Irish Medical Journal
Established 1867

Issue: Ir Med J; Vol 113; No. 8; P148

New Technologies in the Field of Orthopaedic and Spine Surgery – Navigating the Learning Curve

A.J. Hughes[1], I.H. Feeley[1], D.P. Ahern[1], M.K. Dodds[1], N. Cassidy[1], M. Timlin[1], S. Morris[1], K. Synnott[1], J.S. Butler[1,2]

1. National Spinal Injuries Unit, Department of Trauma and Orthopaedic Surgery, Mater Misericordiae University Hospital, Dublin, Ireland.
2. UCD School of Medicine & Medical Science, Mater Misericordiae University Hospital, Dublin, Ireland.

The last thirty years have seen significant advancements in surgical techniques and emerging technologies within the fields of orthopaedic and spine surgery[1]. Computer-assisted navigation is a supportive intraoperative technology, used as an adjunct by spine and arthroplasty surgeons since the 1990's[2]. Navigation utilises three-dimensional (3D) reconstructed imaging, such that surgical instruments can be tracked within the surgical field. This technology is of particular benefit in spine surgery, a high-risk discipline with a low margin for error. Navigation systems enable accurate placement of pedicle screws, between the spinal cord and neurovascular structures, during trauma, deformity, tumour and revision cases, where anatomical landmarks may be difficult to appreciate. Intraoperative navigation has been reported to improve implant accuracy, enhance surgical reproducibility, reduce adverse events, minimise radiation exposure and result in a relative cost efficiency[3].

The procurement of an intraoperative navigation system requires significant capital investment. Adequate staff education and training is crucial prior to safely introducing a new technology into the live surgical environment. The operative theatre workflow is initially disturbed, with an associated learning curve. The resultant instrumentation accuracy, reduction in surgical duration and reduction in radiation dosage leads to 80% of spine surgeons preferring navigation to freehand techniques, disproving initial reported scepticism[4,5]. Complex cervical and upper thoracic anatomy makes pedicle access a technical challenge. Navigation allows for reliable cervical pedicle screw instrumentation, which has been consistently proven to be biomechanically superior to more traditional techniques[6]. High volume spine centres benefit from the use of navigation due to the reduction in reoperation rates, which carries important cost-effectiveness implications and thus offsets high acquisition and maintenance costs[7].

The National Spinal Injuries Unit (NSIU) at the Mater Misericordiae University Hospital (MMUH), Dublin, introduced the O-Arm imaging and StealthStation navigation system (Medtronic, Minneapolis, Minnesota, USA) in August 2018. The NSIU receives a high volume of complex referrals annually that often require surgical management. This system was introduced to improve surgical precision, minimise risk and increase patient safety, particularly for the more complex surgical cases.

Navigated spinal surgery usually involves prone positioning of a patient with careful attention to pressure points and superficial nervous structures. This is followed by meticulous dissection to expose the posterior elements of the spine, placement of self-retaining retractors and rigid application of a reference frame clamp to a fixed bony landmark, such as a spinous process. Anatomic registration is performed via a three-dimensional cone beam scan. The position of the reference frame clamp must remain constant throughout the operation. The entry point for the pedicle is identified anatomically, and a navigated drill is used. The integrity of the drill tract is assessed using a ball tipped probe, to gain tactile feedback, both before and after this pathway is prepared, using a tap, prior to pedicle screw insertion.

Awareness of the reference frame's position, most commonly at the proximal limit of the wound in cervical surgeries, or at the distal extent for thoracolumbar surgeries, is paramount to avoid registration disruption. Any suspicion of frame disturbance requires recalibration by way of a repeat scan. Mobile hands, limbs, instruments and drapes threaten the stability of the reference frame. Self-retaining forceps, taped to the drapes, ensure protection of the frame from surrounding soft tissues. Bony decompression and resection compromise the intraoperative stability of the spine and are deferred until all navigated screws have been inserted. Loss of registration, by way of altered anatomy, or loss of reference frame position, can result in a screw breaching the cortical pedicle wall, with potential neurovascular or dural injury, loss of fixation strength, and the need for revision surgery.

Early papers describe a learning curve associated with navigated spine surgery that affect the first fifteen to thirty patients[4, 8]. Saw bone education sessions have been shown to demonstrate adequate pedicle screw accuracy using computer navigation within a surgeon's very first case[5]. Cadaveric training sessions have been shown to result in satisfactory instrumentation accuracy after just eight total pedicle screws[9]. Studies have suggested up to a 30% breech-rate with freehand techniques, as compared to a more consistent 6% rate using navigation, based upon post-operative radiological analysis, however clinically significant implant misplacement rates are both similarly low[8]. There have been no differences identified in length of stay, blood loss or adverse events throughout the learning curve period[7]. Thus, even in the hands of novice surgeons, navigated spine surgery provides high levels of patient safety, even within the early stages of its introduction.

