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Robotic spinal imaging:

A democratization of spinal instrumentation?

David Werner, MD, PhD
Dept. of Neurosurgery, Stavanger University Hospital

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- **5** Neurosurgeons
- **600** spinal cases/year
- **30m2** operating room
- Non-sectioned OR staff

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Review Article

Negotiating for new technologies: guidelines for the procurement of assistive technologies in spinal surgery: a narrative review

Vincent J. Rossi[1,2,3]^, Thomas A. Wells-Quinn[1], Gregory M. Malham[1,4]

[1]Epworth Hospital, Melbourne, Australia; [2]Carolina Neurosurgery & Spine Associates, Charlotte, NC, USA; [3]Atrium Health Musculoskeletal Institute, Charlotte, NC, USA; [4]Swinburne University of Technology, Melbourne, Australia

Contributions: (I) Conception and design: All authors; (II) Administrative support: All authors; (III) Provision of study material or patients: All authors; (IV) Collection and assembly of data: All authors; (V) Data analysis and interpretation: All authors; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

Correspondence to: Gregory M. Malham, BSc, MB, ChB, FRACS. Professor of Spine Surgery Research, Swinburne University of Technology, Neurosurgeon Epworth Hospital, Melbourne, Australia. Email: gmalham@bigpond.net.au.

- Loop-X currently most advanced cone beam CT
- Robotic
- Largest Gantry
- Largest Field of View

