How Miscentring in CT Scans Affects Radiation Patient Dose and Image Quality

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At a Glance

Computed tomography (CT) imaging is a cornerstone of modern medical diagnostics, yet patient miscentring remains a persistent issue affecting both radiation dose and image quality. Proper patient positioning is critical to optimising scan parameters, reducing unnecessary radiation exposure, and ensuring diagnostic accuracy. Miscentring of patients during CT scanning can result in increased radiation dose, image noise, and potential diagnostic errors. This article explores the impact of patient miscentring on CT imaging, outlines and discusses contributing factors, and highlights strategies for mitigation.

Keywords: Radiology, Computed tomography, Radiation dose, Patient positioning

Introduction

CT is a vital tool in medical imaging, allowing clinicians to visualise internal organs, bones, and soft tissues in detail. While it provides crucial diagnostic information, achieving high-quality images while minimising radiation exposure requires careful application of appropriate scanning parameters, particularly accurate patient positioning.

Correct patient positioning ensures that the body is aligned with the isocentre, the ideal point within the scanner where the X-ray beam is most uniform. This is usually performed manually by radiographers using lasers, table markings, and an initial 'scout/localiser' image to confirm alignment. However, miscentring, described as 'when a patient is not correctly positioned in the CT gantry' remains a common issue that affects both radiation dose and image quality (Figure 1).[1,2]

Miscentring can cause the Automatic Tube Current Modulation (ATCM) system to miscalculate the required radiation dose, leading to either excessive exposure or poor image quality.[3] It can also introduce image noise and artifacts, which may affect diagnosis and require repeat scans, increasing radiation exposure and patient discomfort.[4]

Since CT scans are a widely used diagnostic tool, reducing miscentring is essential for patient safety and imaging accuracy. This article will explore how miscentring affects CT imaging, the factors that contribute to it, and strategies both manual and technology-driven to minimise its impact in clinical practice.
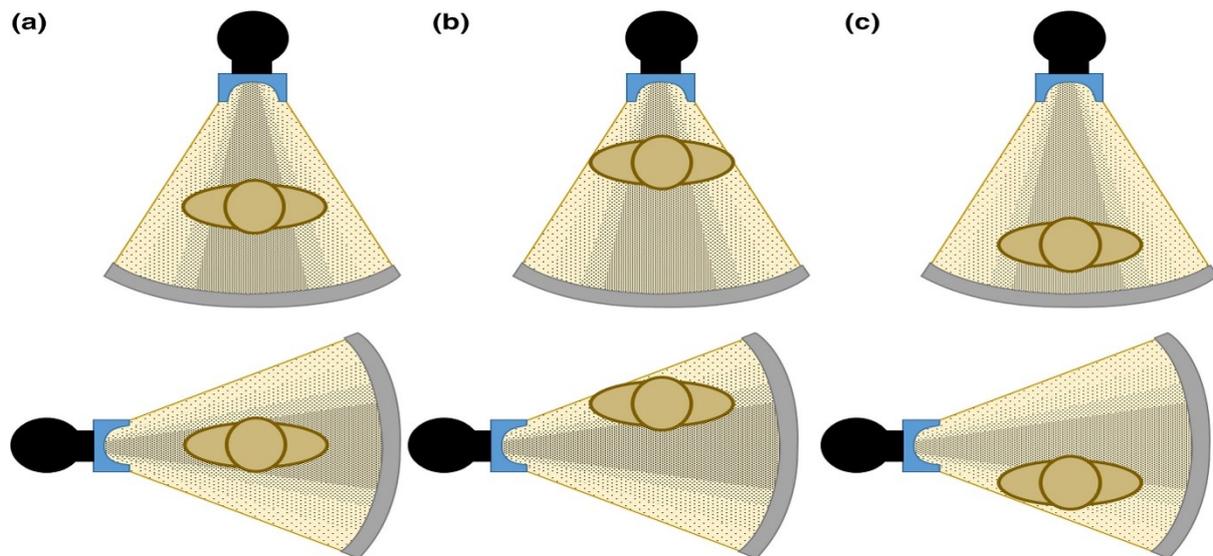

