreign Body	2.3% (125/5256)	2% (33/1644)	2% (26/1308)	2.8% (34/1200)	2.9% (32/1104)
Central Vessel Not Well Seen	1.6% (82/5256)	1.6% (26/1644)	0.8% (11/1308)	1.3% (15/1200)	2.7% (30/1104)
Peripheral Vessels Not Well Seen	2.2% (114/5256)	3.6% (60/1644)	0.7% (9/1308)	1.2% (14/1200)	2.8% (31/1104)
Poor Collimation	5.4% (284/5256)	6% (98/1644)	4.7% (62/1308)	5.3% (64/1200)	5.4% (60/1104)
Tracheobronchial Tree Not Well Seen	2.6% (138/5256)	3.2% (52/1644)	1.6% (21/1308)	2.6% (31/1200)	3.1% (34/1104)
Vessels Behind Heart Not Well Seen	3.3% (175/5256)	3.5% (57/1644)	2.1% (27/1308)	3.3% (40/1200)	4.6% (51/1104)
Wrong/No Left Or Right Marker	0.2% (10/5256)	0.4% (6/1644)	0% (0/1308)	0.2% (2/1200)	0.2% (2/1104)
Total number of errors	33.6% (1766/5256)	33.9% (577/1644)	27% (353/1308)	33.6% (403/1200)	40.1% (433/1104)

Our scoring system demonstrated a range of scores from ‘0’, which represents a perfect score, to a maximum of 9 errors out of a possible score of 12 for each radiograph. No X-ray scored more than 9 because no X-ray had that many radiographic errors. The total possible cumulative score of all the groups added together assuming a maximum number of errors was (12 x 438) 5256. The total score for the overall group, representing the number of errors, was 1766 (33.6%). The total number of possible errors for **group 1** was (137 x 12) 1644 and the total cumulative errors were 577 (35.1%). The total number of possible errors for **group 2** was (12 x 109) 1308 and the total cumulative errors were 353 (26.99%). The total number of possible errors for **group 3** was (12 x 100) 1200 and the total cumulative errors were 403 (33.58%). The total number of possible errors for **group 4** was (12 x 92) 1104 and the total cumulative errors were 433 (39.22%). These are summarized in table 2.3.

Table 2.3 also summarizes the overall and group error prevalence as total and percentages of total possible errors and compares the prevalence of specific quantities of errors per radiograph evaluated in each group. The majority of evaluations demonstrated 2 or more errors per film accounting for 312 of the 438 (71.23%) radiographs evaluated in the overall group; 102 of the radiographs in group 1 (74.45%); 58 of the radiographs in group 2 (53.21%); 78 of the radiographs in group 3 (78.00%); 74 of the radiographs in group 4 (80.43%). Group 2 immediately after the intervention showed an increased percentage of the number of perfect films and 'not so bad' films with a decrease in the percentage of 'bad films'.

Table 2.3 Summary of scores for the overall and subgroups as well as the prevalence of specific numbers of errors per film, overall and in each group

	Overall 438	Grp 1 137	Grp 2 109	Grp 3 100	Grp 4 92
Total possible errors (12 per film)	5256 (12x 438)	1644 (12x 137)	1308 (12x 109)	1200 (12x 100)	1104 (12x92)
Prevalence of errors (scores) total	1766/5256 (33.6%)	577/1644 (35.1%)	353/1308 (27%)	403/1200 (33.6)	433/1104 (39.2%)
Specific number of errors on a film:	**Number of radiographs**				
Total films	**438**	**137**	**109**	**100**	**92**
0 errors (perfect)	1.6% (7/438)	1.5% (2/137)	2.8% (3/109)	1% (1/100)	1.1% (1/92)
1 error	8.2% (36/438)	5.8% (8/137)	14.7% (16/109)	9% (9/100)	3.3% (3/92)
2 errors	19% (83/438)	18.3% (25/137)	29.4% (32/109)	12% (12/100)	15.2% (14/92)
3 errors	17.6% (77/438)	17.5% (24/137)	16.5% (18/109)	24% (24/100)	17.7% (11/92)
4 errors	14.6% (64/438)	13.9% (19/137)	11% (12/109)	19% (19/100)	15.2% (14/92)
5 errors	13.7% (60/438)	16.8% (23/137)	12.8% (14/109)	8% (8/100)	16.3% (15/92)
6 errors	9.8% (43/438)	8.8% (12/137)	2.8% (3/109)	13% (13/100)	16.3% (15/92)
7 errors	8.7% (38/438)	9.5% (13/137)	5.5% (6/109)	11% (11/100)	8.7% (8/92)
8 errors	5% (22/438)	5.1% (7/137)	4.6% (5/109)	2% (2/100)	8.7% (8/92)
9 errors	1.8% (8/438)	2.9% (4/137)	0% (0/109)	1% (1/100)	3.3% (3/92)
5 errors or more 'Bad films'	39% (171/438)	43.1% (59/137)	25.7% (28/109)	35% (35/100)	53.3% (49/92)
4 errors or less but not perfect 'Not so bad films'	59.4% (260/438)	55.5% (76/137)	71.6% (78/109)	64% (64/100)	45.7% (42/92)
'Perfect films'	1.6% (7/438)	1.5% (2/137)	2.8% (3/109)	1% (1/100)	1.1% (1/92)

