



Diagnostic Radiography BSc (Hons)

Level 5 Research Methods Module

Research-informed Teaching experience II
(RiTTe II)

Student Handbook

2018-19

1. The purpose of RiTe II is to build upon your own experiences and knowledge gained from RiTe I and year 1. As you are aware the selection of appropriate exposure factors is an important aspect for the optimisation of radiographic images, as it affects both the image quality and radiation dose.

2. Within RiTe II you will explore these concepts further, using a patient based scenario to investigate the relationships between image quality, effective dose when undertaking an AP supine chest X-ray (**Group A**) or AP supine pelvis X-ray (**Group B**) with and without a grid. The areas you will be researching are outlined below:

- The effect of altering kVp on image quality with and without grid.
- The effect of altering mAs on image quality with and without grid.
- The effect of altering the above on effective dose (E) with and without grid.
- Identify a kVp, mAs and grid / non-grid exposure combination/s that provide optimum image quality **with** the lowest effective dose (E).

3. You will be divided into two enquiry-based collaborative learning groups and undertake your research within the university's imaging facility using either the LUNGMAN or pelvis anthropomorphic phantoms. You should pilot your methodology (e.g. radiographic positioning and technique) to ensure consistency and use your acquired images to analyse the image quality and calculate the effective dose.

4. Your research will investigate and determine a kVp, mAs and grid or non-grid exposure combination/s which provides optimum image quality with the lowest E for your scenario.

5. During RiTe II you will:

- ❑ Perform a systematic literature review (there are articles and materials on Blackboard to help you)
- ❑ Formulate a research question
- ❑ Use the resources available to you to devise a methodology for your research
- ❑ Conduct your research
- ❑ Analyse and draw conclusions from your research
- ❑ Consider potential pitfalls / barriers
- ❑ Consider further work you may undertake

6. Within your RiTe II groups you should also identify the following:

- ❑ **Project Leader.** The project leader works to keep the research project on track. The project leader is charged with ensuring full participation of all group members and helps to moderate those who may try to dominate group discussions or work.
- ❑ **Recorder / Record keeper.** The recorder keeps track of unresolved issues, records results, discussion points, etc so that everyone has access to this information.
- ❑ **Reporter.** The reporter puts together a draft of the groups research methodology from all group members, incorporates agreed-upon-changes.
- ❑ **Timekeeper.** The timekeeper makes sure the group stays on schedule for the research project and ensures that tasks are completed within a given time scale.
- ❑ **Group Member/s.** The group member/s actively participates in the group discussions and practical work. The group member/s should also research all the learning objectives independently and share this information with other group members.

7. All members of the group should:

- ❑ Listen actively to other group members
- ❑ Allow others to express opinions and give information
- ❑ Acknowledge contributions of others
- ❑ Speak directly to group members
- ❑ Attempt to resolve any misunderstanding
- ❑ Ensure punctuality on all days
- ❑ Give prior notice of intended absence
- ❑ Share responsibility in learning/workload
- ❑ Be actively involved within the group
- ❑ Present relevant information to the group
- ❑ Identify irrelevant/excessive information
- ❑ Advance discussions by responding to or expanding on relevant issues
- ❑ Be committed to work and group members
- ❑ Complete assigned tasks and negotiate alternatives if unable to complete them
- ❑ Effectively manage time & resources

All members of the group should participate with **all** aspects of RiTe II, including moving the equipment and using computer software as you peer score members in your group and their contribution to activities during the week.

8. Your first task as a group will be to design a method (within certain parameters), that you will use to investigate the effects of altering kVp, mAs with a fixed SID on image quality and E using anthropomorphic phantoms to simulate a patient for AP chest and pelvis X-ray.

Group A:

You will investigate impact on image quality and E when altering the following factors for an AP supine CXR on a patient trolley:

- kVp
- mAs
- With and without a grid

Group B:

You will investigate impact on image quality and E when altering the following factors for an AP supine pelvis on a patient trolley:

- kVp
- mAs
- With and without a grid

Both groups must note that the patient is stretcher bound and unable to move from the trolley and must utilise the IR tray within the trolley itself.

9. As a group you will need to discuss how you will acquire, analyse and present your data and any suitable statistical concepts that you might use to validate your collected data.

10. You may wish to consider what is meant by 'image quality' for your scenario and how you will perform a standard AP supine chest or AP supine pelvis X-ray projection to ensure consistency and the factors affecting this (you may consult 'Clark's Positioning in Radiography (Whitley, Sloane et al., 2005) and 'McQillan-Martenson Radiographic Critique'.

11. You will need to undertake some form of literature search using resources available to you (e.g. library (SOLAR), BlackBoard resources and the internet).

Note: You will be allowed to propose no more than 32 different sets (e.g. 4 x 4 x 4 with and without grid (2)) of imaging conditions for this research. These 32 selected conditions shall be derived from the literature and your own knowledge of radiographic practice.

