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A survey investigating postero-anterior chest X-ray clinical technique amongst radiographers and assistant practitioners in the UK: An extended pilot study

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ABSTRACT

Introduction: Whilst many technical factors for the postero-anterior (PA) chest projection are well-researched and standardised, anecdotal evidence suggests a discrepancy regarding positioning of the X-ray tube; some radiographers using a horizontal tube, and others apply an angle. Currently there is a lack of published evidence supporting the benefits of either technique.
Methods: Following University ethical approval, an invitation e-mail containing a link to a short questionnaire and participant information sheet was sent to radiographers and assistant practitioners in Liverpool and the surrounding areas, via professional networks/research team contacts. Questions related to length of experience, highest qualification and reasoned choice of horizontal versus angled tube preference in Computed Radiography (CR) and Digital Radiography (DR) rooms. The survey was open for nine weeks, with reminders at five and eight weeks.
Results: There were 63 respondents. Both techniques were commonplace, with a non-statistically significant preference ($p = 0.439$) for a horizontal tube in both DR rooms (59%, $n = 37$) and CR rooms (52%, $n = 30$). Angled technique was employed by 41% ($n = 26$) of participants in DR rooms and 48% ($n = 28$) in CR rooms. Many participants indicated 'taught', or 'protocol', influenced their approach (46% [$n = 29$] in DR, 38% [$n = 22$] in CR). 35% ($n = 10$) of participants using caudal angulation, identified dose optimisation as the rationale in both CR and DR rooms. Most specifically noted reduced dose to the thyroid (69% [$n = 11$] in CR, 73% [$n = 11$] in DR).
Conclusions: There is evidence of variation in practice regarding horizontal versus an angled X-ray tube but no consistent rationale for either choice.
Implications for practice: There is a need to standardise tube positioning in PA chest radiography in line with future empirical research into the dose-optimisation implications of tube angulation.

Introduction

The chest X-ray (CXR) is one of the most widely utilised imaging techniques with 40% of X-ray examinations being performed on the chest.[1] It is important that this crucial examination is performed with effective technique to achieve the best quality images, especially as CXRs are an important step in clinical decision making. Many chest-related pathologies including pneumonia and pneumothorax cannot be diagnosed from a physical examination alone.[2]

It is essential to consider 'ALARP' (As Low As Reasonably Practicable) as it relates to the underpinning concept of optimisation in The Ionising Radiation (Medical Exposure) Regulations 2017 [IR(ME)R17] (3). Exposure factors are carefully selected for the postero-anterior (PA) CXR to ensure optimum 'contrast density' on the image.[4] A high kilovolt peak (kVp) allows the X-rays to over-penetrate the bony anatomy resulting in visualisation of the thoracic soft tissues.[5] This high kVp technique necessitates the use of a grid to reduce scatter and improve image contrast.[6] Automatic exposure devices (AEDs) are also typical used for PA CXRs to ensure optimal density. The upper two chambers are selected as these lie over the lung fields; therefore the exposure given ensures adequate soft tissue density on the resulting image.[7] Such technical features

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may influence an operator's choice of technique. Anecdotal evidence suggests operators believe that applying an angle to the X-ray tube would cause grid-line artefacts. This, however, is not necessarily accurate as many systems use a moving grid to eliminate such artefacts.[8]

Prior to data collection the authors validated the survey gathering feedback from qualified radiographers; this feedback highlighted variation between United Kingdom (UK) operators. Either positioning of the X-ray tube was horizontal, being at 90º to the image receptor (IR) or an angle was applied. There is a discrepancy in radiographic positioning texts, where some describe the use of a horizontal beam while the use of both a caudal angle and a horizontal beam are also evident in some texts.[9–12] Carver & Carver suggest the application of a caudal angle demonstrates an increased amount of lung tissue below the diaphragm, although this has not been quantified empirically.[13] Preliminary data obtained as feedback on the questionnaire suggested operators believe in applying a caudal angle the dose is reduced to the patient's occiput, although respondents did not justify this further. Conversely, Carver & Carver propose the application of the angle increases the radiation dose to the patient's abdominal organs.[13] The findings from a study conducted by Unett and Carver[14] show that both straight and angled X-ray tubes are used in practice. The aims of their study were focussed on centring point usage rather than application of tube angle and given the study had a small number of participants (n = 12) and was limited to one hospital it does not necessarily add context to this study.[14]

Given the number of CXR performed in the UK each year (7,629,040 between June 2020–June 2021)[1] and the variations in technique indicated in the feedback to the questionnaire, the aim of this empirical study was to investigate the prevalence of each technique in order to understand what influences operator choice and evaluate the factors which impact the selected technique. Anecdotal evidence suggests operators (as defined under IR(ME) R17)[3] employ different techniques when performing the PA erect CXR. Some use a straight, horizontal tube whilst others apply tube angulation. There is a lack of research supporting either technique, therefore necessitating this study.

