Can Fan-Beam Interactive Computed Tomography Accurately Predict Indirect Decompression in Minimally Invasive Spine Surgery Fusion Procedures?

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■ BACKGROUND: **Recently, novel mobile intraoperative fan-beam computed tomography (CT) was introduced, allowing for real-time navigation and immediate intraoperative evaluation of neural decompression in spine surgery. This study sought to investigate whether intraoperatively assessed neural decompression during minimally invasive spine surgery (MISS) has a predictive value for clinical and radiographic outcome.**

■ METHODS: **A retrospective study of patients undergoing intraoperative CT (iCT)-guided extreme lateral interbody fusion or transforaminal lumbar interbody fusion was conducted. 1) Preoperative, 2) intraoperative (after cage implantation, 3) postoperative, and 4) follow-up radiographic and clinical parameters obtained from radiography or CT were quantified.**

■ RESULTS: **Thirty-four patients (41 spinal segments) were analyzed. iCT-based navigation was successfully accomplished in all patients. Radiographic parameters showed significant improvement from preoperatively to intraoperatively after cage implantation in both MISS procedures (extreme lateral interbody fusion/transforaminal lumbar interbody fusion) ($P \leq 0.05$). Radiologic parameters for both MISS fusion procedures did not show significant differences to the assessed radiographic measures at follow-up ($P > 0.05$). Radiologic outcome values did not decrease when compared intraoperatively (after cage implantation) to latest follow-up.**

■ CONCLUSIONS: **Intraoperative fan-beam CT is capable of assessing neural decompression intraoperatively with high accuracy, allowing for precise prediction of radiologic outcome and earliest possible feedback during MISS fusion procedures. These findings are highly valuable for routine practice and future investigations toward finding a threshold for neural decompression that translates into clinical improvement. If sufficient neural decompression has been confirmed with iCT imaging studies, additional postoperative and/or follow-up imaging studies might no longer be required if patients remain asymptomatic.**

Key words
- CT
- Degeneration
- Fusion
- Navigation
- Spine
- TLIF
- XLIF

Abbreviations and Acronyms
3D: Three-dimensional
CSA: Central canal surface area
CT: Computed tomography
DDD: Degenerative disc disease
DH: Disc height
FA: Foraminal area
iCBCT: Intraoperative cone-beam computed tomography
iCT: Intraoperative computed tomography
iFBCT: Intraoperative fan-beam computed tomography
LL: Lumbar lordosis
MISS: Minimally invasive spine surgery
MRI: Magnetic resonance imaging
ODI: Oswestry Disability Index
OR: Operating room
SDA: Segmental disc angle
TLIF: Transforaminal lumbar interbody fusion
VAS: Visual Analog Scale
XLIF: Extreme lateral interbody fusion

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INTRODUCTION

Extreme lateral interbody fusion (XLIF) and minimally invasive transforaminal lumbar interbody fusion (TLIF) have gained wide acceptance as indirect and direct neural decompression techniques for patients with degenerative spinal diseases, respectively.[1-3] Although having different indications (because of anatomic limitations with XLIF such as the iliac crest at L5/S1), both techniques achieve significant pain relief and restore spinal biomechanics and also reduce approach-related morbidity compared with traditional open procedures.[1,4-12] However, minimally invasive spine surgery (MISS) often results in higher radiation exposure for both the patient and the surgeon because of the limited surgical exposure in situ. Current evidence supports the application of novel computed tomography (CT)-guided navigation technologies to reduce radiation exposure and improve the accuracy of instrumentation.[13-20] Specifically, intraoperative CT (iCT) offers new opportunities for more precise navigation in MISS by allowing for immediate intraoperative evaluation of neural decompression, cage position, and pedicle screw placement.[21] Despite the various benefits, iCT is not commonly used in MISS because of high costs, deceleration of surgical work flow, limited scan volume, and gantry size. Two different modalities of iCT are available: intraoperative cone-beam CT (iCBCT) and intraoperative fan-beam CT (iFBCT; **Figure 1**). Although iFBCT and iCBCT bear some similarities in the nature of the images they produce, they are inherently different imaging modalities. iCBCT is classified as a mobile radiography system and uses a cone-beam configuration, whereas iFBCT is classified as a true or conventional CT scanner that uses a fan-beam configuration. The main advantage of the iFBCT is its greater anatomic reconstruction and high soft tissue resolution, which provides more accurate depictions of important soft tissue structures, such as neurovascular, subcutaneous, or muscle tissue, than does the iCBCT.[22] The iFBCT uses a portable iCT scanner that translates in the rostral to caudal axis over the patient, thereby producing an image of similar quality to a diagnostic conventional CT most likely available only at radiology services. In addition, the iFBCT is capable of imaging multiple spinal segments within a single scan, which is particularly relevant during extensive deformity and fusion surgeries. In the interest of reflecting our institution's experience with the navigation systems described, we refer to iCBCT and iFBCT as O-Arm and AIRO, respectively. However, during the last couple of years, our institution has used several navigation systems from multiple different brands.

