Dose optimization in direct digital radiography: A study of practitioners' assessments of image quality and perceptions

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Background

The Canadian population's largest exposure to ionizing radiation from man-made sources comes from the radiation used for medical diagnosis (Health Canada, n.d.). Thus, the call from the Canadian Association of Medical Radiation Technologists (CAMRT) to keep radiation exposure to patients "as low as reasonably achievable" (ALARA) is of paramount importance (CAMRT, 2012). Much research has been conducted to investigate dose optimization strategies that can reduce the dose delivered to patients in general radiographic examinations while still producing images of diagnostic quality. From this research a variety of dose optimization strategies have been identified that reduce dose by a considerable percentage without significant affect on the quality of the images for diagnosis (Uffman & Shaefer-Prokop, 2008; Veldkamp et al., 2009). In particular, the strategy of increasing the tube voltage (kVp) and decreasing the tube current and time product (mAs) shows particular promise (Allen et al., 2013; Tsai et al., 2010). However, despite CAMRT's ALARA mandate and the wealth of evidence regarding dose optimization strategies, there is evidence that this mandate and these strategies are not being fully realized within radiology departments and teaching practices (Joyce et al., 2013).

Investigating the reason for this lack of dose optimization is the principal aim of our research project. It has been suggested that the rapid evolution of technology in this field has contributed to the challenge of optimizing dose delivered to patients. For example, Joyce et al. (2013) argue that "throughout the transition from film-screen to digital technology in the clinical environment many of the examination parameters such as tube current (kVp), tube voltage (mA), and filtration were directly translated from film screen exposures to computed radiography and direct digital radiography (dDR)" (p. 180), this view is seconded by Uffman & Shaefer-Prokop (2009). The reason for why this might be is not well understood. Khalifah et al. (2004) suggest that perhaps these concepts are "not well understood by all technologists [radiographers]" (p. 120). Thus the reductions in dose that these new technologies and dose optimization strategies can afford patients "can only be leveraged appropriately if clinicians are competent in a diverse set of skills, including image acquisition [and] image optimization" (Gillan et al., 2013, p. 151). This suggests that there may be a knowledge and/or education gap amongst practicing radiographers, and a curriculum gap amongst in-training radiographers in regards to the understanding and implementation of dose optimization strategies.

Purpose

The purposes of this research are to: (a) investigate practitioners' image quality assessments of direct digital radiographic images acquired with different levels of kVp and mAs; and (b) examine practitioners' perceptions regarding the practice of acquiring direct digital radiographic images with increased kVp and decreased mAs in an effort to optimize patient dose.

Method

Following ethical clearance by Fanshawe College's Research Ethics Board, all radiologists, radiology residents, radiographers, and student radiographers from 8 clinical sites within the LHIN were invited to participate in the study (N=100). The only inclusion criterion was to be a member of one of these professional groups at a LHIN clinical site, and to regularly review or acquire radiographic images on a regular basis; there were no exclusion criteria. These professional groups were selected because they are the individuals who are regularly involved in the acquisition and review of clinical radiographic images, this is consistent with most other dose optimization and/or image quality studies reviewed.

Qualitative Questionnaire

Questionnaire of Practitioners' Perceptions. The research group developed a questionnaire not only to gather participants' demographic information (i.e. age, education, profession, years of experience, clinical site) and to ensure participants met the inclusion criteria, but also to investigate participants' behaviour, knowledge, and opinions about dose optimization and image quality via open-ended and forced-choice questions. The following are some of the questions posed to participants:

- Prior to initiating an exposure, how do you select the kVp and mAs? Check all that apply:
  - ☐ Day to day experience in the workplace
  - ☐ Personal preference
  - ☐ School training
  - ☐ In-service education sessions (i.e. professional development)
  - ☐ Self-education (i.e. seeking out own information via web or literature search)
  - ☐ Protocol from site
  - ☐ Other: ____________
  - ☐ I do not acquire images
- When using direct digital radiography, which kVp and mAs factors should be used to image the following body parts:

Body Part	kVp	mAs	I don't know (please indicate why)
Pelvis			
Chest			
Skull			
Hand			