Methods

Ethical approval

As this study involves human participants ethical approval from the University's Research Ethics Committee was granted (Approval number:10132) prior to distribution of the questionnaire.

Questionnaire

To validate the questionnaire, it was distributed to four radiographers to obtain feedback on the questions and indicative responses. These initial responses further justified the need for the study given the variety demonstrated.

The finalised questionnaire consisted of a total of sixteen questions. It was written and distributed using the JISC online survey tool (https://www.onlinesurveys.ac.uk). The first seven questions gained consent from the participant using a 'tick to confirm' approach against all questions. This confirmed UK job title (practicing radiographer or AP – assistant practitioner) and ensured the inclusion criteria were met. Relevant demographics were obtained in relation to highest academic qualification and length of time since qualification. To ensure accurate thematic coding these questions were 'multiple choice'. The remainder of the questionnaire was divided between the use of computed radiography (CR) equipment and digital radiography (DR) equipment. Responses from those using both CR and DR equipment were required to indicate the direction and size of the angle, if applied. Participants were then asked to justify their technique. These questions were open-ended questions to allow participants to justify their technique and inform the researchers of evidential reasoning for their choice of approach.

Data collection

The questionnaire was emailed to professional contacts in local hospitals in the Liverpool network, allowing the study to reach seven public hospital systems (NHS Trusts). Those professional contacts were asked to forward the questionnaire to all radiographers and APs. Emailing the questionnaire is advantageous as it is inexpensive and time efficient.[15] Responses were recorded over a 9-week period and the professional contacts were sent standardised email reminders after a 5- and 8-week time period.

Data analysis

The data collected was migrated to Microsoft Excel (Microsoft Corp, Redmond, WA) for analysis allowing calculation of basic statistics and production of bar graphs and pie charts. The data was then organised into 2 × 2 contingency tables and further exported into SPSS Version 27.0.1.0 (IBM Inc, Armonk, NY) in order to perform Chi-squared tests on nominal data. Statistical significance (at the 5% level) was identified where p-values for the test were below 0.05.

Thematic coding was undertaken in analysing the participant responses relating to 'choice of technique' (questions 5, 6, 8, 9). A 'coding for content' approach was used to group themes of applied context[16] and amalgamate sub-themes into overall themes.

Results

Response rate

A total of 63 full responses to the questionnaire were recorded. From the most recent NHS workforce statistics, it can be assumed there are approximately 1942 diagnostic radiographers and assistant practitioners employed by North-West NHS Trusts.[17] The questionnaire was distributed to seven out of the 34 North-West NHS Trusts; therefore 20% of the North-West radiography work force received the questionnaire, which was approximately 400 professionals. The response rate can therefore be calculated from 63 out of a possible 400 responses, approximately 16%.

Participant demographics

All participants worked in hospitals within the Liverpool and surrounding regions at the time of answering the questionnaire. Most participants had been qualified for less than 15 years, with 83% (n = 52/63) of participants identifying this. The remaining 17% (n = 11/63) had been qualified for 15 years or more. Participants also held varying qualification levels, with 75% (n = 47/63) holding a Bachelor's degree, 16% (n = 10/63) having a Postgraduate certificate or had completed individual Master's level modules and 10% (n = 6/63) with either a Foundation degree, a Diploma of the College of Radiographers, or a Postgraduate Diploma.