Extensive multidisciplinary training took place prior to commencing navigated surgery at our institution. Surgical simulation using saw bones familiarised surgical team members with registration and instrumentation processes. The senior author, JB, underwent fellowship training in a navigated spine surgery centre, thus facilitating on-site proctorship training. Perceptorship training, whereby surgeons would visit a specialised centre to observe an experienced surgeon, as well as cadaveric sessions, have been described as safe methods ahead of introducing new techniques in to live surgical practice[10]. Subsequent training was carried out with theatre nursing staff, radiographers and porters to improve workflow and reduce the time and hazards associated with theatre setup, patient transfer and scanning. Dual surgeon cases were prioritised throughout the learning curve, to maximise surgeon exposure to the new technology and minimise risk. Initial workflow disturbances were accomodated, serving as training opportunities with on site industry technical support staff, and reduced in frequency alongside the experience of the entire theatre team. A pedicle breach rate of 3.5% was seen throughout the first 18 cases, comparable to that quoted in the literature.

All consultant spine surgeons in our centre were fellowship trained in freehand instrumentation techniques. Surgeons could call on their cumulative experience when accessing a pedicle, determining screw trajectory and interpreting tactile feedback.

If a pedicle was compromised, surgeons could refer to their freehand techniques and safely reposition the screw. The learning curve was thus navigated with extensive surgical experience, and the technology initially served as an intraoperative adjunct. The navigated system earned the trust of the surgeon body throughout this introductory period.

Navigation is particularly beneficial to trainees. Pedicle entry points can be identified clinically, trajectory verified using the 3D image, and instrumentation supervised live by the trainer. Subtle adjustments can be made, with real time feedback provided, to improve trainee technique throughout each case. Freehand accuracy amongst trainee surgeons has been shown to improve post navigation training due to an acquired appreciation of accurate entry point location, awareness of optimal drill trajectory and comprehensive tactile judgement throughout the pedicle prior to screw insertion[5].

Introducing state-of-the-art technology into the Irish healthcare environment poses challenges, which are worth sharing with the widespread medical community. By mitigating risk during the initial learning curve, the tangible benefits of improved surgical precision, alongside greater patient safety, particularly for more challenging surgical cases, has resulted in navigation becoming an integral part of the surgical armamentarium of the National Spinal Injuries Unit. The successful introduction of this surgical technology will lead to a safer surgical environment and further strengthen the care afforded to Irish spine patients for many years to come.

Corresponding Author:
Andrew Hughes
Specialist Registrar in Trauma and Orthopaedic Surgery
Mater Misericordiae University Hospital,
Dublin,
Ireland.
Email: hughesajk@gmail.com

References:

1. F. S. Haddad, Horriat S. Robotic and other enhanced technologies: Are we prepared for such innovation? Bone Joint J. 2019;101-B(12):1469-71.
2. Karkenny AJ, Mendelis JR, Geller DS, Gomez JA. The Role of Intraoperative Navigation in Orthopaedic Surgery. J Am Acad Othop Surg. 2019;27:e849-58.
3. D. T. Cawley, R. Dhokia, J. Sales, N. Darwish, Molloy S. Ten techniques for improving navigated spinal surgery. Bone Joint J. 2020;102-B(3):371-5.
4. D. T. Cawley, V. Rajamani, M. Cawley, S. Selvadurai, A. Gibson, Molloy S. Using lean principles to introduce intraoperative navigation for scoliosis surgery. Bone Joint J. 2020;102-B(1):5-10.
5. Leitner L, Bratschitsch G, Sadoghi P, Adelsmayr G, Puchwein P, Leithner A, et al. Navigation versus experience: providing training in accurate lumbar pedicle screw positioning. Arch Orth Trauma Surg. 2019;139:1699-704.
6. Chachan S, Razak HRBA, Loo WL, Allen JC, Kumar DS. Cervical pedicle screw instrumentation is more reliable with O‑arm‑based 3D navigation: analysis of cervical pedicle screw placement accuracy with O‑arm‑based 3D navigation. European Spine J. 2018;27:2729–36.
7. Dea N, Fisher CG, Batke J, Strelzow J, Mendelsohn D, Paquette SJ, et al. Economic evaluation comparing intraoperative cone beam CT-based navigation and conventional fluoroscopy for the placement of spinal pedicle screws: a patient-level data cost-effectiveness analysis. Spine J. 2016;16:23-31.

8. Rivkin MA, Yocom SS. Thoracolumbar instrumentation with CT-guided navigation (O-arm) in 270 consecutive patients: accuracy rates and lessons learned. Neurosurg Focus. 2014;36(3):E7.
9. Sclafani JA, Regev GJ, Webb J, Garfin SR, Choll W. Kim. Use of a quantitative pedicle screw accuracy system to assess new technology: Initial studies on O-arm navigation and its effect on the learning curve of percutaneous pedicle screw insertion. SAS J. 2011;5:57-62.
10. Garneau P, Ahmad K, Carignan S, Trudeau P. Preceptorship and proctorship as an effective way to learn laparoscopic sleeve gastrectomy. Obes Surg. 2014;24(12):2021-4.