12. Imaging parameter conditions that you will research are summarised below:

- ❑ kVp, N to M, stepping through 4 set kVp values for each mAs
- ❑ mAs, X to Y, stepping through 4 set mAs values for each kVp
- ❑ kVp and mAs adjustment are stepped through using **BROAD FOCUS ONLY**
- ❑ Imaging undertaken **both with and without a grid with a fixed SID**

13. Some common exposure factors for both are provided below:

Some examples of exposure factors:

Chest:

Without Grid - 90kVp and 4mAs

With Grid - 125kVp and 2mAs

Pelvis:

Without Grid – 66 kVp and 8mAs

With Grid – 75kVp 2.5mAs

14. Each group will present their method to a facilitator for discussion on day three. Following feedback from the facilitator you should then discuss and reflect upon any areas of the methodology that require altering and why before starting your research.

15. By the end of RiTe II, you should have acquired and analysed enough data to determine an optimum (or range of optimum) exposure/s for an AP supine chest or /AP supine pelvis that satisfies the criteria for optimum radiographic image quality **with** the lowest possible E. You should also be able to describe the influence of these parameters on one another.

16. Assessment: See Blackboard for full assessment brief:

Part 1: You will need to prepare a presentation (e.g. PowerPoint) of your research and conclusions. You should also discuss how your method could be improved and identify further research that might be undertaken within the same context (e.g. what other factors could affect image quality or patient dose within the context of this scenario). **This presentation will last no more than 20 minutes and you will give the presentation as a group.**

Part 2: Peer scoring of member contribution to group activities and team working during RiTe II.

EFFECTIVE DOSE

1. Effective dose (E) is the standard measure for comparing risks from various sources of radiation exposure, including those resulting from diagnostic radiology. The precise determination of effective dose is complex and its calculation is unlikely to be carried out routinely in a hospital radiology department. However, estimates of effective dose can be made from quantities easily measurable in an x-ray room. Using mathematical modelling (Monte Carlo) and equivalent dose / dose area product (DAP) measurements, it is possible to calculate the effective dose to the patient using the International Commission on Radiological Protection (ICRP) 103 (2007) tissue weighting factors.

2. E is found by calculating a weighted average of the equivalent dose (H_t) to different body tissues, with the weighting factors (W_t) designed to reflect the different radiosensitivities of the tissues. The unit for effective dose is the Sievert (Sv).

$$E = \sum_t H_t \cdot W_t$$

- H_t are the tissue-specific equivalent doses in tissues T
- W_t are committee-defined dimensionless tissue-specific weighting factors

3. Tissue weighting factors as recommended by the International Commission on Radiological Protection (ICRP) 103 (2007) are shown in Table 1.

Table 1: Tissue weighting factors according to ICRP 103 (ICRP 2007)

Tissue	Tissue weighting factor W_t
Bone-marrow (red), colon, lung, stomach, breast, remaining tissues(*)	0.12
Gonads	0.08
Bladder, oesophagus, liver, thyroid	0.04
Bone surface, brain, salivary glands, skin	0.01
Total	1.00

(*) Remaining tissues: Adrenals, extrathoracic region, gall bladder, heart, kidneys, lymphatic nodes, muscle, oral mucosa, pancreas, prostate (♂), small intestine, spleen, thymus, uterus/cervix (♀).

4. Some median adult patient effective doses for common radiographic examinations are given below for your information:

Examination	Effective Dose (mSv)
Chest, PA	0.017
Abdomen, AP	0.7
Pelvis, AP	0.66
Thoracic Spine, AP	0.4
Lumbar Spine, AP	0.69
Lumbar Spine, LAT	0.29

Group A (Chest)

1. You are a Diagnostic Radiographer working in a busy emergency department (ED). The X-ray department uses digital radiography (DR) equipment.

2. An elderly patient has been just brought into the emergency department following a fall at home. They exhibit some signs of confusion but are compliant. Subsequent assessment by the medical team, means you receive the following request card:

X-RAY REQUEST FORM

Radiology Department				
Patient Details:	Sex: M	DOB: 3/1/1965	Record Number: J54698	GP Name and Address:
First name: Eric		Last name: Vimes		
			Ward/Department: ED	
			Consultant: TP	
Address: 1 Frederick Road Salford M6 6PU			Previous Imaging: No	Pregnant: N/A LMP: N/A
			Previous Surgery: No	Patient Mobility: Trolley
Clinical Details/Information: Fall at home. Tender to groin Confused ++ ?pubic rami # ?chest infection			Investigations Requested: <ul style="list-style-type: none"> • Pelvis X-ray • CXR 	
			Signature: Dr Colon (e-signature confirmed)	
			Date: Today	

6. You will also need to consider the following for this scenario:

Patient presentation:

- The patient is on a trolley.
- The patient IS UNABLE to be moved off the trolley onto the x-ray table.

RESEARCH PARAMETERS – Group A (Chest Only)

Part A. Minimising Error

1. Prior to conducting your research, you will need to 'warm up the tube' and consult the quality control (QC) data for the X-ray equipment that you will use. You will need to analyse this QC data against the expected manufacturer specifications. The QC data should include recent information (e.g. from within the same week as your research); if not then you should consider collecting such data. These QC tests shall be determined and performed as part of your experimental design.