Frequency of technique

In both CR and DR rooms both techniques are widely used, with a straight tube being marginally more evident in DR rooms. In CR rooms 52% (n = 30/58) of participants indicated use of a

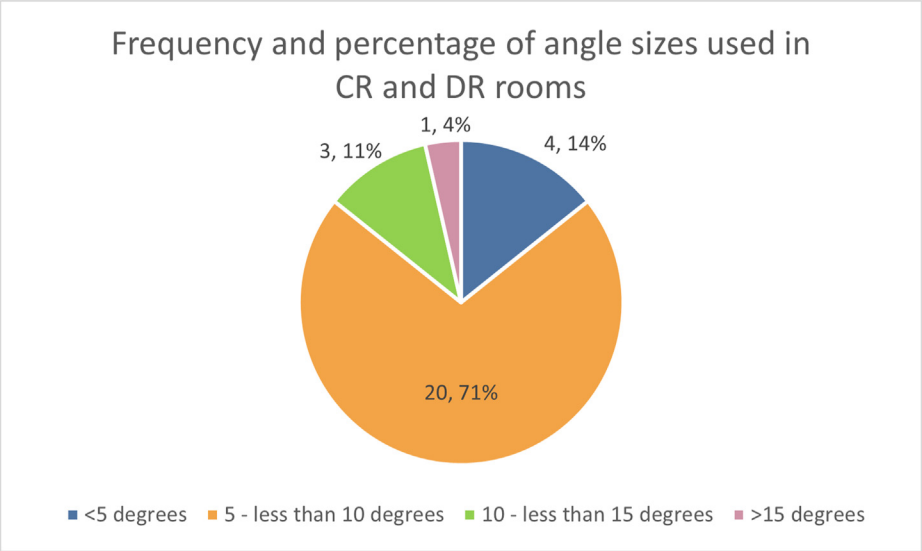

Figure 1. Frequency and percentage of each angle range.

straight tube. The remaining 48% (n = 28/58) applied an angle to the tube. Non-use of CR equipment was stated by five participants (8%; n = 5/63). In DR rooms 59% (n = 37/63) indicated use of a straight tube, with the remaining 41% (n = 26/63) applying an angle.

A Chi-squared test utilising a 2 × 2 contingency table demonstrated a p-value of 0.439 indicating no statistically significant difference between the use of an angled tube or a horizontal tube in CR and DR rooms.

Tube angulation

Of the participants applying an angle to the X-ray tube all reported that it was a caudal angle, with the most common angle applied between 5 and 10° (71%; n = 20/28). The size of the angle applied ranged from <5° to >15° (Fig. 1).

Reasons for using a straight tube

The participants' reasons for using a straight tube were coded into 15 sub-themes using thematic analysis and then combined into 4 main themes (Table 1).

In CR rooms the most common reason was habit or how the participants were taught (either academically or clinically). These themes combined accounted for 45% (n = 18/40) of the reasons. For example, participant 33 wrote: *"I apply straight tube technique for all the PA chest X-rays, I perform, no matter what equipment is used"*. Both 'habit' and 'prior teaching' were also the predominant reasons in DR rooms, with these combined accounting for 38% (n = 17/45) of responses. Participants with varying lengths of qualification/experience indicated undergraduate training as a reason in both CR and DR rooms.

In CR rooms 43% (n = 17/40) of responses related to image quality. For example, participant 3 wrote: *"Accurate demonstration of anatomy and any fluid levels within chest cavity"*. Anatomy demonstration was considered less frequently by respondents in DR rooms, as image quality factors only accounted for 24% (n = 11/45) of reasons for straight tube choice.

Participants indicated that technical features of the DR equipment like the 'auto positioning' feature influenced radiographic positioning choice, as this auto-positions using a horizontal tube with no angle applied. Similarly, employment of the AED requires consideration in radiographic positioning choice to ensure correct usage. Furthermore, responses indicated a need to employ a straight tube in conjunction with 'grid use' in DR rooms to ensure no evidence of grid line artefacts, but this rationale is not necessarily accurate. In addition, most participants considered just one technical feature. For example, participant 60 said: *"the way the auto position positions the tube"*. Participant 27 considered the use of both a grid and AEDs: *"Modern equipment uses AED's and tends to not like angulation … also grid CXR's should not have angulation …"*.

Some participants (11%; n = 7/63) identified a change in technique between CR and DR rooms and in all cases an angled tube was used in CR rooms and a straight tube in DR rooms. Over half (57%; n = 4/7) of these participants stated this was due to the technical aspect of DR rooms, such as auto positioning, which does not allow for application of an angle.

Table 1
Themes (amalgamated and sub-themes) for using a straight tube.