Figure 1: Anterior (top) and lateral (bottom) views of the X-ray beam distribution relative to patient positioning. (a) The patient is correctly centred within the gantry, ensuring optimal beam alignment. (b) The patient is positioned too far anteriorly, altering the beam distribution. (c) The patient is positioned too far posteriorly, leading to changes in dose distribution. Adapted from Barreto et al.[2]

Effects of Miscentring on Patient Radiation Dose

Correct patient alignment within the CT scanner is essential for optimising radiation dose. One of the key components regulating CT dose is the ATCM system, which adjusts the tube current (quantity of radiation) in real-time based on the patient's size and attenuation (the reduction in X-ray beam intensity as it passes through tissue) characteristics. When a patient is not correctly aligned 'miscentred' within the gantry, the ATCM system receives inaccurate information, leading to miscalculations in radiation dose. Even minor deviations from the isocentre can have significant consequences, affecting both patient safety and image interpretability.

Miscentering influences radiation dose mainly because it alters how the scanner estimates patient size, leading to either an overestimation or underestimation that directly affects the amount of radiation applied. When a patient is positioned too low relative to the isocentre, the CT scanner perceives them as larger than they actually are. In response, the ATCM system increases the tube current to compensate for the assumed increased attenuation, unnecessarily raising radiation dose. Conversely, when a patient is positioned too high, the system under-

estimates the patient's size, applying a lower tube current than required. While this reduces radiation dose, it often results in increased image noise, potentially obscuring critical anatomical structures and leading to diagnostic uncertainty.

Several studies have quantified the impact of miscentring on radiation dose. A study by Kaasalainen et al. reported that vertical miscentring, where the patient is positioned too high or too low relative to the scanner's isocentre, by just 3 cm increased radiation dose by approximately 18%, while a 6 cm deviation resulted in a 41% increase due to overcompensation by the ATCM system.[4] Similarly, Christner et al. demonstrated that a 4 cm misalignment led to a 30–50% increase in dose, reinforcing the importance of accurate patient positioning.[5] Furthermore, a study by Kaasalainen et al. identified that vertical off-centring in paediatric chest CT using a 5-year-old anthropomorphic phantom increased organ dose, with breast dose rising by up to 16% and thyroid dose by 24% in lower positions.[6]

The magnitude of dose variation due to miscentring is also influenced by patient body habitus and the specific CT protocol used. For example, vertical misalignment in chest, abdomen, and pelvis CT scans impacts organ dose, with variations ranging from -35% to 22% for the lung, colon, uterus, ovary, and skin, while the liver, stomach, and breast experience dose changes between -13% and 15%, increasing proportionally with vertical distance from the isocenter.[2] These findings underscore the necessity of meticulous patient positioning, particularly in dose-sensitive populations such as paediatric, oncology patients, Crohn's or cystic fibrosis, where cumulative radiation exposure is a major concern.

Effects of Miscentring on Image Quality

Image quality in CT imaging is highly dependent on proper patient positioning, as deviations from the isocentre significantly affect beam geometry, reconstruction algorithms, and scanner calibration. Even minor misalignments can introduce image noise, geometric distortions, and a loss of spatial resolution, all of which may impair a radiologist's ability to detect and interpret abnormalities.

One of the most common consequences of miscentring is increased image noise. Noise in CT images refers to random variations in pixel intensity that reduce the ability to distinguish fine details. When a patient is positioned too high or too low relative to the isocentre, the scanner's beam-hardening correction algorithms may fail to adjust properly, leading to an uneven distribution of X-ray intensity across the image. This effect is particularly pronounced in low-dose CT scans, where any increase in noise can further degrade image quality.

