Clinical Assessment of Musculoskeletal Spatial Resolution Degradation With Distance From Isocenter in EID CT

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INTRODUCTION

CT images with high spatial resolution are essential for the assessment of the bones in musculoskeletal (MSK) imaging, and critical for fracture detection [1]. In-plane high-resolution degrades with increasing distance from the isocenter of the CT gantry [2]. Therefore, proper positioning of the patients at isocenter is important for acquiring high spatial resolution imaging. Unfortunately, off isocenter positioning is not uncommon [3, 4]. A large-scale analysis of CT scans of the chest, abdomen, and pelvis found that 83.7% of the scans were performed with patients positioned off isocenter [5]. Isocenter positioning can be additionally challenging in MSK patients, who frequently have limited mobility, experience pain, or restrictive orthopedic hardware or casts. Nevertheless, there are examples in which consistency of patient centering has been improved via quality improvement and educational efforts [6]. In order to optimize imaging quality and standardize patient positioning protocols, there is a need to define an optimal range of distances from the isocenter where image quality is consistent and clinically acceptable. In-plane spatial resolution is commonly quantified using the modulation transfer function (MTF) [7]. However, the impact of off-isocenter positioning on MSK clinical image quality has not been specifically investigated.

PURPOSE

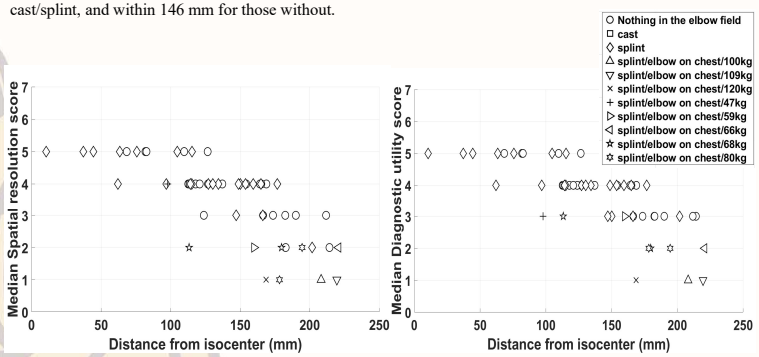
To our knowledge, this work is the first to systematically examine the effect of increasing off-center distance on both spatial resolution and clinical usefulness of trabecular bone imaging at joint interfaces in energy-integrating detector CT. Image quality was assessed subjectively using Likert-scale evaluations by musculoskeletal radiologists, with the goal of identifying an optimal scanning region in which image performance is preserved for MSK examinations.

MATERIAL AND METHODS

This retrospective study included 57 elbow EID CT examinations acquired at varying distances from the isocenter. Three radiologists independently evaluated spatial resolution and diagnostic utility using a 5-point Likert scale (5 = much better than standard of care; 1 = much worse than standard of care), and interrater agreement was quantified using intraclass correlation coefficients (ICC). Ordinal logistic regression assessed the association between distance from the isocenter and image quality scores separately in two cohorts—(1) patients with a cast, splint, or splinted elbow positioned over the chest and (2) patients without these factors—to account for potential confounding from casts, splints, or chest beam attenuation.

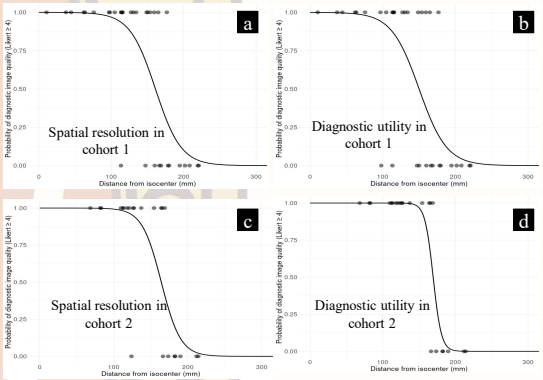
RESULTS

Mean age was 48 ± 19 years (38 males, 19 females). ICC was excellent for both spatial resolution and diagnostic utility (ICC = 0.975/ ICC = 0.973). For each 1-mm increase in distance from the isocenter, the odds of being in a higher Likert score category decreased significantly by approximately 5-7% and 5-16% for spatial resolution and diagnostic utility score, respectively ($p < 0.05$). The probability of achieving a diagnostic utility Likert score ≥4 exceeded 0.8 when the elbow was positioned within 123.7 mm for patients with a cast/splint, and within 161.5 mm for those without. For spatial resolution, this was within 136.3 mm for patients with a cast/splint, and within 146 mm for those without.



