Mini-invasive Surgery

Editorial

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Is intraoperative navigation in minimally invasive spine surgery cost-effective?

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Intraoperative navigation in spinal surgery involves the use of advanced technology, such as the O-arm, to produce real-time CT imaging of the patient in their surgical position and improve the surgeon's visualization of the spatial positions of their surgical instruments during the procedure[1]. Image-guidance technology has already demonstrated utility in improving surgical outcomes and holds great promise in minimally invasive surgery (MIS).

The most prominent benefit of intraoperative navigation within spinal surgery lies in the reduction of pedicle screw misplacement following lumbar interbody fusion procedures and subsequent reduction of revision procedure rates[2]. While many surgeons are comfortable with the placement of pedicle screws, freehand pedicle screw placement accuracy appears to be variable, with reported accuracy rates ranging from 50% to 80% among different surgeons[3]. Misplacement can result in neurological injury[4], and has been identified in up to 15.07% of cases with up to a 7.42% reoperation rate using traditional techniques[5]. The use of intraoperative imaging technology has been seen to improve the accuracy of pedicle screw placement to up to 96%[3], and therefore may provide a direct and effective solution to the issue of pedicle screw misplacement.

Advanced operative technology is an expensive investment and cost-effectiveness must be accounted for when considering its adoption. Likely the most imposing cost associated with the adoption of this technology is related to the software and maintenance of the equipment[6]. The 4-year capital and

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maintenance cost of the O-arm system has been estimated near $589,205[3], though this cost may be offset by improved accuracy and primary procedure outcomes.

In the absence of intraoperative imaging technology, pedicle screw misplacement often results in the need for readmission to the hospital for revision surgery. This poses a substantial cost to the hospital that could be avoided with accurate pedicle screw placement. The cost of revision surgery and ongoing management for patients experiencing pedicle screw breach has been estimated to be around $33,939 per patient. When compared to the estimated cost of the O-arm, cost-neutrality is achieved when the O-arm is able to prevent revision procedures in 17 patients[3].

This provides an interesting dichotomy in hospital costs: is the cost of advanced technology worth offsetting the cost associated with hospital readmissions and revision surgeries? A recent study comparing conventional and stereotactic (image-guided) pedicle screw placement in the correction of spinal deformities found that upon initial admission to the hospital, all costs favored conventional pedicle screw placements. However, stereotactic pedicle screw placements saw dramatic reductions in instrumentation-related complications, unplanned readmissions, and postoperative revisions[7]. In this way, despite the seemingly imposing costs of adopting advanced intraoperative imaging technology, this technology becomes cost-effective when accounting for the cost of revision surgeries and its improvement in patient outcomes[3].

Two imaging technologies commonly employed during spine surgery are the C-arm and the O-arm. Traditional C-arm imaging allows for 2-dimensional intraoperative imaging, in contrast to the O-arm's real-time 3-dimensional imaging that allows for improved accuracy regardless of the patient's positioning. When comparing these two technologies, the O-arm appears to hold superiority in accuracy of pedicle screw placement as well as complication profile, although efficiency was negatively impacted by a longer required preparation time[8]. Again accounting for the hospital costs associated with revision surgeries brought by initial pedicle screw misplacement, an improvement in accuracy and complication reduction can provide long-term cost-effectiveness for spinal surgery programs that see high volumes of lumbar interbody fusions requiring pedicle screws.

When considering patient safety, the case for navigation in spine surgery becomes even more compelling. The reduction in required revision procedures renders the adoption of imaging technology cost-effective or cost-neutral compared to traditional methods. The commitment to patient health and well-being makes imaging technologies even more cost-effective through this prevention of revision procedures, which have been observed to fall to rates as low as 0%[5].

MIS techniques in procedures like lumbar interbody fusions can derive great benefit from image-guided navigation. These techniques aim to achieve desirable surgical outcomes while minimizing muscle damage, blood loss, and postoperative pain[6]. The dramatic reduction in incision size incorporated by MIS procedures reduces the surgeon's visualization of the involved anatomy, and therefore presents a unique opportunity for intraoperative navigation technologies to flourish. As MIS techniques continue to gain popularity within spinal surgery, image-guidance may present itself as a vital tool that improves surgical efficiency and accuracy by allowing for real-time visualization of key anatomical structures during surgery.

While intraoperative navigation technology is very expensive, not only in terms of initial capital but also in maintenance costs, its benefits appear to be vast. By significantly improving the accuracy of pedicle screw placement by the surgeon, the need for revision procedures is reduced, which not only provides monetary cost-effectiveness for the hospital but also reduces the burden placed on the patient as a result of physician error and subsequent revision procedures. This expensive technology in turn actually becomes considerably cost-effective, from both financial and patient-centric viewpoints.

DECLARATIONS

Authors' contributions

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REFERENCES

1. Kochanski RB, Lombardi JM, Laratta JL, Lehman RA, O'Toole JE. Image-guided navigation and robotics in spine surgery. *Neurosurgery* 2019;84:1179-89. DOI PubMed
2. Tonetti J, Boudissa M, Kerschbaumer G, Seurat O. Role of 3D intraoperative imaging in orthopedic and trauma surgery. *Orthop Traumatol Surg Res* 2020;106:S19-25. DOI PubMed
3. Lee YC, Lee R. Image-guided pedicle screws using intraoperative cone-beam CT and navigation. A cost-effectiveness study. *J Clin Neurosci* 2020;72:68-71. DOI PubMed
4. Watkins RG, Gupta A, Watkins RG. Cost-effectiveness of image-guided spine surgery. *Open Orthop J* 2010;4:228-33. DOI PubMed PMC
5. Al-Khouja L, Shweikeh F, Pashman R, Johnson JP, Kim TT, Drazin D. Economics of image guidance and navigation in spine surgery. *Surg Neurol Int* 2015;6:S323-6. DOI PubMed PMC
6. Virk S, Qureshi S. Navigation in minimally invasive spine surgery. *J Spine Surg* 2019;5:S25-30. DOI PubMed PMC
7. Rezaii PG, Pendharkar AV, Ho AL, et al. Conventional versus stereotactic image guided pedicle screw placement during spinal deformity correction: a retrospective propensity score-matched study of a national longitudinal database. *Int J Neurosci* 2021;131:953-61. DOI PubMed
8. Feng W, Wang W, Chen S, Wu K, Wang H. O-arm navigation versus C-arm guidance for pedicle screw placement in spine surgery: a systematic review and meta-analysis. *Int Orthop* 2020;44:919-26. DOI PubMed