2. If there is difference with your QC data from manufacturer specifications, then you should seek advice from a member of staff before proceeding.

3. You may need to acquire a number of pilot images to check your supine CXR positioning and method.

4. You will also need to minimise sources of error with regards to the image viewing conditions (e.g. ambient lighting conditions and viewer to screen distance). You should also consider using a test card for monitor calibration and optimisation prior to undertaking any image analysis.

6. You will need to record your radiographic positioning and technique to ensure consistency during your phantom research.

Part B. Controlling for Variables

1. As outlined in Part A, you will use your method to acquire images of the chest phantom in the **AP supine** position across a range of conditions. Remember, your choice of conditions to generate these images is limited. Test your method first and make changes to your methodology as required (you should also record and reflect upon your reasons for changing your original design if you do so).

2. Other factors that you should aim to keep constant, within your research, include

the following:

- The position of the chest phantom - You should aim to ensure that the chest is imaged as you would in the clinical environment using the **same** radiographic positional technique throughout your research
- Source to image-receptor distance (SID) / Source-detector distance (SDD)
- Focal spot size (**broad focus only**)
- Collimation should be to the size of the IR and remain constant (once set)
- The use / non- use of the air gap technique.
- The horizontal position of the x-ray beam over the phantom
- The vertical position of the x-ray beam over the phantom
- The distance between the phantom and the object to image-receptor distance (OID)

***** You will need to justify your choices for these factors *****

Part C. Conducting the research

1. Take your first exposure, record the exposure factors, SID and take a reading from the DAP meter. You should ensure that all your images have a logical / clear file name. You may wish to design a table to record your data so that you can compare the results and use this to refine your method.

2. You should aim to position the chest phantom in the AP supine position for a chest X-ray as far as practical and in accordance with 'Clark's positioning in Radiography'. In terms of position, you should aspire to have the chest phantom in a position that produces a good quality image to demonstrate the anatomy of the chest in the AP supine position.

3. When assessing subsequent images, you should consider the technical information from 'Clark's Positioning in Radiography' (Whitley, Sloane et al., 2005) and 'McQillan-Martenson Radiographic Critique' to determine positional accuracy and image analysis. Once you have achieved an image that is of good positional quality, the chest phantom will then remain in that fixed position.

4. You should also record the following to identify your images later:

- kVp
- mAs
- Grid / No grid
- SID
- DAP

DAP - Be aware that this may be read in cGycm^2 and as such will require converting to mGycm^2 prior to entering into the PCXMC software – Check your units!

DATA ANALYSIS – CHEST PHANTOM

Part A: Chest X-ray image quality (un-blinded) analysis

1. After you have completed your research using the chest phantom, you will need to transfer these images onto a PC so that you can use the 2AFC software to critique your chest images. These should not contain any annotation to identify which parameters were used to acquire the image.

2. You will then need to select a **REFERENCE** image to use in the 2AFC software. You will compare your other images with the **REFERENCE** image and score each of these images against the **REFERENCE** image as to image quality. Use the dual screen monitors within the Imaging Suite to score your images.

3. You will also calculate the effective dose to the patient for each image. To do this you will need to enter the relevant examination data. It is therefore very important that you note the following data during your research / image analysis in order to calculate the estimated dose using the PCXMC software:

- kVp
- mAs
- X-ray filtration thickness / X-ray filter
- Grid / No grid
- SID
- DAP

4. Select one of your 32 images to be the **REFERENCE** image. You should be able to justify your selection. You will need to appraise and score each of your selected images against the selected **REFERENCE** image for image quality using the two-alternative forced choice analysis (2AFC) software. The 'Criteria for the Appraisal of Radiographs' can be found in **Table 2**, you may wish to use some or all of these for your image appraisal criteria. In **Table 3** you will also find some 'PA Chest Image Quality Criteria' which you may find helpful in setting your scoring appraisal criteria.

See the 2AFC guide on BlackBoard on how to upload and score your images

Table 2. CRITERIA FOR THE APPRAISAL OF RADIOGRAPHS
Explanatory Guidance

Every image should be appraised according to the essential image characteristics ^[1] and image analysis guidelines ^[2] for that particular projection.

CRITERIA	GUIDANCE
Projection:	<p>Are you able to recognise what projection has been produced?</p> <p>Is this projection appropriate for the anatomical region and/or the clinical history (if provided)</p>
Identification:	<p>Required to ensure that you have selected the correct/current image for appraisal. <i>Patients may have multiple images of the same anatomical region and/or multiples images taken on the same day.</i></p> <p>Images should be checked for: Patient name, hospital/patient number, date and time of examination.</p>
Markers & annotation:	<p>The marker should be applied within the primary beam (at the time of exposure), should be in the correct orientation and not obscuring clinically relevant anatomy.</p> <p>Make an assessment of the marker, is it the correct one, is it correctly orientated and are there any limitations with its position?</p> <p><i>If the marker has been applied during post processing check carefully for any evidence that the image may have been flipped as this may render the side marker incorrect.</i></p> <p>Look for any annotation indicating the technique used to acquire the image and consider if this is appropriate. Explain how the annotation is useful to the observer in this case. Is any further annotation required?</p> <p><i>Annotation should be applied to the image when non-standard technique was used.</i></p>
Position:	<p>Has the patient been positioned according to the projections essential image criteria?</p> <p><i>Remember that 'positioning' is the relationship between the patient, primary beam and image receptor.</i></p> <p>Assess patient position in 2 planes. E.g. rotation in the sagittal and/or coronal and/or axial planes.</p> <p>You must justify your decision by explaining how you have made an assessment of the patient position. What anatomy are you looking at to make this appraisal?</p> <p>Where necessary you should suggest how the patient position should be corrected.</p> <p>Make a judgement about the centring point used. Is this centring point appropriate for the projection? What is the correct centring point?</p>