- Which modality offers the opportunity for the most dose savings to patients? Check:
  - ☐ Computed Radiography
  - ☐ Direct digital radiography
  - ☐ No difference
  - ☐ I don't know
- When acquiring a digital image, how does increasing kVp and decreasing mAs (within acceptable exposure indices) affect patient dose?
  - ☐ Increases patient dose
  - ☐ Decreases patient dose
  - ☐ No change in patient dose
  - ☐ I don't know
- When acquiring a digital image, how does increasing kVp and decreasing mAs (within acceptable exposure indices) affect image quality?
- Describe with detail your comfort level acquiring or reviewing images that are exposed with an increased kVp and decreased mAs (so as to deliver a dose to patients that is as low as reasonably achievable) and may have a somewhat lower image quality (i.e. level three or four on the following scale).

1 Very Dissatisfied (Inadequate for diagnosis, definite loss of information, the image should be rejected)	2 Dissatisfied (Poor image that impairs interpretation important information could be lost, interpreter would consider rejecting)	3 Neither Satisfied or Dissatisfied (Acceptable for interpretation bordering on loss of information)	4 Satisfied (Acceptable for interpretation, no loss of information)	5 Very Satisfied (Optimal for evaluating the appropriate category of information)

- In your current practice, do you increase kVp and decrease mAs as one way to acquire digital images that optimize patient dose?
  - ☐ Yes (See Part B below)
  - ☐ No (See Part C below)
  - ☐ I do not acquire images
- If yes, can you describe whether or not there is an opportunity to increase kVp and decrease mAs factors more than you currently are? Why or why not?
- If no, would you be comfortable changing your practice to involve increasing kVp and decreasing mAs as a way to optimize patient dose when acquiring digital images? Why or why not?
- Do you feel that you have the opportunity to make changes regarding the practice of increasing kVp and decreasing mAs to acquire digital images that optimize patient dose in your workplace? Why or why not?
- What can influence change regarding the kVp and mAs factors used to acquire digital images in your workplace?
- How do you think that changes regarding the practice of increasing kVp and decreasing mAs to acquire digital images that optimize patient dose can be implemented in your workplace?
- Describe how the rapid changes in Radiology/Radiography and technology impact your knowledge of dose optimization in digital direct imaging?
- How do you stay current regarding digital dose optimization best practices?
- How can you be best supported to stay current on developments in digital dose optimization, and the translation of this knowledge into your practice?

Lastly, this questionnaire also provided the opportunity for participants to add comments or pose questions.

Anthropomorphic Phantoms Image Display and Quantitative questionnaire

Chest

Rank	Image Number
Best image in terms of overall quality	
Middle image in terms of overall quality	
Worst image in terms of overall quality	

Chest	'Standard' kVp Image	20 kVp Increase Image	30 kVp Increase Image
Tube Voltage	120 kVp	140 kVp	150 kVp
Tube Current and Time Product	0.7 mAs	0.9 mAs	0.7 mAs
Exposure Index	1543	1529	1552
Dose Area Product	1.1 dGycm²	0.8 dGycm²	0.8 dGycm²

	Very Dissatisfied (Inadequate for diagnosis, definite loss of information, the image should be rejected)	Dissatisfied (Poor image that impairs interpretation, important information could be lost, interpreter would consider rejecting)	Neither Satisfied or Dissatisfied (Acceptable for interpretation, bordering on loss of information)	Satisfied (Acceptable for interpretation, no loss of information)	Very Satisfied (Optimal for evaluating the appropriate category of information)	I Cannot Judge (Please explain why in the boxes below)
A. A visually sharp reproduction of the trachea and proximal bronchi?	1	2	3	4	5	0
B. A visually sharp reproduction of the borders of the heart and aorta?	1	2	3	4	5	0
C. A visually sharp reproduction of the diaphragm and lateral costo-phrenic angles?	1	2	3	4	5	0
D. A visually sharp reproduction of the retrocardiac lung and the mediastinum?	1	2	3	4	5	0
E. A visualization of the spine through the heart shadow?	1	2	3	4	5	0

Pelvis

Rank	Image Number
Best image in terms of overall quality	
Middle image in terms of overall quality	
Worst image in terms of overall quality	