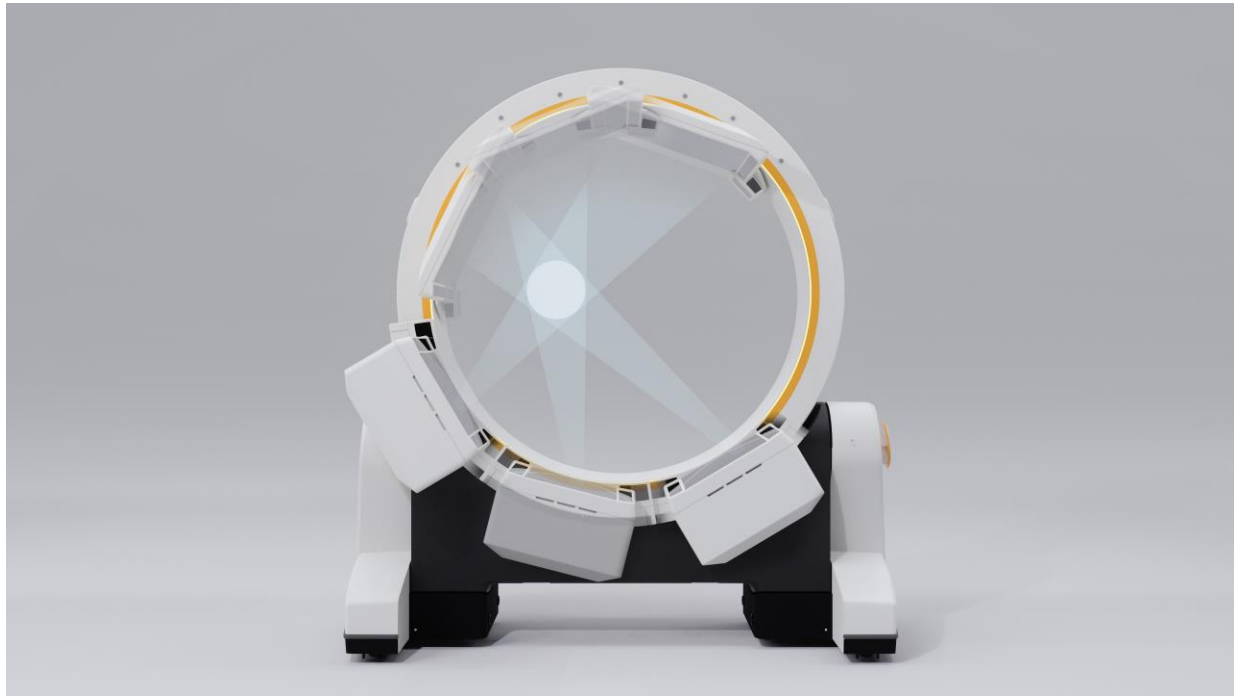

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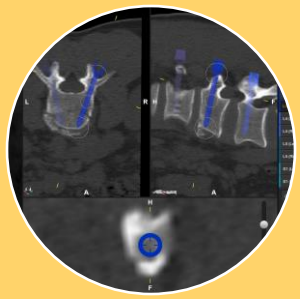
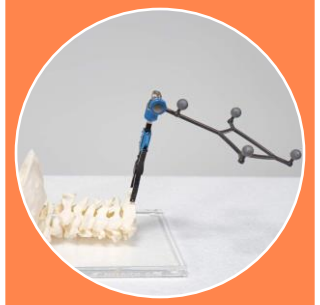
Image Quality

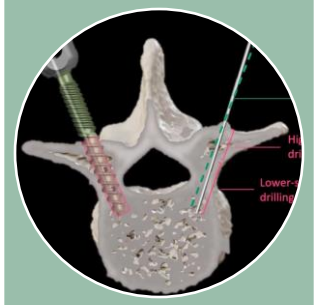


Precise Planning



Patient Registration

Instrument Tracking



Spine Flexibility

Extended Visualization

Robotics

Accuracy can only be as good as the weakest link in the chain

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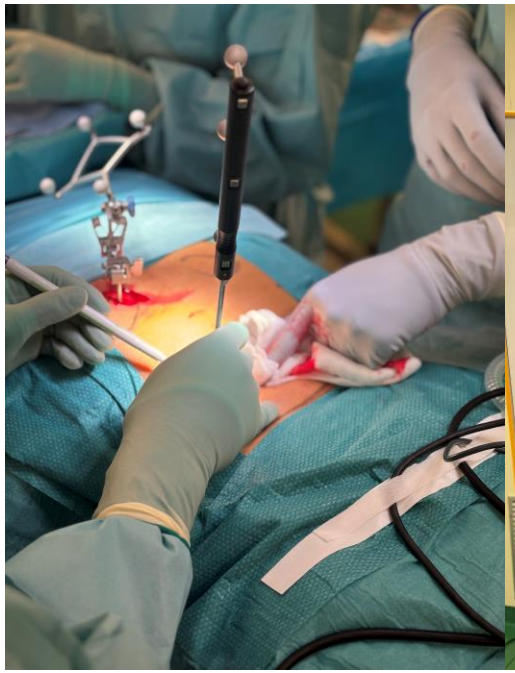
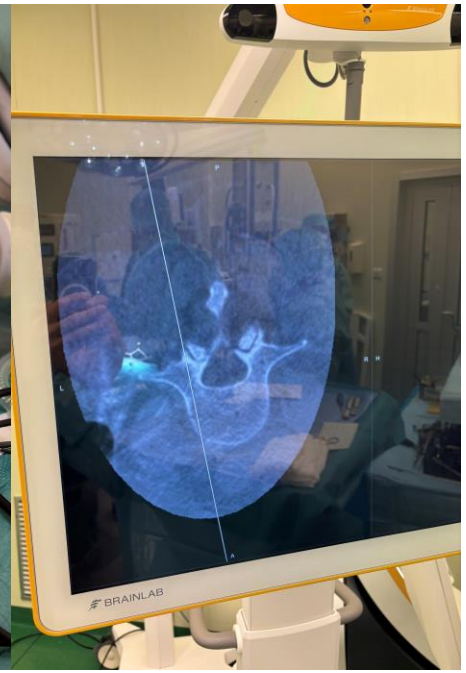
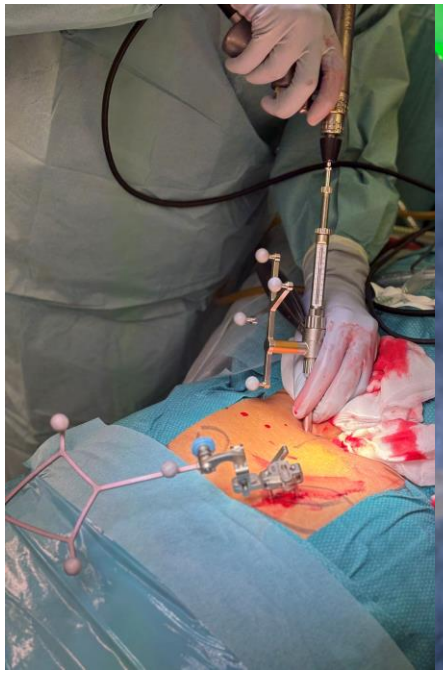
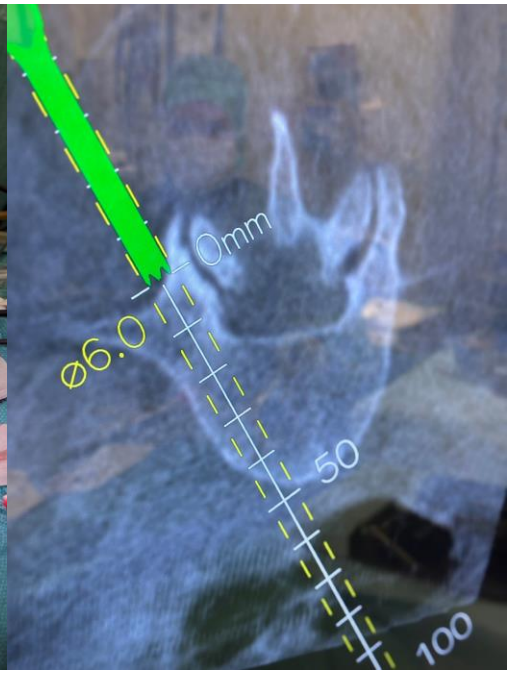
Robotic Image guided MIS-**TLIF**