Recently, Sembrano et al.[23] assessed neural decompression in spine surgery by performing a myelogram via O-arm. The O-arm's "rapid feedback" was highly valuable during the procedures because it provided real-time information to the surgeon such that he was able to swiftly change the course of the surgery when need be (i.e., performing further decompression). Without the rapid feedback from iCBCT, important changes to the customary work flow would have been overlooked and the results of the surgery would likely have been less successful. Lately, a novel mobile iFBCT was introduced (AIRO [Brainlab AG, Feldkirchen, Germany]) that, unlike earlier models, proved to accelerate surgical work flow and support pedicle screw instrumentation.[15,24] Furthermore, compared with the iCT used by

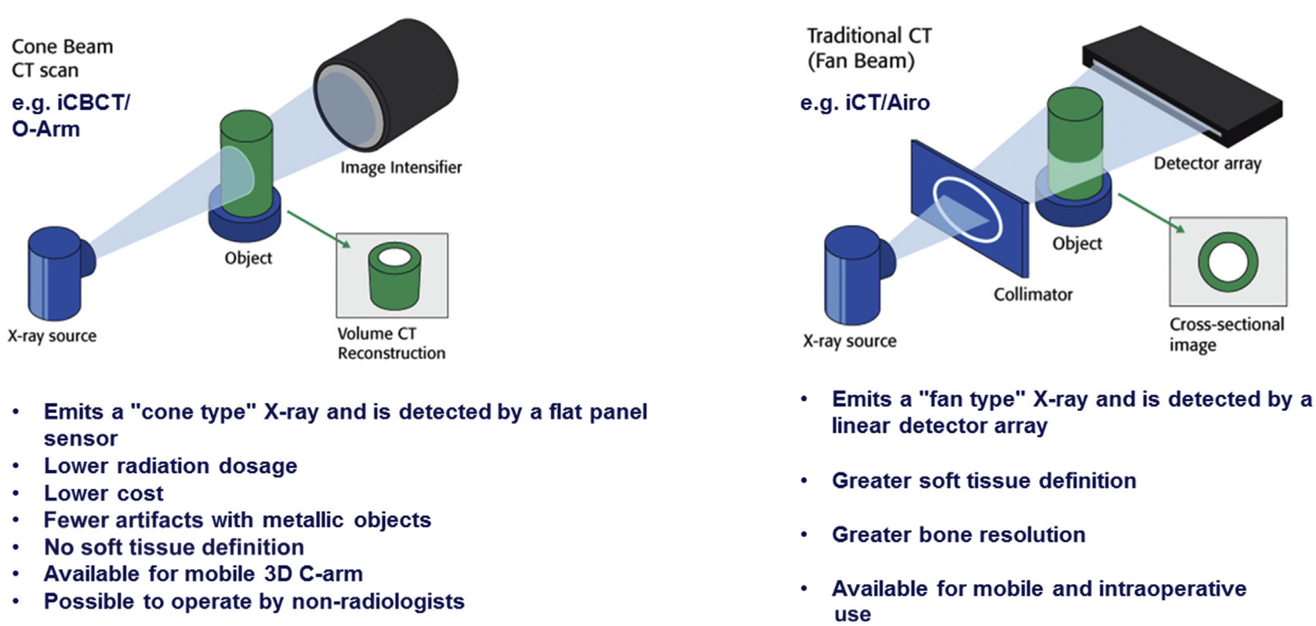

Figure 1. Comparison of cone-beam computed tomography (CT) versus fan-beam computed tomography. 3D, three-dimensional; iCBCT, intraoperative cone-beam computed tomography; iCT, intraoperative computed tomography. Copyright AO Foundation, Switzerland. Source: AO Surgery Reference, www.aosurgery.org.