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Comparing Absorbed Doses of Properly and Improperly Collimated Abdominal Exposures

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During a radiography examination, the beam should be restricted, or *collimated*, to the anatomy in question. If a repeat exposure is necessary because an anatomical area was clipped or missed in the original exposure, the beam should be collimated to the clipped or missing anatomy to limit the radiation dose to the patient. If the repeated exposure is not properly collimated, the patient potentially is exposed to another full dose of ionizing radiation.

The purpose of this study was to calculate and compare the absorbed doses of properly and improperly collimated repeat examination exposures and to measure the anode heel effect to determine the difference in intensity between the cathode and anode ends of the x-ray beam. The investigators wanted to document the amount of additional radiation a patient receives due to improper collimation techniques and determine whether the difference in intensity between the anode and cathode ends of the x-ray beam was large enough to cause concern for increased patient absorbed doses for specific radiography examinations.

The researchers obtained radiographs of the abdomen using different collimation techniques and then measured and compared the entrance skin exposures. They also examined the anode heel effect, which causes a difference in energy between the cathode and anode ends of the x-ray beam, and the reduction of beam intensity proportional to the inverse of the distance squared.

Using similar methods, Chaparian et al found that patient absorbed doses for radiography examinations of the lumbar spine could be reduced by using certain positioning techniques.[1] Their study measured the skin entrance dose of the x-ray beam with a solid-state electronic dosimeter and used the measurement to calculate the absorbed and effective doses delivered to the patient. In addition, Fung and Gilboy observed that patient positioning could be altered according to the anode heel effect in such a manner that the absorbed doses for male and female gonads could be decreased.[2] This decrease in patient absorbed dose with position relative to the anode and cathode showed the researchers that a difference in the intensity of the beam at either end of the x-ray tube exists and that this difference should be measurable.

In the current study, the researchers used a nanoDot OSLD (Landauer) radiation dosimeter to measure the entrance skin exposure. The nanoDot OSLD is small, compact, and capable of accurately measuring the level of exposure. An Armstrong X-Ray/CT full body phantom with an anatomically correct skeletal structure was used to allow for optimal collimation, as well as placement of the nanoDot OSLDs in areas that relate to where radiosensitive organs would be located in a human patient. A Philips DigitalDiagnost digital radiography system located at a regional medical center in Kentucky was used. Two setups were used for the research: one to evaluate the anode heel effect, and another to evaluate the absorbed dose differences in anatomical structures between properly and improperly collimated exposures.

Anode Heel Effect

To observe the anode heel effect, the researchers first placed dosimeters in a straight line on the table starting at the anode end of the x-ray tube and extending to the cathode end. Five dosimeters were placed for each exposure: 1 directly in the central ray of the x-ray beam, 2 on the outer edge of the collimated x-ray beam, and 2 outside the collimated beam on each end of the tube (see **Figure 1**). Dosimeters 1 and 2 measured the exposure on the anode side of the tube, whereas dosimeters 4 and 5 measured the exposure at the cathode side of the tube. Dosimeter 3 measured the exposure at the central ray. The exposure factors for the x-ray tube were set at 80 kVp and 50 mAs for each exposure.

Three exposures were made with the x-ray source at a distance of 40 inches from the table top where the dosimeters were placed. A 14 × 17 inch collimated beam field size was used. After each exposure, the dosimeters were removed and replaced with unexposed dosimeters. Two exposures also were made with the x-ray source at a distance of 20 inches from the table top, with a 10.5 × 10.5 inch collimated field size. The technical exposure factors and the serial numbers of each dosimeter were recorded in a spreadsheet. For verification purposes, the dosimeters were arranged in a straight line, perpendicular to the first setup. As in the first setup, 1 dosimeter was placed in the central ray, 2 on the outer edge of the collimated x-ray beam, and 2 outside the collimated x-ray beam. All exposures were made with x-ray source-to-table distances of 20 and 40 inches, with a 14 × 17 inch field size.

Absorbed Dose Differences

To analyze the differences in patient absorbed doses for improper collimation techniques, the investigators placed dosimeters on the phantom in the areas representing the right eye, thyroid, right breast, female gonads/central ray, and male gonads (**see Figure 2**). The researchers chose the abdominal examination because more radiosensitive organs are exposed with this examination than with a chest examination. In addition, the technical exposure factors used to obtain abdominal radiographs also are higher than that of chest radiographs because of tissue density, which can lead to higher patient absorbed doses. For an abdominal radiograph to be of diagnostic quality, certain anatomy must be present on the image, including full views of the kidneys, ureters, and urinary bladder; if any of this anatomy is not present, the image is considered to be clipped (**see Figure 3**).

For this study, the investigators positioned the phantom supine on the radiographic table, set the x-ray source-to-image receptor distance at 40 inches—which is standard for an abdominal radiograph—and used a 14 × 17 inch collimated field size. The technical exposure factors used for every exposure for this part of the research were 80 kVp and 40 mAs, which are common techniques used for an average-sized adult patient.