	<p>Other factors relating to positioning to be considered e.g. scapula clear of lung fields for chest examination etc.</p>
<p>Collimation / shuttering:</p>	<p>State whether all of the relevant anatomy is included in the image (according to the essential criteria).</p> <p>If anatomy is missing you must make an assessment of why it has not been included: Has the anatomy/patient been projected off the edge of the image receptor? Has the image been shuttered during post processing? Has the anatomy been collimated off?</p> <p><i>You will need to look at the border of the image to identify the edge of the IR, shuttering (sharp 'black' edge) or the collimated field (identified by its penumbra).</i></p> <p>If the borders of collimation are evident, state whether the field size is appropriate. Is it too small (some anatomy is missing) or too large (there is too much anatomy included on the image).</p>
<p>Image quality:</p>	<p>Was the exposure (mAs and kV) applied appropriate to visualise all of the necessary anatomy?</p> <p>Assessment of penetration: both high and low density structures should be visualised.</p> <p>If the more dense structures can be visualised there has been sufficient penetration (enough kV) - note that the structures assessed will vary depending on the projection.</p> <p>If the lower density structures are obliterated/black (but the high density ones are visualised) then this may be due to over penetration (kV too high) or over exposure (mAs too high).</p> <p>If the lower density structures can't be visualised adequately (too bright) but the higher density structures are seen then this indicates insufficient mAs (penetration was adequate but the exposure was not great enough).</p> <p>Assessment of contrast: there should be differentiation between all of the tissues in the region (bone, soft tissues, fat and air filled structures).</p> <p>If these can all be seen well there has been sufficient exposure (mAs and kV).</p> <p>Lack of contrast may be due to both mAs and kV. See assessment of penetration above to determine if adjustments to kV or mAs are required.</p> <p>Make an assessment of the signal to noise ration.</p> <p>Noise (mottle) usually indicates insufficient mAs however as before the specific anatomic details should be assessed. <i>Significant over exposure may result in noise due to large amounts of scatter.</i></p> <p>Does the image display an exposure index? If so is it appropriate for the examination?</p> <p>Is there any unsharpness? Explain how you have evaluated this and how it should have been avoided.</p>

	<p>Are there any avoidable artefacts?</p> <p><i>Some artefacts may be unavoidable depending on patient condition but you should consider if the radiographer made attempts to reduce their impact on image quality?</i></p>
Anatomy and pathology	<p>Appraise the radiographic anatomy. Is it normal?</p> <p>Are there any normal variants?</p> <p>Describe any pathology using appropriate radiographic terminology.</p>
Diagnostic acceptability	<p>Is this image acceptable?</p> <p><i>In the absence of any clinical history you will need to make this decision based on the essential image characteristics ^[1] and image analysis guidelines ^[2] for this particular projection.</i></p> <p>Does it require a repeat or additional supplementary projection?</p> <p>Discuss further/additional projections required to complete this examination.</p>

References

Each radiographic projection has what are regarded as 'essential image characteristics' ^[1] or 'image analysis guidelines' ^[2] that guide our assessment of that image and help us to decide if it is adequate. Being able to identify these characteristics / criteria is crucial for our decision making and for understanding how any improvements may be made. The characteristics / criteria are different for each projection.

[1] Clark's Positioning in Radiography, 13th Ed. CRC Press. 2016.

[2] Radiographic Image Analysis, 4th Ed. Elsevier. 2015.

Table 3. Chest Image Quality Criteria*

Number	Image quality in Computed Radiography: PA chest projection*
1.	The spinous processes of the thoracic vertebrae T1–T4 are visualised adequately
2.	The anterior ribs are adequately visualised through the heart
3.	The vertebral bodies are not sufficiently visualised through the heart
4.	The vascular patterns of the lungs are adequately visualised in the retro-cardiac region
5.	The carena is not visualised adequately
6.	The vertebral disc spaces are not visualised clearly
7.	The mediastinum is visualised clearly
8.	There is clear differentiation between soft tissue and bone
9.	There is good contrast between air-filled structures and the surrounding tissue/structures
10.	The trabecular patterns of the bones are visualised sufficiently
11.	The trachea is visualised clearly
12.	The vascular patterns of the lungs are not clearly visualised from the hila to the periphery
13.	The left costophrenic angle is defined sharply
14.	The right costophrenic angle is defined sharply
15.	The left cardiophrenic angle is defined sharply
16.	The right cardiophrenic angle is defined sharply
17.	The borders of the heart and aorta are visualised sharply
18.	The proximal bronchi are visualised sharply
19.	The trachea is not defined sharply
20.	The left hemi-diaphragm is visualised sharply
21.	The right hemi-diaphragm is visualised sharply
22.	There is a significant amount of noise in this image.