Groups were compared with regard to their scores and with regard to the number of each type of error. There was statistically significant improvement between groups 1and 2 with regard to overall scores. There was statistically significant deterioration in scores between group 2 and 3 and group 2 and 4.

In addition there were statistically significant differences in the prevalence of specific errors. There was a statistically significant improvement between group 1 and 2 with regard to: peripheral vessels not well seen ($p < 0.0001$); tracheobronchial tree not well seen ($p< 0.0019$); vessels behind heart not well seen ($p< 0.0067$). There was a statistically significant deterioration between group 2 and 4 with regard to: central vessels not well seen ($p< 0.0001$); peripheral vessels not well seen ($p < 0.0001$); tracheobronchial tree not well seen ($p< 0.0068$); vessels behind heart not well seen ($p< 0.0001$). There was a statistically significant deterioration between group 3 and 4 with regard to: central vessels not well seen ($p< 0.0060$); peripheral vessels not well seen ($p < 0.0019$). The results of the statistical analysis comparing the different groups are summarized in table 2.4, 2.5 and 2.6.

Table 2.4 P values of statistical significance when comparing groups with regard to summated scores (i.e. total numbers of errors for each group)

	Grp 1 vs 2	**Grp 1 vs 3**	**Grp 1 vs 4**	**Grp 2 vs 3**	**Grp 2 vs 4**	**Grp 3 vs 4**
p-value	**0.0001**	0.6054	**0.0004**	**0.0001**	**0.0001**	**0.0055**

Table 2.5 P-values of statistical significance when comparing groups with regard to the prevalence of specific types of errors.

Type of error	Grp 1 vs 2	Grp 1 vs 3	Grp 1 vs 4	Grp 2 vs 3	Grp 2 vs 4	Grp 3 vs 4
Cutoff	1.0000	0.01402	0.6506	0.02478	0.6267	0.4792
Underinspiration	0.1966	0.3719	1.0000	0.7667	0.2127	0.1509
Rotation	0.7968	**0.0056**	**0.0045**	0.0182	0.0112	1.0000
Scapula in the way	0.0207	0.1481	1.0000	0.4853	0.0239	0.1510
Kyphosis/Lordosis	0.2464	0.0647	0.0772	0.5698	0.5616	1.0000
Artifact/Foreign body	1.0000	0.1088	0.0998	0.1263	0.1178	1.0000
Central vessels not well seen	0.0717	0.4886	0.0276	0.3019	**0.0001**	**0.0060**
Peripheral vessels not well seen	**0.0001**	**0.0001**	0.1324	0.1941	**0.0001**	**0.0019**
Poor collimation	0.0219	0.2582	0.3128	0.3236	0.2486	0.8810
Tracheobronchial tree not well seen	**0.0019**	0.2744	0.8903	0.0558	**0.0068**	0.4459
Vessels behind heart not well seen	**0.0067**	0.8937	0.0437	0.0257	**0.0001**	0.0427
Wrong/no left or right marker	0.0354	0.4729	0.0802	0.2277	0.2083	1.0000

The number of errors were subcategorized into ‘bad films’ which represented films with 5 or more errors, ‘not so bad films’ which represented films with 4 or less errors but not perfect, and ‘perfect films’ which represented films with no errors. Groups were compared with regard to these subcategories. There was statistically significant improvement between group 1 and group 2 in the ‘bad films’ subcategory. There was statistically significant deterioration between group 2 and group 4 in the ‘bad film’ and ‘not so bad’ subcategories. Table 2.6 summarizes the statistical results of the comparison of these subcategories between the groups.