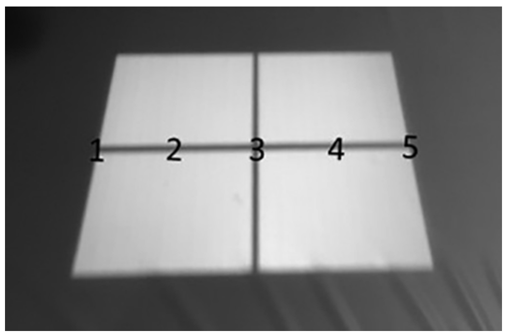

Figure 1. *Dosimeter placement to determine the effects of the anode heel effect. Dosimeters were placed at locations 1 through 5; locations 1 and 2 are on the anode side, location 3 is the central ray, and locations 4 and 5 are on the cathode side. Image courtesy of the author.*

Figure 2. *Location of dosimeters on the phantom. Image courtesy of the author.*

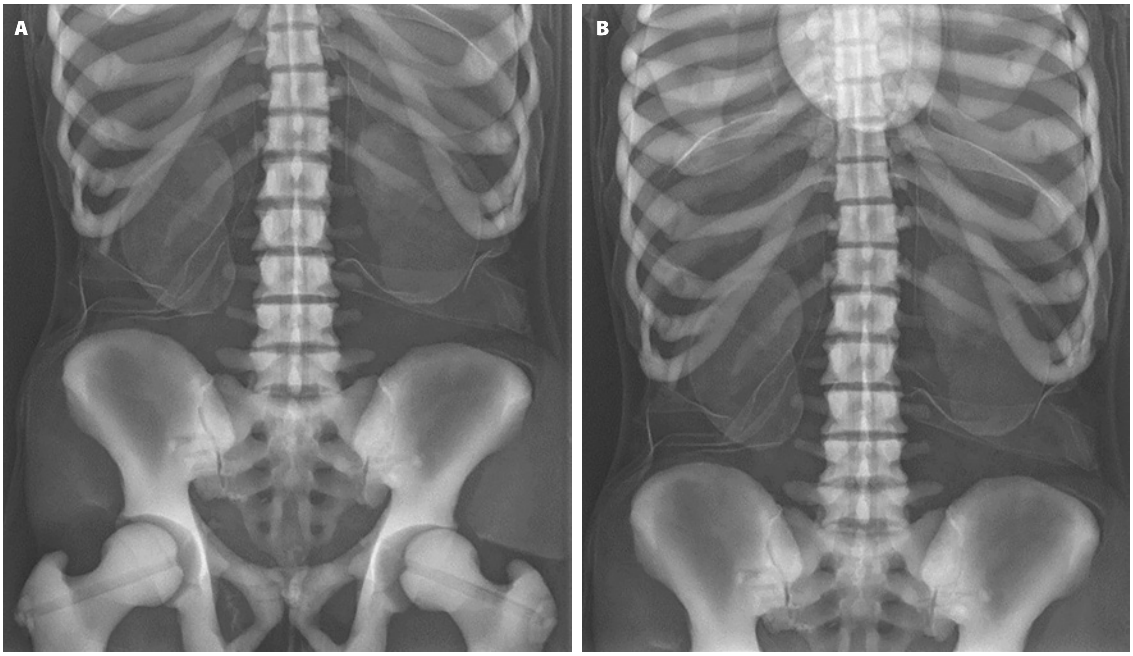

Figure 3. *A. Correctly positioned and collimated abdominal radiograph that includes all pertinent anatomy. B. Clipped abdominal radiograph that does not include the bladder. Images courtesy of the author.*

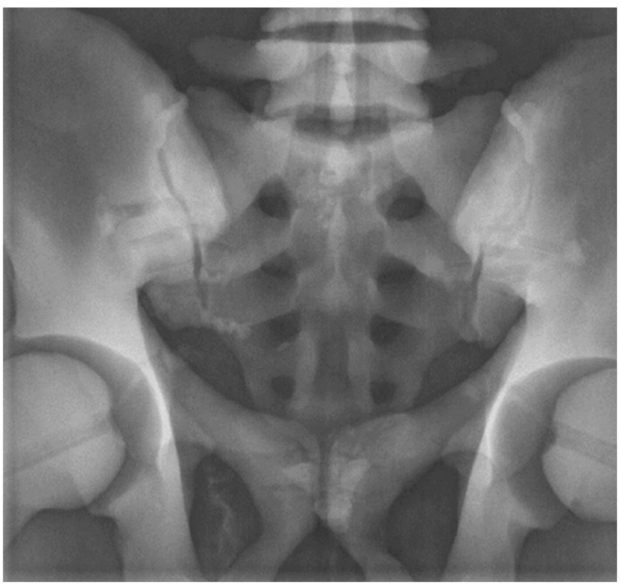

Figure 4. *Properly collimated repeat exposure for the clipped bladder. Image courtesy of the author.*