* **Development and validation of a psychometric scale for assessing PA chest image quality: A pilot study.** H. Mraity, A. England, I. Akhtar, A. Aslam, R. De Lange, H. Momoniat, S. Nicoulaz, A. Ribeiro, S. Mazhir, P. Hogg. *Radiography*, p312–317. Published online: April 10, 2014

5. You will work as a group to decide upon optimum viewing conditions and consider any quality control measures when viewing your images e.g. PC screen calibration, dark or light room when evaluating the images.

6. Using the 2AFC software, each member of the group should appraise and score each image. Repeat this procedure so that each member of the group has generated two sets of scores for each image. **DO NOT** look at your previous scores when you do this the second-time round.

7. You will score each of your 32 chest images against the **REFERENCE** image, using some or all of the image quality criteria in Tables 2 and 3 (you may also wish to add other relevant criteria identified from the literature). You have the option of either using a 5 or 3-point Likert summative rating scale. You should consider and be able to justify your choice of a 5 or 3-point Likert scale.

You will need to consider for each image whether it is:

- much worse than (-2)
- worse than (-1)
- equal to (0)
- better than (+1)
- much better than (+2)

Or

- worse than (-1)
- equal to (0)
- better than (+1)

...than the **REFERENCE** image.

8. Your results will be stored as a .tsv file on the computer. This file can then be exported to Excel and opened as a spreadsheet so that you can review the results.

9. Remember that when evaluating different images for the same purpose, the evaluation environment must be conducted in the same viewing conditions.

Part C: Effective dose

1. As well as scoring each of your images for image quality and lung nodule / tumour visibility, you will also need to calculate E for each of the chest images you selected. This will be calculated using a combination of Monte Carlo dose estimate calculation computer software, the DAP measurements collected related to your 32 chosen conditions and the tissue weighting factors from ICRP 103.

2. The Monte Carlo dose estimate calculation software is located on the PCs in the imaging suite.

A guide on using the PCXMC software is located on BlackBoard

3. The PCXMC software used to calculate E requires that you input certain parameters from the image acquisition. It is important that all values are inputted correctly. Ensure that all units used are correct; some values may need to be converted. You will need the following data in order to calculate E:

- kVp
- mAs
- X-ray filtration thickness / X-ray filter
- Grid / No grid
- SID
- DAP

5. Once you have calculated E, record the results for each of your appraised images.

Part D: Data analysis and statistical tests

1. Calculate the mean and standard deviation of the first and second reading scores for the images you have scored.

2. Calculate the mean and standard deviation of the first and second reading scores for the whole group.

3. Compare your mean and standard deviation to your overall group results. Are there any differences? If so revisit the images on which the differences exist. As a group scrutinise the images and understand why the differences have occurred; reach consensus on your individual scores (they should be 'similar').

4. Having scored your chest images and calculated the effective dose to the patient, you should be able to consider image quality versus effective dose and effective dose and image quality versus the use and non-use of a grid and the relationship between these conditions.

5. Following analysis of the images you have generated you should be able to analyse all three data sets and synthesise a conclusion from your findings in order to make recommendations on the best option/s for acceptable image quality, lung nodule visibility and effective dose to the patient. To do this you should:

- Identify the images which have 'good' image quality scores
- Of those images, assign E values to them
- Put these in rank order
- Discuss your findings

6. You should also assess your images and scores to determine whether this has any clinical significance with regards to image quality and the use or non-use of a grid. Can you identify a kVp, mAs, grid or no grid and SID exposure combination/s which provide optimum Chest X-ray image quality with the lowest E?

7. You should consider how this exposure factor combination compares with your selected **REFERENCE** image.

Group B (Pelvis)

1. You are a Diagnostic Radiographer working in a busy emergency department (ED). The X-ray department uses digital radiography (DR) equipment.

2. An elderly patient has been just brought into the emergency department following a fall at home. They exhibit some signs of confusion but are compliant. Subsequent assessment by the medical team, means you receive the following request card:

X-RAY REQUEST FORM

Radiology Department				
Patient Details:	Sex: M	DOB: 3/1/1965	Record Number: J54698	GP Name and Address:
First name: Eric	Last name: Vimes		Ward/Department: ED	
Address: 1 Frederick Road Salford M6 6PU			Consultant: TP	
			Previous Imaging: No	
			Previous Surgery: No	Patient Mobility: Trolley
Clinical Details/Information: Fall at home. Tender to groin Confused ++ ?pubic rami # ?chest infection			Investigations Requested: <ul style="list-style-type: none"> • Pelvis X-ray • CXR 	
			Signature: Dr Colon (e-signature confirmed)	
			Date: Today	

6. You will also need to consider the following within this scenario:

Patient presentation:

- ❑ The patient is on a trolley.