Table 2.6 P-values of statistical significances when comparing the subcategories with regard to the number of radiographs with specific numbers of errors (i.e. to determine if there are more radiographs with perfect scores = improvement; or more radiographs with scores of 5,6,7,8 and 9 = deterioration)

	Grp 1 vs 2	Grp 1 vs 3	Grp 1 vs 4	Grp 2 vs 3	Grp 2 vs 4	Grp 3 vs 4
5 errors or more **‘Bad films’**	**0.0016**	0.2631	0.5269	0.0868	**0.0002**	0.0824
4 errors or less but not perfect **‘Not so bad films’**	0.1301	0.2367	0.1858	0.9230	**0.0059**	0.0160
0 errors **‘Perfect films’**	0.7958	0.7829	0.7266	0.6757	0.7373	0.5143

3.0 CONCLUDING CHAPTER

3.1 Discussion

From these results which show an initial improvement and then a progressive decline, it can be deduced that to fully benefit from a QA 'intervention' it should be performed at least on a monthly basis. Even minor indicators of image quality need to be monitored to continuously improve image quality.[6] QA should therefore (ideally) be performed on a daily and continuous basis so as to improve the quality of radiography in the department.

There was a statistically significant overall improvement in the number of errors in the radiographs reviewed immediately after the intervention (i.e. group 2) and in particular with regard to peripheral vessel, tracheobronchial tree and vessels behind the heart visibility. There should be consistency in the degree of quality achieved and emphasis should be placed on diagnostic quality, not best quality.[1] In paediatric radiology the importance of radiation protection is undisputable. The technique used must be adapted to the size of the patient, with the use of good collimation and shielding. There was a steady increase in the number of errors in the radiographs reviewed beyond this period. There was a statistically significant deterioration between group 2 and 4 in the same categories. From these results it can be deduced that to fully benefit from a QA 'intervention' it should be performed at least on a monthly basis.

The commonest error was poor collimation, which is in keeping with findings from other international QA studies,[7,12] followed by 'kyphotic/lordotic' view and 'rotation'. The above three errors are related to patient positioning which is often a challenge in the paediatric patient.[12] The least common errors were ‘parts cut-off’ and ‘no/wrong left or right marker’ which are errors relating to radiographer diligence. From this, one can extrapolate more specialized paediatric training is necessary at this centre to decrease other technical errors encountered specifically when imaging children.

In addition the number of errors per film improved immediately after the intervention with a higher percentage of ‘not so bad films (4 errors or less) and a lower percentage of ‘bad’ radiographs (5 errors or more). “Good radiographic technique is the most important factor in improving quality without the cost of increased dose.”[1] The ‘bad’ radiographs should have probably been repeated to reach diagnostic quality and this would have resulted in an increase dose to the patient. The study did not include analysis of the reject box as this was not technically possible, since the study was performed retrospectively and the reject box in the paediatric department is disposed of with haphazard frequency. This challenge would have been obviated if the hospital had a picture archiving and communication system (PACS.)

The ‘crash course’ played an important part in the effectiveness of the ‘intervention’ as from the results it is clear that the poster alone was not enough to keep the quality of radiography at the high standard obtained in the first month after the ‘intervention.’ The quality of radiographs of radiographs after three months was worse than before the ‘intervention’ this may be partly due to the smaller number of radiographs reviewed in the last phase of the study. (137 radiographs reviewed prior to intervention compared with 92 radiographs reviewed in the third month after the intervention). The deterioration of quality over time also supports the fact that QA should be a continuous process because quality deteriorates over time without regular QA and quality improvement (QI).