For the first set of 4 exposures, abdominal radiographs were obtained using correct positioning and collimation. After each exposure, the dosimeters were replaced with unexposed dosimeters. For the second set of 4 exposures, a portion of the bladder was not included on the abdominal radiograph. The researchers—following the proper method for obtaining a repeat image for an abdominal radiograph in which the full bladder was not included—centered the central ray of the x-ray beam over the bladder and collimated the field size (6.5 × 6.5 inches) to the area of the bladder (**see Figure 4**). Another 4 exposures with this positioning were made, and dosimeters were changed between exposures. The technical exposure factors for each set of exposures and the serial number for each of the dosimeters used were recorded in a spreadsheet.

The exposed dosimeters were delivered to Landauer for analysis. A control dosimeter was included so that background radiation exposure could be accounted for. The exposures for each of the dosimeters were received from Landauer and recorded in a spreadsheet for interpretation.

Results

Using the data collected from the first setup, the investigators analyzed the anode heel effect. The resulting doses for the dosimeters showed an increase in the total dose received at the cathode end of the x-ray tube (see **Table 1**). The difference in the amount of dose from the anode to the cathode was calculated. For the measurements that occurred with a source-to-table distance of 40 inches, the maximum percent difference in dose was 25.1%. The maximum percent difference in dose for the 20-inch source-to-table distance was 23.4% (see **Table 2**).

The researchers then determined whether a substantial difference in dose existed between properly and improperly collimated repeat radiographs of the abdomen. The data showed a decrease in entrance skin exposure for all measured parts when the repeat radiograph was properly collimated to the bladder. Although the doses of the collimated bladder exposures are lower than the improperly collimated full abdomen exposure, hypothesis testing was performed to ensure that the decreases were statistically significant and apply to the entire population. A *t* test was applied to the small sample size (n = 4 for each body part), and a *t* test program written for Excel (Microsoft) was used to perform the calculation (see **Table 3**). A left-tailed test was used, with the null hypothesis being that the population mean of the collimated bladder dose was greater than or equal to the population mean of the full abdomen view. The authors expected no difference between the collimated and full exposure doses; a *P* value of less than .05 allowed the researchers to reject the null hypothesis. The alternative hypothesis was that the population mean of the collimated bladder dose was less than the population mean of the full abdomen view. The eyes were the only area of exposure not statistically significant.

Conclusion

The purpose of this research was to look at the anode heel effect and the absorbed doses for correctly and incorrectly collimated abdominal radiographs and determine how this information could be used to decrease patient exposure. Findings for the anode heel effect show a measurable difference in the exposure between the anode and the cathode. These findings could be applicable to lower absorbed doses experienced by patients during radiography examinations. If patients were positioned in such a way, the exposure from the cathode end could be reduced, which could lower overall exposure.

Table 1

Dose at Anode and Cathode Ends Per Exposure

Exposure	Source-to-table Distance, (in)	Dose at Anode End, (mrad)	Dose at Cathode end, (mrad)
1	40	2.5	2.4
2	40	0.7	2.9
3	40	1.9	1.5
4	20	4.5	6.7
5	20	6	7

Table 2

Average Dose at Anode and Cathode Ends and Percent Difference

Source-to-table Distance	X-ray Tube End	Dose (mrad)	% Difference
40	Anode	1.7	25.1
	Cathode	2.27	
20	Anode	5.25	23.4
	Cathode	6.85	

Table 3

Dose Comparison for the Full Abdomen View and Collimated Bladder[a]

	Full Abdominal, (mrad)	Collimated Bladder, (mrad)		
Anatomy	Mean (SD)	Mean (SD)	*t*	*P* value
Eyes	.9 (.6)	.5 (.6)	−0.79	.23
Thyroid	2.3 (.4)	.6 (1.2)	−2.85	< .05
Breast	34.3 (2.6)	2.7 (.7)	−23.35	< .05
Female Gonads	418.8 (4.1)	52 (31.4)	−23.14	< .05
Male Gonads	419.6 (7)	405.2 (5.1)	−3.35	< .05

[a] *n = 4 per body part*
Abbreviation: SD, standard deviation.

Proper collimation practices reduce the x-ray field size and reduce patient exposure. The repeat abdomen exposures demonstrated the extent of the differences between the doses delivered with proper and improper collimation and showed significant increases between the doses of the full abdomen and collimated urinary bladder repeat exposures.

Patient safety always should be the highest priority for every medical professional. Radiographers can reduce patient dose by adhering to the guidelines set forth by the principles of ALARA (as low as reasonably achievable) and by using proper patient positioning and collimation techniques.

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