Another major issue caused by miscentring is geometric distortion. When a patient is not correctly positioned, the X-ray beam does not pass through the body symmetrically, causing nonlinear attenuation effects that can lead to image artifacts and reconstruction errors. A study by Szczykutowicz et al. found that mispositioning 4–6 cm above the isocentre caused significant Hounsfield unit (HU) variations (where HU values represent tissue density on CT images), with 4 cm shifts resulting in -15 ± 5 HU in the mid thorax and -8 ± 2 HU in the abdomen, while

6 cm shifts led to 13–20 HU variations in the thorax.[7] A 6 cm misalignment led to standard deviations ranging from 13 to 20 HU in the high thorax and midthorax posterior regions.[7]

The impact of miscentring on image quality is particularly concerning in specialised imaging protocols, such as cardiac CT angiography, where maintaining a consistent field of view is crucial for accurate assessment of coronary arteries. Accurate patient positioning is crucial in cardiac CT angiography to prevent motion artifacts and vessel blurring, which can reduce diagnostic confidence in detecting coronary artery disease. Misalignment in cardiac CT studies can introduce artifacts that mimic perfusion defects (areas of the heart muscle that appear to have reduced blood flow), potentially leading to misdiagnosis.[8]

Factors Contributing to Miscentring

Miscentring in CT imaging is a common issue influenced by multiple factors, including radiographer experience, scanner design, patient characteristics, and workflow pressures. Despite efforts to standardise positioning techniques, miscentring remains frequent, often leading to repeat scans and increased radiation exposure. A study by Habibzadeh et al. reported that 40–60% of CT scans were affected by miscentring, with operator variability being a key contributor.[1]

Radiographer experience plays a crucial role in patient positioning accuracy. Variability in technique and familiarity with different scanner models can lead to errors in centring, impacting image quality and radiation dose. A study highlighted that incorrect patient positioning might outweigh the benefits of automatic exposure control, emphasising the radiographers' role in dose reduction and image quality enhancement. Additionally, continuous professional development activities, including CT-related courses and staying updated with advancements like 3D cameras for automatic patient centring, are recommended to enhance radiographers' knowledge and skills, thereby reducing positioning errors.[9]

Scanner design limitations can indeed contribute to patient miscentring during CT imaging. Variations in table height adjustments, isocentre markers, and user interfaces across different CT scanner models can lead to inconsistencies in patient alignment. A study by Habibzadeh et al. investigated the impact of patient miscentring on dose and image noise across different CT scanners, highlighting that such misalignments can result in increased radiation exposure and degraded image quality.[1]

Patient-related factors such as obesity, limited mobility, and difficulty following instructions can significantly impact accurate positioning during CT imaging. Obesity poses challenges in accommodating patients on standard imaging equipment, often leading to suboptimal positioning and compromised image quality. Elderly patients frequently face difficulties in maintaining proper alignment due to age-related physiological changes and comorbidities, which can affect their ability to cooperate during scans. Paediatric patients present unique challenges; their unpredictable movements necessitate specialised positioning aids and tailored communication strategies to ensure accurate imaging and minimise the need for repeat scans.

Time constraints and workflow pressures in high-volume imaging departments can increase rates of patient miscentring during CT examinations. In busy hospitals and emergency settings, radiographers often manage high patient throughput within limited timeframes, which may lead to prioritising speed over precise positioning. A multi-centre study across seven imaging centres reported an average misalignment of 2.2 cm below the isocentre, associated with a 23% increase in radiation dose and a 7% rise in image noise. The study suggested that high workload and time pressures limited radiographers' ability to make accurate positioning adjustments. These findings highlight the need for effective workload management and the use of technologies such as automated positioning systems to support accurate centring, particularly in time-constrained environments.[1]

Strategies to Reduce Miscentring in CT

Technological advancements, such as artificial intelligence (AI) -assisted positioning systems, show promise in reducing miscentring errors. These systems analyse patient alignment in real-time and provide adjustments before the scan. Continuous education and training programs for radiographers are vital in reducing positioning errors.