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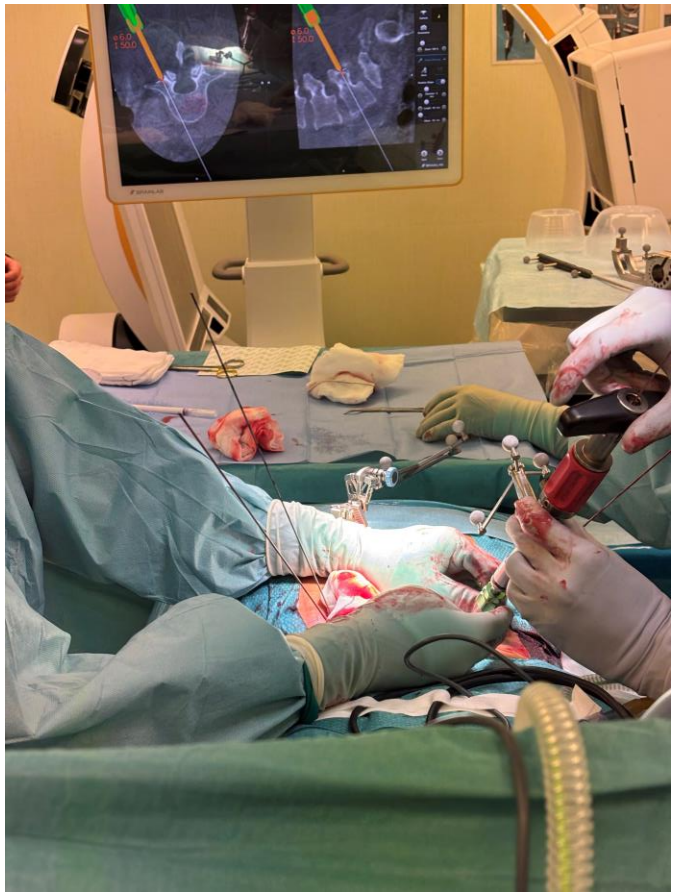