- ❑ The patient IS UNABLE to be moved off the trolley onto the x-ray table

RESEARCH PARAMETERS – Group B (Pelvis Only)

Part A. Minimising Error

1. Prior to conducting your research, you will need to ‘warm up the tube’ and consult the quality control (QC) data for the X-ray equipment that you will use. You will need to analyse this QC data against the expected manufacturer specifications. The QC data should include recent information (e.g. from within the same week as your research); if not then you should consider collecting such data. These QC tests shall be determined and performed as part of your experimental design.

2. If there is difference with your QC data from manufacturer specifications, then you should seek advice from a member of staff before proceeding.

3. You may need to acquire a number of pilot images to check your AP pelvis x-ray positioning and method.

4. You will also need to minimise sources of error with regards to the image viewing conditions (e.g. ambient lighting conditions and viewer to screen distance). You should also consider using a test card for monitor calibration and optimisation prior to undertaking any image analysis.

6. You will need to record your radiographic positioning and technique to ensure consistency during your phantom research

Part B. Controlling for Variables

1. You will use your method to acquire images of the anthropomorphic pelvis phantom in the AP supine position across a range of conditions. Remember, your choice of conditions to generate these images is limited. Test your method first and make changes to your methodology as required (you should also record and reflect upon your reasons for changing your original design if you do so).

2. Other factors that you should aim to keep constant, within your research, include the following:

- The position of the pelvis phantom - You should aim to ensure that the pelvis is imaged as you would in the clinical environment using the **same** radiographic positional technique throughout your research
- Source to image-receptor distance (SID) / Source-detector distance (SDD)
- Focal spot size (**broad focus only**)
- Collimation should remain constant (once set)
- The horizontal position of the x-ray beam over the phantom
- The vertical position of the x-ray beam over the phantom
- The distance between the phantom and the object to image receptor distance (OID)

***** You will need to justify your choices for these factors *****

Part C. Conducting the research

1. Take your first exposure, record the exposure factors, SID and take a reading from the DAP meter. You should ensure that all your images have a logical / clear file name. You may wish to design a table to record your data so that you can compare the results and use this to refine your method.

2. You should aim to position the pelvis phantom in the AP supine position as far as practical and in accordance with 'Clark's positioning in Radiography'. In terms of position, you should aspire to have the pelvis phantom in a position that produces a good quality image to demonstrate the anatomy of the pelvis in the AP supine position. This may involve you acquiring one or more images to ensure the phantom is placed correctly and always remember that you are producing a two-dimensional image of three-dimensional anatomy.

3. When assessing subsequent images, you should consider the technical information from 'Clark's Positioning in Radiography' (Whitley, Sloane et al., 2005) and 'McQillan-Martenson Radiographic Critique' to determine positional accuracy and image analysis. Once you have achieved an image that is of good positional quality, the pelvis phantom will then remain in that fixed position.

4. You should also record the following to identify your images later:

- kVp
- mAs
- Grid / No grid
- SID
- DAP

DAP - Be aware that this may be read in cGycm^2 and as such will require converting to mGycm^2 prior to entering into the PCXMC software – Check your units!

DATA ANALYSIS – PELVIS PHANTOM

Part A: Pelvis X-ray image quality (un-blinded) analysis

1. After you have completed your research using the pelvis phantom, you will need to transfer these images onto a PC so that you can use the 2AFC software to critique your pelvis images. These should not contain any annotation to identify which parameters were used to acquire the image.

2. You will then need to select a **REFERENCE** image to use in the 2AFC software. You will compare your other images with the **REFERENCE** image and score each of these images against the **REFERENCE** image as to image quality. Use the dual screen monitors within the Imaging Suite to score your images.

3. You will also calculate the effective dose to the patient for each image. To do this you will need to enter the relevant examination data. It is therefore very important that

you note the following data during your research / image analysis in order to calculate the estimated dose using the PCXMC software:

- kVp
- mAs
- X-ray filtration thickness / X-ray filter
- Grid / No grid
- SID
- DAP

4. Select one of your 32 images to be the **REFERENCE** image. You should be able to justify your selection. You will need to appraise and score each of your selected images against the selected **REFERENCE** image for image quality using the two-alternative forced choice analysis (2AFC) software. The 'Criteria for the Appraisal of Radiographs' can be found in **Table 5**, you may wish to use some or all of these for your image appraisal criteria. In **Table 6** you will also find some 'AP Plevis Image Quality Criteria' which you may find helpful in setting your scoring appraisal criteria

See the 2AFC guide on BlackBoard on how to upload and score your images

Table 4. CRITERIA FOR THE APPRAISAL OF RADIOGRAPHS
Explanatory Guidance

Every image should be appraised according to the essential image characteristics ^[1] and image analysis guidelines ^[2] for that particular projection.