Up to approximately 123 mm from isocenter: Image quality remained uniformly high, with most examinations receiving scores of 4–5 regardless of the presence of a cast or splint, and only a small number of exceptions.

More than approximately 123 mm from isocenter: Image quality showed greater variability, spanning the full range of scores from 1–5. Although some scans still achieved excellent ratings, lower scores occurred more frequently, reflecting a decline in the consistency and predictability of image quality.



Ordinal logistic regression model-predicted probability of diagnostic image quality (Likert ≥ 4) versus distance from isocenter. The solid line shows probabilities derived from an ordinal logistic regression fit to ordinal Likert scores. Overlaid points represent observed diagnostic (probability 1, Likert≥ 4) and non-diagnostic (probability 0, Likert< 4) image quality classifications for individual cases.

Distance associated with a high likelihood of image quality scores ≥4 (probability ≥0.8):

Patients with a cast or splint:

Diagnostic Utility - Approximately 124 mm or less from iso-center

Spatial Resolution - Approximately 136 mm or less from iso-center

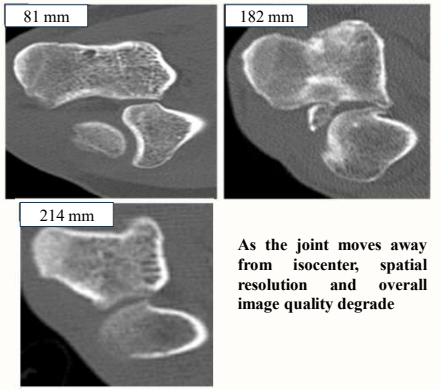
Patients without a cast or splint:

Diagnostic Utility - Approximately 162 mm or less from iso-center

Spatial Resolution - Approximately 146 mm or less from iso-center

Main finding: As positioning moves farther from isocenter, the likelihood of obtaining images with high diagnostic utility and spatial resolution progressively decreases, indicating that off-center imaging is associated with reduced confidence in achieving consistently high-quality examinations.

The clinical images of the elbow positioned at different distances from the isocenter.



As the joint moves away from isocenter, spatial resolution and overall image quality degrade

CONCLUSION

In EID CT, overall image quality for musculoskeletal (MSK) exams can be maintained with high probability when the organ of interest is within 123 mm of isocenter.

REFERENCES

1. Burghardt AJ, Link TM, Majumdar S. High-resolution computed tomography for clinical imaging of bone microarchitecture. Clin Orthop. 2011 Aug 1;469(8):2179-93.
2. Szczykutowicz T. The CT handbook: optimizing protocols for today's feature-rich scanners. Medical Physics Publishing, Madison WI. 2020: 318-319.
3. Szczykutowicz, Timothy P., Andrew DuPlissis, and Perry J. Pickhardt. "Variation in CT number and image noise uniformity according to patient positioning in MDCT." *AJR* 208, no. 5 (2017): 1064-1072.
4. Toth, Thomas, Zhanyu Ge, and Michael P. Daly. "The influence of patient centering on CT dose and image noise." *Med phys* 34, no. 7 (2007): 3093-3101.
5. Akin-Akintayo OO, Alexander LF, Neill R, Krupinksi EA, Tang X, Mittal PK, et al. Prevalence and severity of off-centering during diagnostic CT: observations from 57,621 CT scans of the chest, abdomen, and/or pelvis. Curr. Probl. Diagn. Radiol. 2019 May 1;48(3):229-34.
6. DeWeese L, Griglock T, Moody A, Mehlberg A, Winters C. The improvement of patient centering in computed tomography through a technologist-focused education initiative. Digit. Imaging. 2022 Apr;35(2):327-34.
7. Samei E, Bakalyar D, Boedeker KL, Brady S, Fan J, Leng S, Myers KJ, Popescu LM, Ramirez Giraldo JC, Ranallo F, Solomon J. Performance evaluation of computed tomography systems: summary of AAPM Task Group 233. Medical physics. 2019 Nov;46(11):e735-56.

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