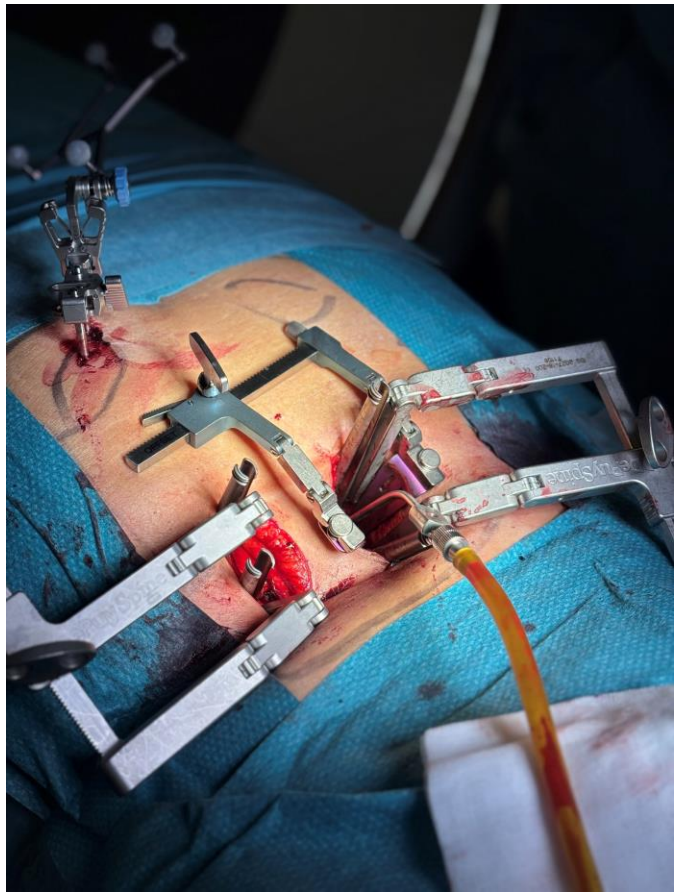

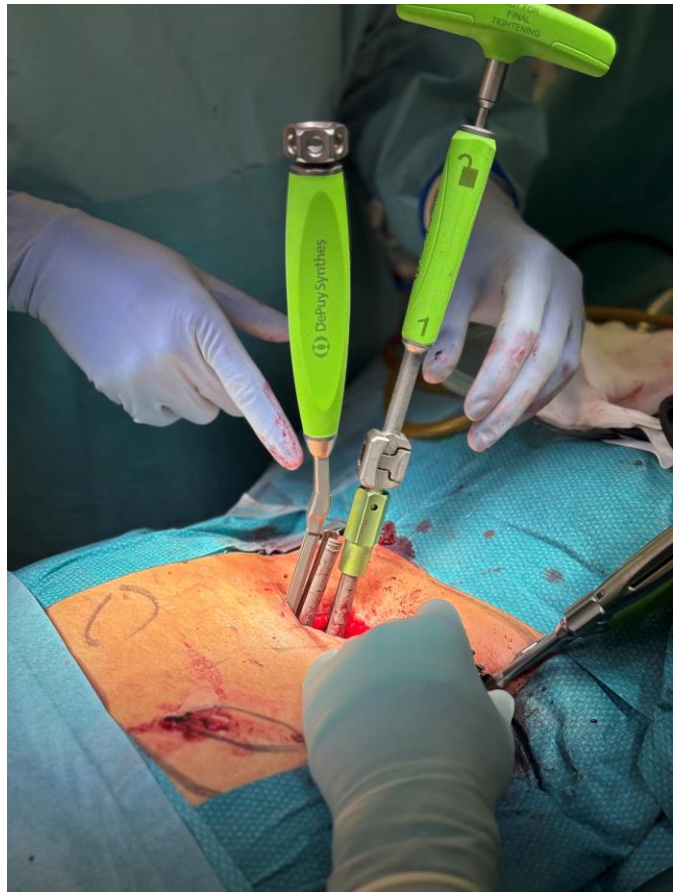

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Robotic Image guided **LLIF**

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Haida *et al. Journal of Orthopaedic Surgery and Research* (2024) 19:565
https://doi.org/10.1186/s13018-024-05044-9

Journal of Orthopaedic Surgery and Research

RESEARCH ARTICLE **Open Access**

Hybrid-3D robotic suite in spine and trauma surgery - experiences in 210 patients

Dominik M. Haida[1,2], Peter Mohr[3], Sae-Yeon Won[4], Thorsten Möhlig[2], Mike Holl[2], Thorsten Enk[5], Marc Hanschen[1] and Stefan Huber-Wagner[1,2*]

- 1171 screws were inserted into 210 patients at a **high accuracy of 98.8%**,
- **dose for the OR team is definitely reduced**
- **2 mSv per 3D scan** or about 6 mSv for an average spine surgery

Neurospine 2024;21(1):76-82.
https://doi.org/10.14245/ns.2347106.553

Neurospine
pISSN 2586-6583 eISSN 2586-6591

Original Article

Intraoperative Cone-Beam Computed Tomography Navigation Versus 2-Dimensional Fluoroscopy in Single-Level Lumbar Spinal Fusion: A Comparative Analysis

Corresponding Author
Giuseppe Francesco Papalia
https://orcid.org/0000-0002-4140-738X

Department of Orthopaedic and Trauma Surgery, Fondazione Policlinico Universitario Campus Bio-Medico, Via Alvaro del Portillo 200, Rome 00128, Italy
Email: g.papalia@policlinicocampus.it

Received: October 24, 2023
Revised: February 13, 2024
Accepted: February 17, 2024

Gianluca Vadalà[1,2], Giuseppe Francesco Papalia[1,2], Fabrizio Russo[1,2], Paolo Brigato[1,2], Luca Ambrosio[1,2], Rocco Papalia[1,2], Vincenzo Denaro[1]

[1]Operative Research Unit of Orthopaedic and Trauma Surgery, Fondazione Policlinico Universitario Campus Bio-Medico, Via Alvaro del Portillo, Rome, Italy
[2]Research Unit of Orthopaedic and Trauma Surgery, Department of Medicine and Surgery, Università Campus Bio-Medico di Roma, Via Alvaro del Portillo, Rome, Italy

- **Significantly lower surgical time** in the navigation group (123 min vs 179 min)
- Radiation dose higher with Navigation (1.229 vs 331 mGy*cm²) **Reduced dose for surgical staff**
- **Length of Stay significantly reduced** in the IGS cluster (4 vs 6 days)
- In the navigation branch **less pedicle breaches** (5% vs none)

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REVIEWS IN SPINAL SURGERY

Ryan B. Kochanski, MD*
Joseph M. Lombardi, MD†
Joseph L. Laratta, MD†
Ronald A. Lehman, MD†
John E. O'Toole, MD, MS*

Image-Guided Navigation and Robotics in Spine Surgery

Image guidance (IG) and robotics systems are becoming more widespread in their utilization and can be invaluable intraoperative adjuncts during spine surgery. Both are highly reliant upon stereotaxy and either pre- or intraoperative radiographic imaging. While user-operated IG systems have been commercially available longer and subsequently are more widely utilized across centers, robotics systems provide unique theoretical advantages over freehand and IG techniques for placing instrumentation

ELSEVIER

Check for updates

The Spine Journal 19 (2019) 1397–1411

THE SPINE JOURNAL

Review Article

Evaluation of surgeon and patient radiation exposure by imaging technology in patients undergoing thoracolumbar fusion: systematic review of the literature

Zach Pennington, BS, Ethan Cottrill, MS, Erick M. Westbroek, MD, Matthew L. Goodwin, MD, PhD, Daniel Lubelski, MD, A. Karim Ahmed, BS, Daniel M. Sciubba, MD*

Department of Neurosurgery, Johns Hopkins University School of Medicine, 600 N. Wolfe St, Meyer 5-185A, Baltimore, MD 21287, USA

Received 6 February 2019; revised 5 April 2019; accepted 5 April 2019

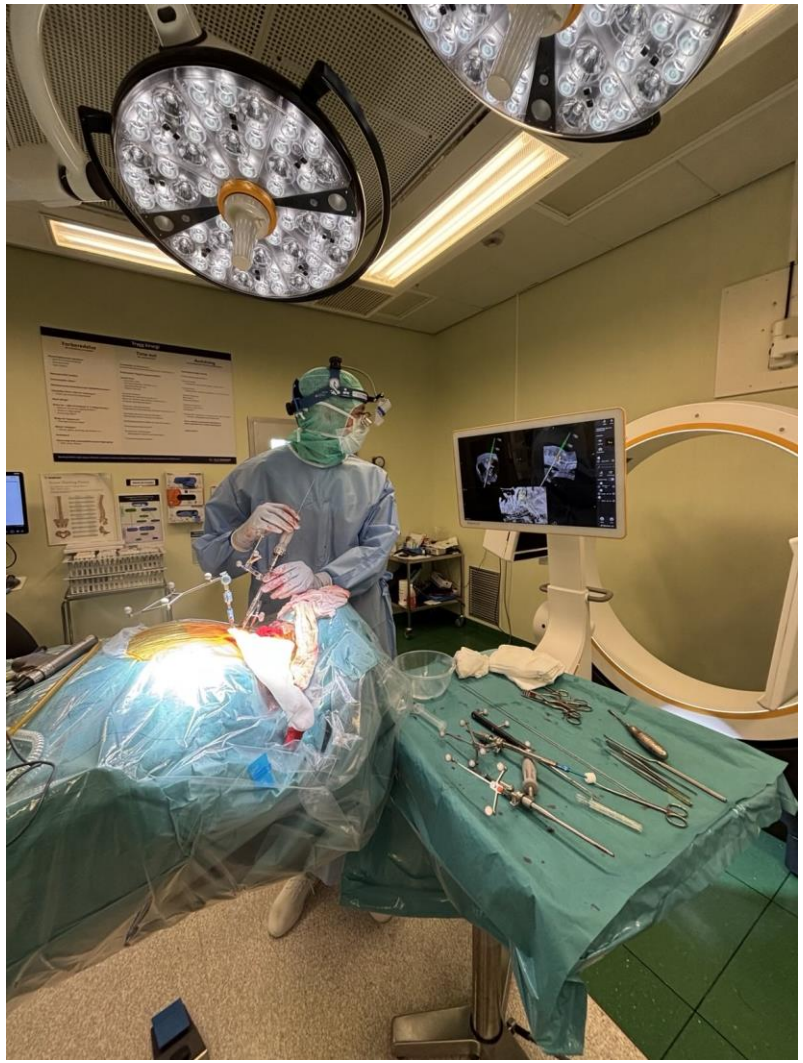
- Enhanced **precision** vs freehand methods
- Low **invasiveness**
- Reduced **radiation** exposure
  - Surgeon exposure is 10x greater with fluoroscopy guidance
- Better **outcomes**
  - Shorter surgical duration
  - Shorter duration of hospital stay
  - Reduced rates of reoperation

	Accuracy A	Accuracy B	Accuracy C	Accuracy D	Accuracy E
With Navigation	336 (**76**)	72 (**16**)	15 (3)	13 (3)	13 (3)
Without Navigation	69 (**53**)	46 (**35**)	6 (5)	3 (2)	3 (2)