Straight tube amalgamated theme	Frequency		%		Straight tube sub-theme	Frequency	
	CR	DR	CR	DR		CR	DR
Dose optimisation	0	1	0	2	Reduce dose to eyes	0	1
Equipment factors	0	11			Accurate use of AEDs	0	3
			0	24	Auto-position	0	4
					Eliminate grid lines	0	4
Image quality	17	11			Accurate anatomy	4	4
					Accurate fluid level	6	5
			43	24	Consistency	2	1
					Parallel to patient	1	1
					View the apices	2	0
					View the lung bases	2	0
Taught or protocol	23	22			Habit	6	7
			58	49	Protocol	4	5
					Taught in Clark's handbook[11]	1	0
					Taught in place of work	2	2
					Taught in undergraduate degree	10	8
					Total frequency	40	45

Reasons for using an angled tube

The reasons given for using an angled tube were coded into the 13 sub-themes and 3 main themes seen in Table 2.

Most participants identified reduction of the dose of radiation to radiosensitive organs, accounting for 34% (n = 31/92) of reasons for this approach in both CR and DR rooms. Some participants specifically stated the angle reduces the dose to the patient's eyes and thyroid; Participant 9 wrote: *"I was taught that this technique reduced scatter radiation to the eyes and thyroid"*. Within the dose optimisation theme indication of dose reduction to the thyroid was consistent amongst participants using CR and DR rooms, with responses at 69% (n = 11/16) and 73% (n = 11/15) respectively.

Some participants also identified undergraduate training as the reason for choosing a caudal angle, accounting for 15% (n = 7/46) of the reasons given in CR rooms and 13% (n = 6/46) of reasons in DR rooms. For those participants qualified less than 10 years undergraduate training was given as the reason for using a caudal angle in many cases (42%; n = 8/19).

Participants who preferred a straight tube also generally stated application of a caudal angle to CXR, where the patient is particularly kyphotic, allowing the X-rays to be emitted parallel to the relevant anatomy. This was referenced by 22% (n = 14/63) of participants who would ordinarily utilise a straight tube. For example, Participant 29 wrote: *"I use a straight tube for most patients but if the patient is kyphotic I will put a 5-degree caudal angle"*.

Discussion

It was suggested by Carver & Carver that operators erroneously believe the application of a caudal angle allows better visualisation of the lung bases behind the diaphragm, with the effectiveness of small angles questionable.[13] It should be noted that these comments are supported by correspondence to the *Radiography* journal in 1981[18] and 1982[19] which are inaccessible electronically as volume one of the journal online commences in 1995. It may be presumed that this notion was not based on empirical evidence[13] given the supporting references are correspondence only. Applying a caudal angle to visualise the lung bases is also not necessarily supported by the results of the current study, as this was given as reasoning for using a caudal angle by just 1 participant. In addition, this study revealed 9% (n = 8/85) of participants thought the use of a straight tube provides the most accurate visualisation of anatomy. Conversely, 16% (n = 15/92) of participants believed applying a caudal angle aids visualisation of the apices, again contradictory to the suggestions from Carver & Carver.[13]

A novel finding from 30% (n = 28/92) of the responses of this study indicated participants stated dose reduction to radiosensitive organs (eyes and thyroid) was likely with the application of a caudal angle and offered this as reasoning. However, no empirical studies demonstrating this relationship exist. It is important to note that Carver & Carver suggested the application of a caudal angle may increase the dose to the abdominal organs.[13] Indeed, responses from the Unett and Carver study indicate better visualisation of lung fields and reduction of radiation dose to the patient's head, when a caudal angle is applied.[14] While the assumption of radiation dose reduction to the patient's head concurs with the findings of this study there is disagreement as to which technique gives the improved visualisation of chest anatomy. In addition, whilst reduction of radiation dose to the eyes and departmental protocols were given in responses for the Unett and Carver study as rationale for caudal angulation, detailed reasoning was not recorded thereby limiting comparative discussion with the current study. The variation in rationale provided for the techniques in the current study suggests there is further scope to quantify any radiation dose implications through a dose optimisation study.

The results from the current study show the straight tube was the preferred technique among participants, however the statistical testing showed no significance in this result when compared with angulation. Ultimately, a variation in techniques was evident across the Liverpool and the surrounding regions, supporting the findings from the anecdotal evidence presented.