3.2 Limiting factors and weaknesses of the study were:

- The standard deviation of the ages in all groups are higher than the mean. This indicates a very skewed population. The majority of the ages of the patients reviewed were below the age of 12 months and do not follow a normal distribution. It should be noted that radiographs were included sequentially and were not preselected. However, the study was performed during a fixed period of the year, spanning a period of January to October which includes all of the winter months. The patients presenting for the included radiographs may reflect the age group most susceptible to infection during the winter months. In addition, younger children are more susceptible to endemic infectious diseases such as Tuberculosis in our community, which may be responsible for skewing the age distribution. However, this does represent the reality of our radiographic practice.
- Senior staff were changed during the review period which broke the chain of supervision but which may have to be factored in to programs trying to maintain quality standards.
- The junior radiographers (this includes student and the recently qualified radiographers) working in paediatric department were constantly changing on a day-to-day and week-to-week basis and a chief radiographer did not always supervise them. Due to staff shortages one chief radiographer often had to supervise both the main X-ray department and the paediatric X-ray department simultaneously.

- The computer system in the hospital was not working for two of the four months in the period of data collection, this limited the number of radiographs, which could be traced and located for review.
- The reliability of the findings scored by a single radiologist.
- There was no correlation with analysis of the radiographs that were repeated and placed in the reject box.

3.3 Recommended improvements to the study:

- If the group of radiographers working in the paediatric department could be constant throughout the period of the study. This would allow for a more specific group to be assessed, which would more accurately assess the impact of the ‘intervention’ and the decline there after.
- Knowledge of the experience of the radiographer and correlation of this with the error rate would provide useful information.
- Having a second radiologist to score the films would add balance to the outcome and reduce any bias.
- The poster could have been reprinted on a different coloured background and replaced on a monthly basis. This would have made the radiographers pay more attention to it as after a while posters often become part of the ‘furniture’ and are not noticed.
- Correlation with reject analysis to assess how many radiographs are repeated and the degree of improvement after they have been repeated would be useful information.

3.4 Recommendations from the study:

- An educational and awareness intervention is recommended monthly or at least bi-monthly for all staff rotating through a paediatric imaging department. This may be in the form of oral or webinar lectures from in-house or travelling lecturers, changing the colour of the poster on a monthly basis, changing the position of the poster within the paediatric X-ray department.

3.5 Recommended improvements to the department:

- The patient environment should be as welcoming and child friendly as possible. There are many simple and inexpensive ways of making the environment as child-friendly and distracting as possible including:
- Having a separate child friendly waiting area for children with suitable decoration and toys
- Placing pictures/murals in X-ray room
- Hanging /musical toys on the X-ray/ultrasound equipment
- Providing patterned lead aprons for staff and care givers[1,7]

Staff should invest time to ensure that they take the radiograph right the first time preventing the need for repeat radiographs.[7] Frightened and non-cooperative children who are often accompanied by worried and ill-informed parents are factors that contribute to poor quality radiography.

- Some articles suggest the use of a patient immobilization device (PID) for hospitals with radiographers not specifically trained for paediatric examination.[13]

- The education of the radiographers and radiologists remains the most important factor in paediatric radiation protection.[7]
- All X-ray departments examining children should have a dedicated core group of staff trained in the care and imaging of paediatric patients. These staff members would also train and supervisor junior staff.[1]
- Departments should develop standardised protocols, techniques and diagnostic pathways. They should have comparable diagnostic quality images and use doses within published reference ranges for children.[1]

3.6 Recommendations for future research:

- Correlation of findings with the level of radiographer expertise.
- Correlation with reject analysis
- Roll out of the study to a variety of resource levels of radiographic service using the Internet and social media.
- Review of radiographs by more than one radiologist (this may include general radiologists, paediatric sub-specialised radiologists) with and without the assistance of the tick-sheet. A further step would be to correlate the analysis with level of expertise.
- Review of radiographs by radiographers (students and qualified radiographers and specially trained paediatric radiographers) with and without the assistance of the tick-sheet. A further step would be to correlate the analysis with level of expertise.

3.7 Conclusion

A simple method of providing a short lecture ('crash course') and raising awareness through posters, has been successful in improving radiographic errors in an un-supervised paediatric practice. This includes the overall quantity of errors as well as the number of errors per radiograph. It is imperative to note that there is a decline in quality after a month from the intervention, with a downward trend over the next few months. This is in keeping with existing teaching the QA is an ongoing process and that the intervention we propose should best be repeated monthly. Roll-out of this type of cost effective and simple QA intervention tool using continuous support via the internet and social media may form the backbone of high quality pediatric chest radiographs in a developing country faced with the burden of imaging children with chest diseases in the Tb and HIV setting.