Implementing real-time feedback systems can provide immediate corrections to patient positioning before scanning, thereby improving image quality and reducing radiation exposure. This technology aids in achieving accurate positioning without unnecessary imaging doses.

Future Considerations

AI-assisted CT positioning has the potential to significantly reduce miscentring errors by automatically adjusting table height and alignment in real time. Studies suggest these systems can lower positioning errors by over 30%, improving both radiation dose optimisation and image quality.[1] However, successful integration into clinical practice requires not only further validation but also consideration of patient acceptance. Factors such as comfort, trust in AI-driven positioning, and perceptions of automation in healthcare will play a crucial role in ensuring widespread adoption and effectiveness.

Conclusion

Miscentring in CT imaging significantly impacts both patient radiation dose and image quality. Understanding the causes and consequences of misalignment is essential for optimising CT scan protocols. The radiology community can enhance imaging accuracy and ensure patient safety by implementing standardised positioning strategies, integrating automated technologies, and providing ongoing training for radiographers.

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Declaration of Interests

There is nothing to declare.

Author Bio

Yasser Hadi is a senior CT radiographer pursuing a PhD at University College Cork. Under the supervision of Professor Mark McEntee and Dr Andrew England, Yasser Hadi's research focuses on the application of artificial intelligence in CT imaging, specifically its impact on optimising radiation dose and imaging quality to provide the best patient care. With a background in clinical radiography and a passion for improving patient outcomes, Yasser Hadi is dedicated to advancing the field of radiography through evidence-based research and innovative practices.

References

[1] M. A. Habibzadeh, M. R. Ay, A. R. K. Asl, H. Ghadiri, and H. Zaidi. Impact of miscentering on patient dose and image noise in x-ray CT imaging: phantom and clinical studies. *Physica Medica*, 28:191–199, 2012.

[2] I. Barreto, R. Lamoureux, C. Olguin, N. Quails, N. Correa, L. Rill, and et al. Impact of patient centering in CT on organ dose and the effect of using a positioning compensation system: Evidence from OSLD measurements in postmortem subjects. *Journal of Applied Clinical Medical Physics*, 20:141–151, 2019.

[3] K. Perisinakis, I. Seimenis, A. Tzedakis, A. E. Papadakis, and J. Damilakis. The effect of head size/shape, miscentering, and bowtie filter on peak patient tissue doses from modern brain perfusion 256-slice CT: How can we minimize the risk for deterministic effects. *Medical physics*, 40, 2013.

[4] T. Kaasalainen, K. Palmu, V. Reijonen, and M. Kortesniemi. Effect of patient centering on patient dose and image noise in chest CT. *American Journal of Roentgenology*, 203:123–130, 2014.

[5] J. A. Christner, N. N. Braun, M. C. Jacobsen, R. E. Carter, J. M. Kofler, and C. H. McCollough. Size-specific dose estimates for adult patients at CT of the torso. *Radiology*, 265:841–847, 2012.

[6] T. Kaasalainen, K. Palmu, A. Lampinen, and M. Kortesniemi. Effect of vertical positioning on organ dose, image noise and contrast in pediatric chest CT–phantom study. *Pediatric Radiology*, 43:673–684, 2013.

[7] T. P. Szczykutowicz, A. DuPlissis, and P. J. Pickhardt. Variation in CT Number and Image Noise Uniformity According to Patient Positioning in MDCT. *American Journal of Roentgenology*, 208:1064–1072, 2017.

[8] J. Yu and J. Iwaz. *Practical Guide to Cardiac CT*, chapter Recognizing and Addressing Artifacts in Cardiac CT, page 81–89. Springer Nature Singapore Pte Ltd., 2024.

[9] Y. Al-Hayek, K. Spuur, R. Davidson, C. Hayre, G. Currie, and X. Zheng. The effect of inappropriate patient centring on CT numbers and radiation dose: A survey of current practices and knowledge. *Radiography*, 30:100–106, 2024.