Whilst there are an increased number of participants using a straight tube in DR than CR, the statistical tests indicated no significance suggesting both techniques are utilised comparably across both room types. Using DR equipment had an impact on a straight tube technique choice due to modern auto-position features and the use of a grid. This accounted for 18% (n = 8/45) of reasons given in using a straight tube in DR rooms. This implies the Radiation Protection Advisor and employer, who are heavily involved in choice of equipment installation, may be imposing practice choices on operators.[3] Should any dose optimisation studies be published it would be useful to revisit installed equipment settings to ensure widespread adoption of best evidence-based practice.

Most participants who apply a caudal angle to the PA CXR use an angle ranging from 5 to 10°. It can be suggested operators are aiming to position the X-ray tube parallel to the patient's thoracic spine[20] as the normal angle at the thoraco-lumbar junction is between 0 and 9°.[21] This is further supported by those participants who justified the use of a caudal angle by stating it prevents a lordotic image. Those participants stating a preference for a straight tube also added that if they were positioning a kyphotic patient, they would apply a caudal angle to the tube to match the angle of the patient's spine. Arguably, this approach demonstrates 'adapted technique', taking the angle of the thoracic spine into consideration.[22]

A common theme is participants choose techniques based on undergraduate level teaching (14% [n = 13/92] for an angled tube; 21% [n = 18/85] for a straight tube). As 67% (n = 42/63) of respondents had been qualified for less than 10 years this suggests variation within the taught Diagnostic Radiography curriculum, rather than a change in the curriculum across the years. Similarly, 5% (n = 5/92) of those using an angled tube and 15% (n = 13/85) of those using a straight tube stated hospital training or Trust protocol

Table 2
Themes (amalgamated and sub-themes) for using an angled tube.

Angled tube amalgamated theme	Frequency		%		Angled tube sub-theme	Frequency	
	CR	DR	CR	DR		CR	DR
Dose optimisation	16	15	35	33	Reduce dose to eyes	3	3
					Reduce dose to radiosensitive organs	2	1
					Reduce dose to thyroid	11	11
Image quality	18	21	39	46	Allows for tighter collimation	0	1
					Best image quality	2	2
					Parallel to kyphotic patient	8	8
					Prevent lordosis	2	0
					View the apices	6	9
					View the lung bases	0	1
Taught or protocol	12	10	26	22	Habit	2	2
					Protocol	2	1
					Taught in place of work	1	1
					Taught in undergraduate degree	7	6
					Total frequency	46	46

was the influence for their preferred techniques, implying some variation in clinical protocols and practice.

Technique did not differ between CR and DR rooms in 89% (n = 56/63) of participants. As CR rooms are employed less frequently it could be assumed many operators have been using the same PA CXR technique for the best-part of their radiography career. The identified 'gap' in the knowledge base regarding tube positioning for the PA CXR, however, goes some way to explaining why participants have not altered the choice of technique over the years. This reiterates the need for further empirical studies to identify the dose optimised PA CXR techniques in both CR and DR rooms.

Limitations

The questionnaire had some limitations in that it may have been beneficial to change the question style of Q5 and Q8. There was a variety of responses to this question with varying depths of detail, so it would have been helpful to use a multiple-choice approach to make coding and thematic analysis simpler. A mitigation to this limitation would be to conduct an observational study whereby the nuances of radiographer practice can be fully captured.

Furthermore, the sample size was limiting given the survey was only distributed to 7 NHS Trusts in the North-West and as such the results cannot necessarily be generalised to the whole of the UK. The estimation of the 16% response rate is based on an approximation of staff numbers in these seven NHS Trusts. Given it is an approximation this already relatively low response rate could in fact actually be lower. Additionally, with the low estimated response rate, there is the possibility of non-response bias.

Conclusions

Participants applying a caudal angle in chest technique believe it is to adhere to the ALARP principle stating the angle reduces the dose of radiation to radiosensitive organs such as the eyes and thyroid. Image quality considerations also play a significant role in technique decision-making, with imaging techniques requiring evidence-based standardisation. The lack of published evidence supporting the use of a horizontal or caudally-angulated X-ray beam suggests further studies are needed to examine the impact of a caudal angle on anatomical visualisation and the effective dose to various organs.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.radi.2023.02.014.

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