APPENDIX A

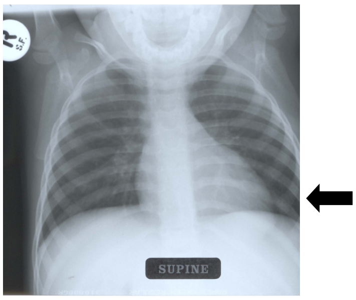
Appendix 4.2: Data Collection Sheet: Quality Assessment [QA] of Frontal Chest Radiographs

Date: **Patient code** **Reviewer name:**

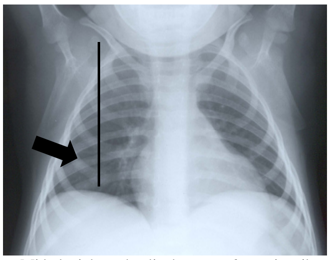
Instructions: Please circle **Yes (Y) or No (N)** for each section

DOB:

1. Parts Cut-off
Y N

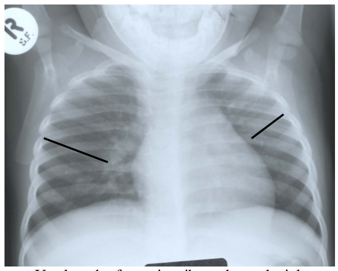


2. Under Inspired (< 6 ant ribs)
Y N



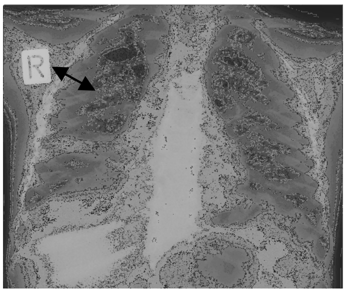
Mid clavicle at the diaphragm > 6 anterior ribs