CRITERIA	GUIDANCE
Projection:	<p>Are you able to recognise what projection has been produced?</p> <p>Is this projection appropriate for the anatomical region and/or the clinical history (if provided)</p>
Identification:	<p>Required to ensure that you have selected the correct/current image for appraisal. <i>Patients may have multiple images of the same anatomical region and/or multiples images taken on the same day.</i></p> <p>Images should be checked for: Patient name, hospital/patient number, date and time of examination.</p>
Markers & annotation:	<p>The marker should be applied within the primary beam (at the time of exposure), should be in the correct orientation and not obscuring clinically relevant anatomy.</p> <p>Make an assessment of the marker, is it the correct one, is it correctly orientated and are there any limitations with its position?</p> <p><i>If the marker has been applied during post processing check carefully for any evidence that the image may have been flipped as this may render the side marker incorrect.</i></p> <p>Look for any annotation indicating the technique used to acquire the image and consider if this is appropriate. Explain how the annotation is useful to the observer in this case. Is any further annotation required?</p> <p><i>Annotation should be applied to the image when non-standard technique was used.</i></p>
Position:	<p>Has the patient been positioned according to the projections essential image criteria?</p> <p><i>Remember that 'positioning' is the relationship between the patient, primary beam and image receptor.</i></p> <p>Assess patient position in 2 planes. E.g. rotation in the sagittal and/or coronal and/or axial planes.</p> <p>You must justify your decision by explaining how you have made an assessment of the patient position. What anatomy are you looking at to make this appraisal?</p> <p>Where necessary you should suggest how the patient position should be corrected.</p> <p>Make a judgement about the centring point used. Is this centring point appropriate for the projection? What is the correct centring point?</p>

	<p>Other factors relating to positioning to be considered e.g. scapula clear of lung fields for chest examination etc.</p>
<p>Collimation / shuttering:</p>	<p>State whether all of the relevant anatomy is included in the image (according to the essential criteria).</p> <p>If anatomy is missing you must make an assessment of why it has not been included: Has the anatomy/patient been projected off the edge of the image receptor? Has the image been shuttered during post processing? Has the anatomy been collimated off?</p> <p><i>You will need to look at the border of the image to identify the edge of the IR, shuttering (sharp 'black' edge) or the collimated field (identified by its penumbra).</i></p> <p>If the borders of collimation are evident, state whether the field size is appropriate. Is it too small (some anatomy is missing) or too large (there is too much anatomy included on the image).</p>
<p>Image quality:</p>	<p>Was the exposure (mAs and kV) applied appropriate to visualise all of the necessary anatomy?</p> <p>Assessment of penetration: both high and low density structures should be visualised.</p> <p>If the more dense structures can be visualised there has been sufficient penetration (enough kV) - note that the structures assessed will vary depending on the projection.</p> <p>If the lower density structures are obliterated/black (but the high density ones are visualised) then this may be due to over penetration (kV too high) or over exposure (mAs too high).</p> <p>If the lower density structures can't be visualised adequately (too bright) but the higher density structures are seen then this indicates insufficient mAs (penetration was adequate but the exposure was not great enough).</p> <p>Assessment of contrast: there should be differentiation between all of the tissues in the region (bone, soft tissues, fat and air filled structures).</p> <p>If these can all be seen well there has been sufficient exposure (mAs and kV).</p> <p>Lack of contrast may be due to both mAs and kV. See assessment of penetration above to determine if adjustments to kV or mAs are required.</p> <p>Make an assessment of the signal to noise ration.</p> <p>Noise (mottle) usually indicates insufficient mAs however as before the specific anatomic details should be assessed. <i>Significant over exposure may result in noise due to large amounts of scatter.</i></p> <p>Does the image display an exposure index? If so is it appropriate for the examination?</p> <p>Is there any unsharpness? Explain how you have evaluated this and how it should have been avoided.</p>

	<p>Are there any avoidable artefacts?</p> <p><i>Some artefacts may be unavoidable depending on patient condition but you should consider if the radiographer made attempts to reduce their impact on image quality?</i></p>
Anatomy and pathology	<p>Appraise the radiographic anatomy. Is it normal?</p> <p>Are there any normal variants?</p> <p>Describe any pathology using appropriate radiographic terminology.</p>
Diagnostic acceptability	<p>Is this image acceptable?</p> <p><i>In the absence of any clinical history you will need to make this decision based on the essential image characteristics ^[1] and image analysis guidelines ^[2] for this particular projection.</i></p> <p>Does it require a repeat or additional supplementary projection?</p> <p>Discuss further/additional projections required to complete this examination.</p>

References

Each radiographic projection has what are regarded as 'essential image characteristics' ^[1] or 'image analysis guidelines' ^[2] that guide our assessment of that image and help us to decide if it is adequate. Being able to identify these characteristics / criteria is crucial for our decision making and for understanding how any improvements may be made. The characteristics / criteria are different for each projection.

[1] Clark's Positioning in Radiography, 13th Ed. CRC Press. 2016.

[2] Radiographic Image Analysis, 4th Ed. Elsevier. 2015.

