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Commentary

Great Expectations with Augmented Reality in Spine Surgery: Hope or Hype?

A commentary on the article 'Operator independent reliability of direct augmented reality navigated pedicle screw placement and rod bending' by Farshad et al.

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In NASSJ, Farshad et al. have reported the results of their cadaveric study wherein they investigated the accuracy and the operator-independent reliability of 'direct' augmented reality navigated pedicle screw placement and rod bending [1] Over the past few decades, pedicle screws have become the undisputed choice for spinal instrumentation. The consequences of inaccurate pedicle screw placement can be disastrous – ranging from decreased pull-out strength owing to compromised purchase in the bone to iatrogenic injury to critical neurovascular structures. Conventional, free-hand technique of pedicle screw insertion relies on anatomical landmarks and experience of the surgeon – the element of skill that this involves had led to variable rates of pedicle screw accuracy across medical literature, with rates of pedicle screw perforation ranging from 10%-40% [2,3].

In a bid to make pedicle screw placement more reproducible and less error-prone while seeking an improvement in safety profile of spinal instrumentation and quality metrics related to spine care, contemporary spine surgery has seen the advent of several technological advancements such as image-guided navigation, deployment of surgical robots and use of patient-specific templates [3–5]. Quite appropriately, there has recently been a surge of Level-1 studies directed towards finding out whether these innovations and emerging technologies have increased the accuracy of pedicle screw placement in comparison to the freehand technique. While the reported accuracy rates have shown an improvement, demonstrable benefits in context to other important outcome measures such as cost-effectiveness, radiation exposure, operative duration and patient-reported functional outcomes have not been conclusively established [6–9].

Augmented reality (AR) technology allows superimposition of images – which usually comprise of navigation pathways and trajectory-related information – onto a view of the actual operative field. In spine surgery, AR technology has been imbibed using 3 main techniques: head-mounted displays (HMD), microscope-mediated heads-up displays (HUD) and AR navigation using an operating room monitor [10]. The rapid influx of newer technology in spine surgery may be a source of confusion to young, novice surgeons in their early years of practice and a source of consternation to senior, experienced surgeons who are content with their mastery over the conventional freehand technique. In such a scenario, it may be prudent to ponder over the pros and cons of each innovation to determine the one that the patient would really benefit from.

The biggest advantage of AR-navigation over fluoroscopy-based, O-arm based or robot-assisted technique is its ability to decrease a surgeon's 'extrinsic' cognitive load [11]. By providing all the necessary navigational information within the surgeon's view of the operative field, AR eliminates the need for the surgeon to switch his attention back and forth between the operative field and the screen display. AR-navigation also avoids frequent 'line-of-sight' interruptions that occur with standard image-guided navigation due to blocking of a clear, unobstructed view of the tracking markers and the camera [10]. By essentially retaining the surgeon's focus on the operative field and using an image overlay on the patient's actual anatomy, AR-navigation comes off as familiar and intuitive to a surgeon already well-versed with the conventional freehand technique.

The existing adaptations of AR-navigation in spine surgery – HMD and HUD – also make it less cost-intensive and enhance its portability, compared to surgical robots or O-arm based navigation. One aspect of robot-assisted pedicle screw insertion where AR-navigation may seem lacking is its ability to reduce fatigue-related errors by 'locking' pre-planned trajectories for pedicle screws by a rigid, robotic arm. This may eliminate misplaced trajectories that arise due to hand tremors or poor hand-eye coordination and vastly reduce human variability in the procedure. It is believed that this would allow aging surgeons to execute their desired surgical plan with the same level of physical and cognitive performance as their younger counterparts [12]. The most glaring short-

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coming for AR in spine surgery, however, remains the lack of evidence – particularly, clinical studies – validating its use. In this regard, the cadaveric study of Farshad et al. is poised to fill a critical gap in medical literature.

A major impediment with newer technology in spine surgery is ensuring a smooth integration in the normal surgical procedure. To enhance surgeon experience and optimize the operative duration, it is essential to have a straightforward workflow in the operation theatre. The use of intraoperative surface digitization approach adopted by the authors in this study allows for the establishment of a communication between preoperative imaging and intraoperative navigation, without the need for getting additional intraoperative imaging which usually is felt to be a deterrent in the operation theatre workflow. This also makes the technique radiation-free and reduces radiation exposure to members of the surgical team and the patient. The short registration time (2-3 minutes) and navigation time (1-2 minutes) reported by the authors is also very encouraging. However, intraoperative surface digitization depends on reliable identification of the patient's anatomy and may not be suitable for revision surgeries with midline laminectomy defects, facetal hypertrophy and congenital spinal deformities, neurofibromatosis where integration of AR-navigation with some form of 3D intraoperative imaging is likely to yield better accuracy. Identification of 'exposed' portion of the vertebra with a pointer is also not amenable for adaptation to a minimally invasive surgery (MIS) - which is where navigated pedicle screw placement is most often needed and used by spine surgeons.

While most aspects of pedicle screw placement, in particular – the rate of perforations, did not vary between surgeons and laymen in the authors' study, it must be kept in mind that these were lumbar screws in a non-deformed spine. As we extend the use to more demanding conditions like scoliosis, kyphosis, dysmorphic pedicles and cervical pedicle screw placement – similar results may not be observed. The tactile feedback that a surgeon receives from his own hands is an important source of real-time 'navigation' – with experience, this becomes deeply ingrained in a surgeon's technique and there will always be situations where a surgeon would deviate from the trajectory suggested by the navigation technique being used.

To summarize, AR in spine surgery is still in a nascent stage with its use largely restricted to research or limited clinical applications in large hospitals based in developed countries. The development, introduction and use of new technology in spine surgery is unfortunately occurring at a pace that far outstrips the generation of an evidence base that supports their efficacy and cost-effectiveness. Existing studies invariably suffer from a 'pro-innovation' publication bias with the results seldom being replicated in diverse hospital and operation theatre setups. Even if the limited evidence that is available is taken into consideration, most navigation techniques have shown an accuracy of >95% for pedicle screw insertion, making it is just a race to be 'first among equals'.

A notable contribution of the study by Farshad et al. is to suggest that short registration and navigation times may be obtained – which is the principle hindrance to widespread acceptance among established spine surgeons. Improved reproducibility and a tendency to make selected outcomes measures less variable are inherent to all techniques which deploy navigated pedicle screw insertion. Very few of the newer technological advancements have expanded their indications to anything beyond pedicle screw placement. Reducing operator-dependence and enabling uniformity for more complex surgical procedures such as spinal osteotomies, neural element decompression, anterior cage placement and spinal deformity correction manoeuvres is undoubtedly going to be an uphill task.

Newer innovations such as AR-navigation must be thoroughly explored, before being embraced. We hope the readers of NASSJ are motivated to conduct more studies on this newer technology and generate much-needed evidence to guide surgeons and researchers worldwide.

Ethics statement

Not applicable.

Inform consent statement

Not applicable.

Declaration of Competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.xnsj.2022.100117.

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