Pelvis	'Standard' kVp Image	20 kVp Increase Image	30 kVp Increase Image
Tube Voltage	85 kVp	105 kVp	115 kVp
Tube Current and Time Product	10 mAs	4 mAs	3.7 mAs
Exposure Index	1406	1449	1472
Dose Area Product	3.7 dGycm²	2.1 dGycm²	3.7 dGycm²

	Very Dissatisfied (Inadequate for diagnosis, definite loss of information, the image should be rejected)	Dissatisfied (Poor image that impairs interpretation, important information could be lost, interpreter would consider rejecting)	Neither Satisfied or Dissatisfied (Acceptable for interpretation, bordering on loss of information)	Satisfied (Acceptable for interpretation, no loss of information)	Very Satisfied (Optimal for evaluating the appropriate category of information)	I Cannot Judge (Please explain why in the boxes below)
A. A visually sharp reproduction of the sacrum and its intervertebral foramina?	1	2	3	4	5	0
B. A visually sharp reproduction of the pubic and ischial rami?	1	2	3	4	5	0
C. A visually sharp reproduction of the sacroiliac joints?	1	2	3	4	5	0
D. A visually sharp reproduction of the necks of the femora?	1	2	3	4	5	0
E. A visually sharp reproduction of the trabecular bone of the trochanters?	1	2	3	4	5	0

Skull

Rank	Image Number
Best image in terms of overall quality	
Middle image in terms of overall quality	
Worst image in terms of overall quality	

Skull	'Standard' kVp Image	20 kVp Increase Image	30 kVp Increase Image
Tube Voltage	75 kVp	95 kVp	105 kVp
Tube Current and Time Product	7.1 mAs	2.5 mAs	1.7 mAs
Exposure Index	1395	1414	1397
Dose Area Product	1.1 dGycm²	0.6 dGycm²	0.4 dGycm²

	Very Dissatisfied (Inadequate for diagnosis, definite loss of information, the image should be rejected)	Dissatisfied (Poor image that impairs interpretation, important information could be lost, interpreter would consider rejecting)	Neither Satisfied or Dissatisfied (Acceptable for interpretation, bordering on loss of information)	Satisfied (Acceptable for interpretation, no loss of information)	Very Satisfied (Optimal for evaluating the appropriate category of information)	I Cannot Judge (Please explain why in the boxes below)
A. A visually sharp reproduction of the outer and inner lamina of the cranial vault?	1	2	3	4	5	0
B. A visually sharp reproduction of the floor of the sella?	1	2	3	4	5	0
C. A visually sharp reproduction of the apex of the petrous temporal bone?	1	2	3	4	5	0
D. A visually sharp visually sharp reproduction of the vertex of the skull?	1	2	3	4	5	0
E. A visually sharp reproduction of the trabecular structure of the cranium?	1	2	3	4	5	0

Hand

Rank	Image Number
Best image in terms of overall quality	
Middle image in terms of overall quality	
Worst image in terms of overall quality	

Hand	'Standard' kVp Image	20 kVp Increase Image	30 kVp Increase Image
Tube Voltage	52 kVp	72 kVp	82 kVp
Tube Current and Time Product	1.2 mAs	.20 mAs	.22 mAs
Exposure Index	1239	1249	1330
Dose Area Product	0.1 dGycm²	.06 dGycm²	.06 dGycm²

	Very Dissatisfied (Inadequate for diagnosis, definite loss of information, the image should be rejected)	Dissatisfied (Poor image that impairs interpretation, important information could be lost, interpreter would consider rejecting)	Neither Satisfied or Dissatisfied (Acceptable for interpretation, bordering on loss of information)	Satisfied (Acceptable for interpretation, no loss of information)	Very Satisfied (Optimal for evaluating the appropriate category of information)	I Cannot Judge (Please explain why in the boxes below)
A. A visually sharp reproduction of the bony trabecular markings?	1	2	3	4	5	0
B. Adequate contrast and density to demonstrate soft tissue?	1	2	3	4	5	0
C. A visually sharp reproduction of the cortical outlines of the anatomic structures?	1	2	3	4	5	0

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