Table 5. AP Pelvis Image Quality Criteria*

Number	Image Quality in Computed Radiography: AP Pelvis projection
1.	The left hip joint is visualised
2.	The right hip joint is visualised
3.	The right lesser trochanter is visualised
4.	The left lesser trochanter is visualised
5.	The left greater trochanter is visualised
6.	The right greater trochanter is visualised
7.	The left iliac crest is visualised
8.	The right iliac crest is visualised
9.	The pubic and ischial rami are visualised
10.	The proximal femora are demonstrated
11.	The left femoral neck is visualised
12.	The right femoral neck is visualised
13.	The left sacro-iliac joint is visualised
14.	The right sacro-iliac joint is visualised
15.	The sacrum and its intervertebral foramina are visualised
16.	There is appropriate differentiation between soft tissues
17.	The exposure factors used for this image are correct.
18.	This image is sufficient for diagnostic purposes.
19.	The medulla and cortex of the pelvis are adequately demonstrated.
20.	The body of L5 is adequately demonstrated
21.	The obturator foramina are symmetrical
22.	Both acetabula are visualised clearly
23.	The levels of rotation and axial tilting are within acceptable limits
24.	Fine bony detail is sufficiently demonstrated

*Adpated from **10 kVp rule – An anthropomorphic pelvis phantom imaging study using a CR system: Impact on image quality and effective dose using AEC and manual mode.** Luís Lança, Loris Franco, Abdulfatah Ahmed, Marloes Harderwijk, Chloe Marti, Sadeeda Nasir, Junior Ndlovu, Miguel Oliveira, Ana Rita Santiago, Peter Hogg. *Radiography*, p333–338. Published online: May 21, 2014

5. You will work as a group to decide upon optimum viewing conditions and consider any quality control measures when viewing your images e.g. PC screen calibration, dark or light room when evaluating the images.

6. Using the 2AFC software, each member of the group should appraise and score each image. Repeat this procedure so that each member of the group has generated two sets of scores for each image. **DO NOT** look at your previous scores when you do this the second-time round.

7. You will score each of your 32 pelvis images against the **REFERENCE** image, using some or all of the image quality criteria in Tables 4 and 5 (you may also wish to add other relevant criteria identified from the literature). You have the option of either using a 5 or 3-point Likert summative rating scale. You should consider and be able to justify your choice of a 5 or 3-point Likert scale.

You will need to consider for each image whether it is:

- much worse than (-2)
- worse than (-1)
- equal to (0)
- better than (+1)
- much better than (+2)

Or

- worse than (-1)
- equal to (0)
- better than (+1)

...than the **REFERENCE** image.

8. Your results will be stored as a .tsv file on the computer. This file can then be exported to Excel and opened as a spreadsheet so that you can review the results.

9. Remember that when evaluating different images for the same purpose, the evaluation environment must be conducted in the same viewing conditions.

Part C: Effective dose

1. As well as scoring each of your images for image quality and lung nodule / tumour visibility, you will also need to calculate E for each of the pelvis images you selected. This will be calculated using a combination of Monte Carlo dose estimate calculation computer software, the DAP measurements collected related to your 32 chosen conditions and the tissue weighting factors from ICRP 103.

2. The Monte Carlo dose estimate calculation software is located on the PCs in the imaging suite.

A guide on using the PCXMC software is located on BlackBoard

3. The PCXMC software used to calculate E requires that you input certain parameters from the image acquisition. It is important that all values are inputted correctly. Ensure that all units used are correct; some values may need to be converted. You will need the following data in order to calculate E:

- kVp
- mAs
- X-ray filtration thickness / X-ray filter
- Grid / No grid
- SID
- DAP

5. Once you have calculated E, record the results for each of your appraised images.

Part D: Data analysis and statistical tests

1. Calculate the mean and standard deviation of the first and second reading scores for the images you have scored.
2. Calculate the mean and standard deviation of the first and second reading scores for the whole group.
3. Compare your mean and standard deviation to your overall group results. Are there any differences? If so revisit the images on which the differences exist. As a group scrutinise the images and understand why the differences have occurred; reach consensus on your individual scores (they should be 'similar').
4. Having scored your pelvis images and calculated the effective dose to the patient, you should be able to consider image quality versus effective dose and effective dose and image quality versus the use and non-use of a grid and the relationship between these conditions.
5. Following analysis of the images you have generated you should be able to analyse all three data sets and synthesise a conclusion from your findings in order to make recommendations on the best option/s for acceptable image quality, lung nodule visibility and effective dose to the patient. To do this you should:
 - Identify the images which have 'good' image quality scores
 - Of those images, assign E values to them
 - Put these in rank order
 - Discuss your findings
6. You should also assess your images and scores to determine whether this has any clinical significance with regards to image quality and the use or non-use of a grid. Can you identify a kVp, mAs, grid or no grid and SID exposure combination/s which provide optimum pelvis x-ray image quality with the lowest E?

7. You should consider how this exposure factor combination compares with your selected **REFERENCE** image.

Indicative texts and learning resources:

- Documents specific to the students' placement:
 - Protocols, policies, procedures
 - Local Rules
 - Health & Safety Regulations
- Learning resources including guides, articles, podcasts and reading lists (Advanced Clinical Skills II) on BlackBoard.
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THIS SPACE IS BLANK FOR YOUR OWN NOTES: