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The importance of patient centering on **CT radiation dose optimization**

How miscentering patients can undermine your dose optimization efforts

Hospital accrediting bodies and state regulatory agencies are requiring institutions to perform reviews of CT imaging protocols and implement dose optimization.¹ However, positioning of the patient in the CT gantry can undermine dose optimization efforts if not performed correctly by the CT technologist.⁵⁻⁸ The purpose of this paper is to describe the impacts when patients are not properly positioned, and how to evaluate and correct patient positioning.

How a patient is positioned for a CT scan?

Current state-of-the-art CT scanners employ bowtie filters for the purpose of shaping the x-ray intensity used to produce the x-ray image based on the attenuation characteristics of the exposed tissue region of the patient; in areas of higher attenuation, a thinner segment of the bowtie filter is used to increase x-ray intensity, and in areas of lower attenuation a thicker segment of the filter is used to reduce the intensity.⁹ However, optimal use of the bowtie filter is based on the presumption that the patient centroid is properly centered in the scanner's field-of-view (FOV).⁵⁻⁸

When a patient is placed on the CT scanner, the technologist uses their best judgment to ensure the patient is centered within the gantry.² Proper positioning of the patient in the gantry means that the patient midline (an imaginary line drawn between the patients eyes to their pubic symphysis) is in the center of the CT bed, and that the table height is adjusted so the center of mass of the region to be scanned is coincident with the center of rotation of the CT scanner.⁷ Currently, most modern scanners use lasers to aid the technologist in positioning the patient. After the patient is positioned on the bed, the technologist retreats to the CT console and performs a "scout" image of the patient so the appropriate region of interest can be selected for the diagnostic scan. Technologists may perform either an anterior-posterior scout image, or a lateral scout image, or both. The purpose of the scout image is to measure the attenuation characteristics of the patient so the scanner can employ the appropriate automatic exposure controls (AEC). These scout images provide an opportunity to verify correct patient positioning. After adjusting the height of the table the technologist should "rescout" the patient to ensure proper AEC is used.

However, studies have shown that technologists frequently do not position the center of the patient with the iso-center of the scanner.⁵⁻⁸ Retrospective studies have shown that patient off-centering is less prevalent in the x,y direction, and most pronounced in the vertical direction. In one study, 67-85% of patients were miscentered more than 1 cm below isocenter.⁷ Patient size has been observed to influence whether the patient is not centered properly. Patients above isocenter tended to be larger than those positioned below isocenter.⁷ And, small patients are more likely to be miscentered than large patients.⁵

What is the impact when a patient is not properly positioned?

Patients that are not properly centered do not have their center of mass properly aligned with the center of the bowtie filter which affects the attenuation of the x-ray beam and image noise.⁵⁻⁸ As a result, dose optimization efforts to reduce radiation dose while maintaining image noise may be compromised in miscentered patients.^{3,4,6,8} In phantom studies, the peripheral and radiation dose increased by 12% and 18% in phantoms 30 mm below isocenter, and 41% and 49% when the phantom was 60 mm below isocenter.⁸ Image noise in phantoms also increased by 16.5% when patients were miscentered (above or below isocenter) by 30 mm. In general, for patients centered above isocenter the center of the bowtie filter corresponds to the posterior abdominal wall and the anterior abdominal wall receives a more attenuated x-ray beam.^{5,6,8} When patients are centered below isocenter, as seen in Figure 1 below, an increase in posterior abdominal wall noise is seen as the x-ray beam is more attenuated by the thicker portion of the bowtie filter.

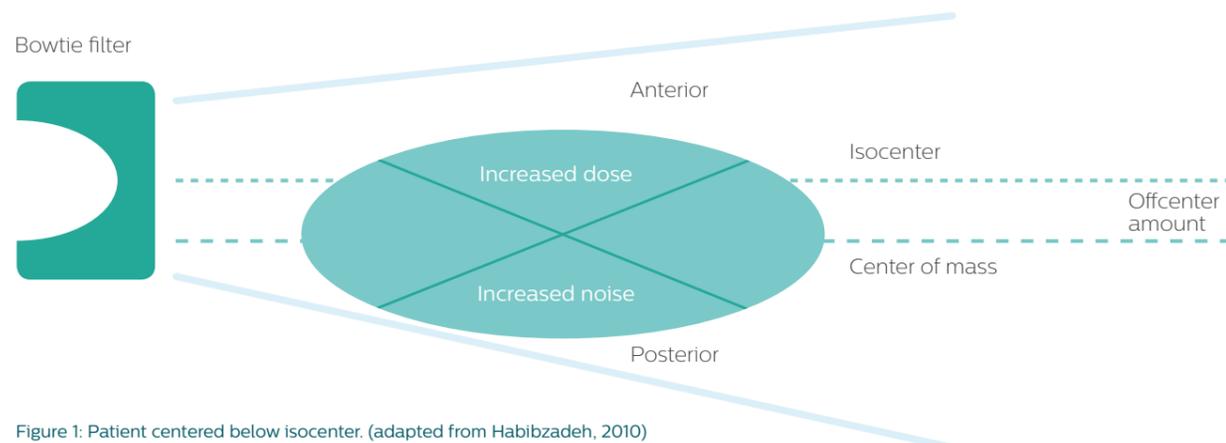


Figure 1: Patient centered below isocenter. (adapted from Habibzadeh, 2010)

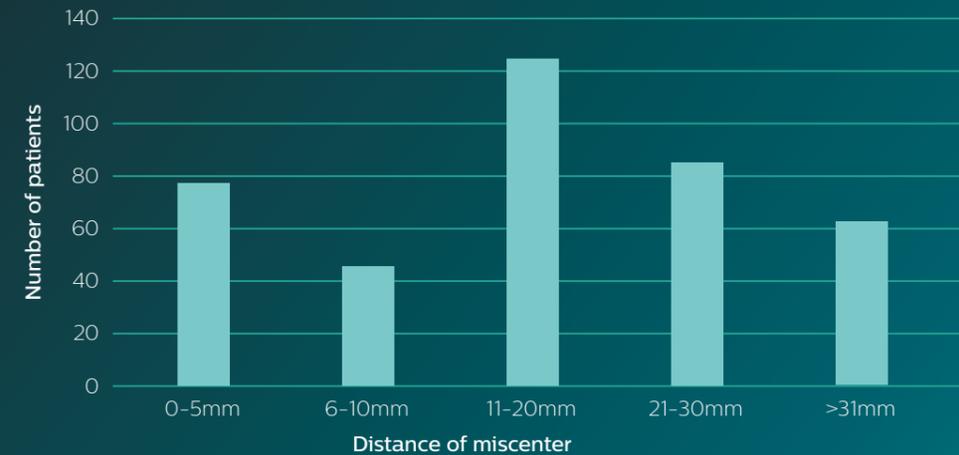


Figure 2: Number of patients miscentered by different distances. (adapted from Kim, 2012)

Figure 2 presents the results of a retrospective study which evaluated the distance that patients were miscentered. One third of all patients were miscentered between 1 to 2 cm with 16% greater than 3 cm. Overall, 81% of 395 patients evaluated were considered miscentered (i.e., >5 mm).

Table 1 presents the results of a separate study of seven imaging centers. The results for the number of patients miscentered are similar. Miscentering of patients has a greater impact on radiation dose than it does on image noise.

| Imaging site | Number of patients | Average miscentering (mm) | Average dose increase | Average noise increase |
|--------------|--------------------|---------------------------|-----------------------|------------------------|
| 1 | 80 | 21 | 21.9% | 6.0% |
| 2 | 33 | 37 | 29.1% | 10.9% |
| 3 | 89 | 25 | 25.0% | 7.6% |
| 4 | 78 | 15 | 17.6% | 5.3% |
| 5 | 72 | 17 | 21.9% | 6.7% |
| 6 | 45 | 24 | 24.4% | 7.8% |
| 7 | 83 | 19 | 19.8% | 4.7% |

Table 1: Average patient miscentering (above or below) and resulting increase in dose and noise for seven imaging sites. (Habibzadeh, 2011)

How do you evaluate whether a patient is positioned correctly, and what to do when they are not?

A properly positioned patient has their center of mass at the isocenter of the CT gantry. In the initial step, the technologist positions the patient using the laser positioning assist based on their professional judgment. The technologist typically performs a lateral projection localizer to see if the patient is close to isocenter (<5 mm). Next,

the technologist acquires an anterior-posterior image. The technologist uses the anterior-posterior image to select the field-of-view (FOV) for the diagnostic image and reconstruction. The anterior-posterior localizer image default is to present the FOV center as the center of the displayed scan. If the technologist identifies that the patient is too high or too low from the localizer, the technologist should lower or raise the table. Table height adjustments may be accomplished remotely with most scanners. After the table position is adjusted, the technologist should "rescout" the patient to ensure the scanner recalculates the automatic exposure control needed for optimum image quality.

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