3. Rotated
Y N

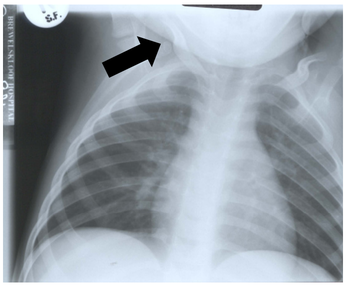


Use length of anterior ribs and not clavicles

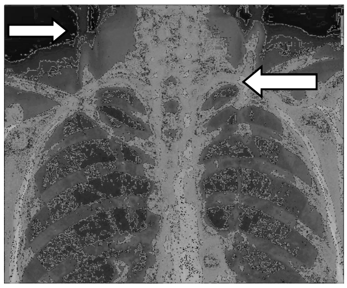
4. Scapula in the way (> 1 cm)
Y N



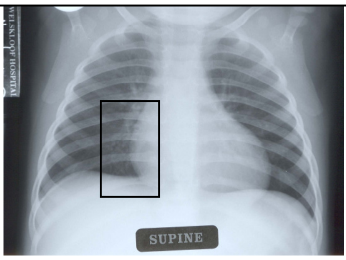
5. Kyphotic or lordotic?
Y N



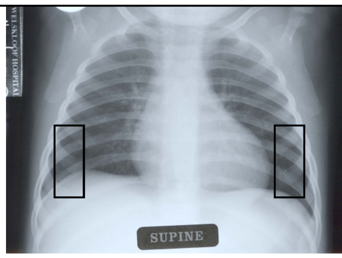
6. Artifact / Foreign body
Y N



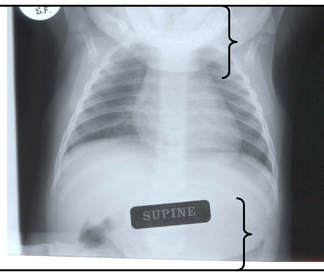
7. Central vessels not well seen
Y N



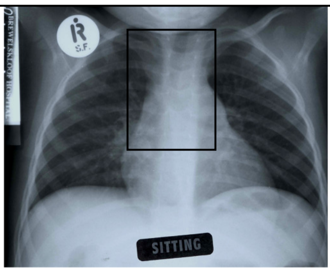
8. Peripheral vessels not well seen
Y N



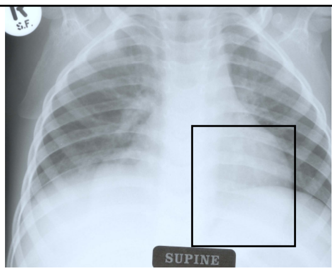
9. Poor collimation
Y N



10. Trachea and bronchi not clearly seen
Y N



11. Vessels behind heart not well seen
Y N



12. Wrong (no) Left/Right marker
Y N

Fig A1 QA Tick-sheet

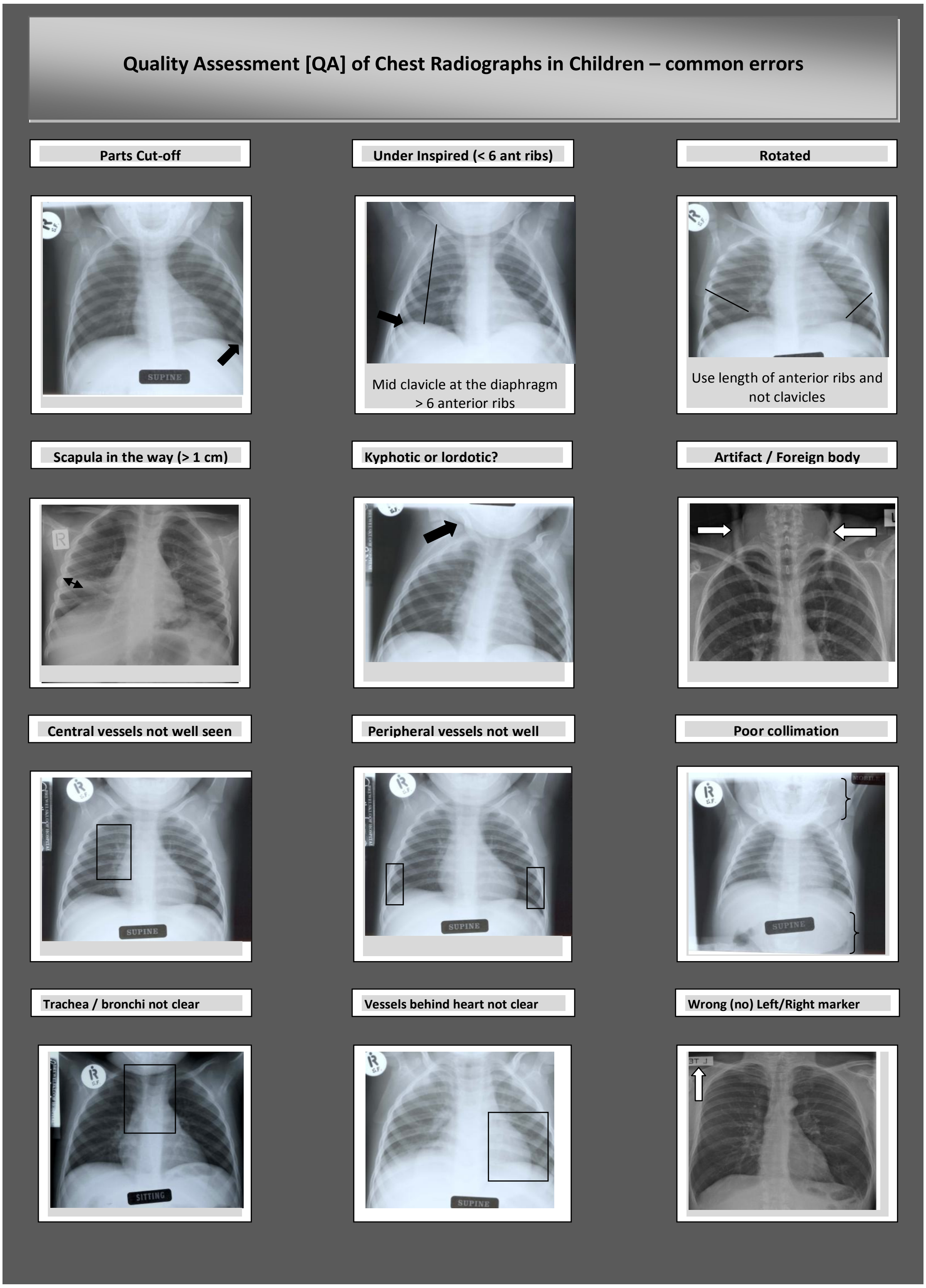


Figure A2 Poster of common radiographic errors in paediatric radiology

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