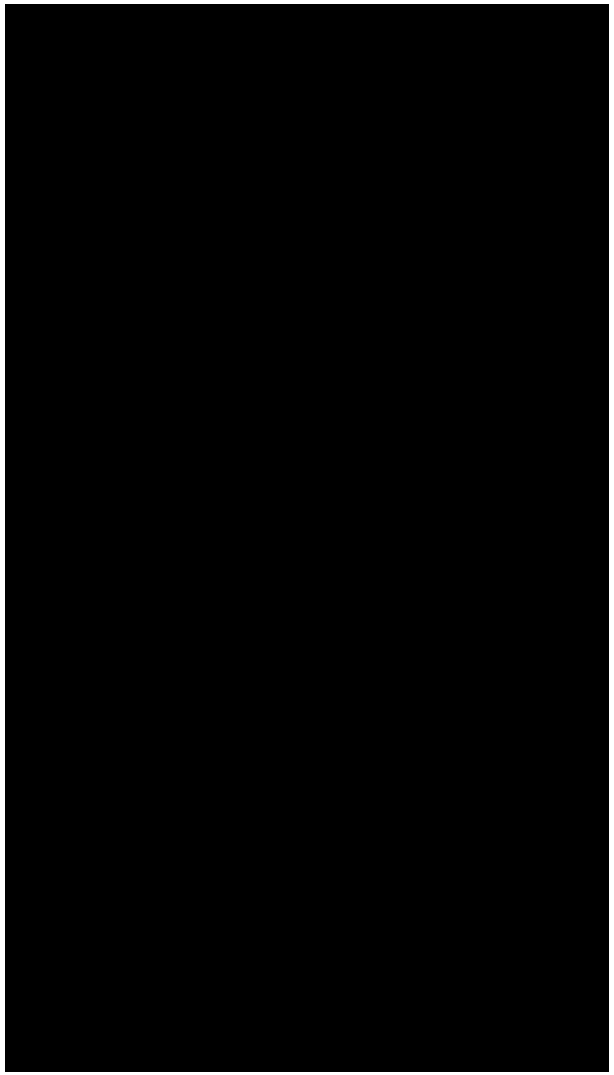
Implant count (% of total)

	Accuracy A	Accuracy B	Accuracy C	Accuracy D	Accuracy E
With Navigation	4.67 (2.72)	1.01 (1.32)	0.21 (0.56)	0.18 (0.68)	0.08 (0.33)
Without Navigation	2.88 (2.74)	1.92 (2.28)	0.25 (0.85)	0.13 (0.34)	0.33 (0.64)
p-value	0.006	0.02	0.783	0.701	0.014

Mean (SD)




GETINGE



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Journal of Orthopaedic Surgery

Review

Augmented, virtual and mixed reality in spinal surgery: A real-world experience

Journal of Orthopaedic Surgery
28(3) 1–12

DOI: 10.1177/2309499020952698
journals.sagepub.com/home/osj
SAGE

Daisuke Sakai[1], Kieran Joyce[2,3], Maki Sugimoto[4], Natsumi Horikita[1], Akihiko Hiyama[1], Masato Sato[1], Aiden Devitt[3] and Masahiko Watanabe[1]

Table 2. Differences between VR, AR, MR and XR specific to spinal procedures.

Characteristic	VR	AR	MR	XR
Virtual components (MRI, CT imaging)	✓	✓	✓	✓
Real environmental components (patient)	X	✓	✓	✓
The user is present in the experience location (the operating theatre is visible through HMD)	X	✓	✓	✓
User interaction with real and virtual components (the surgeon can manipulate the patient and the images projected by the HMD)	X	✓	✓	✓
Real and virtual components interact with each other (the virtual input is altered based on changes in physical environment)	X	X	✓	✓
Multiple systems integration (imaging system, integrated with HMD, other instrument sensors and larger health service network)	X	X	X	✓
Tactile/multisensory feedback (instrument sensors and feedback modalities)	X	X	X	✓

CT: computed tomography; MRI: magnetic resonance imaging; HMD: head-mounted display; XR: extended reality; AR: augmented reality; VR: virtual reality; MR: mixed reality.

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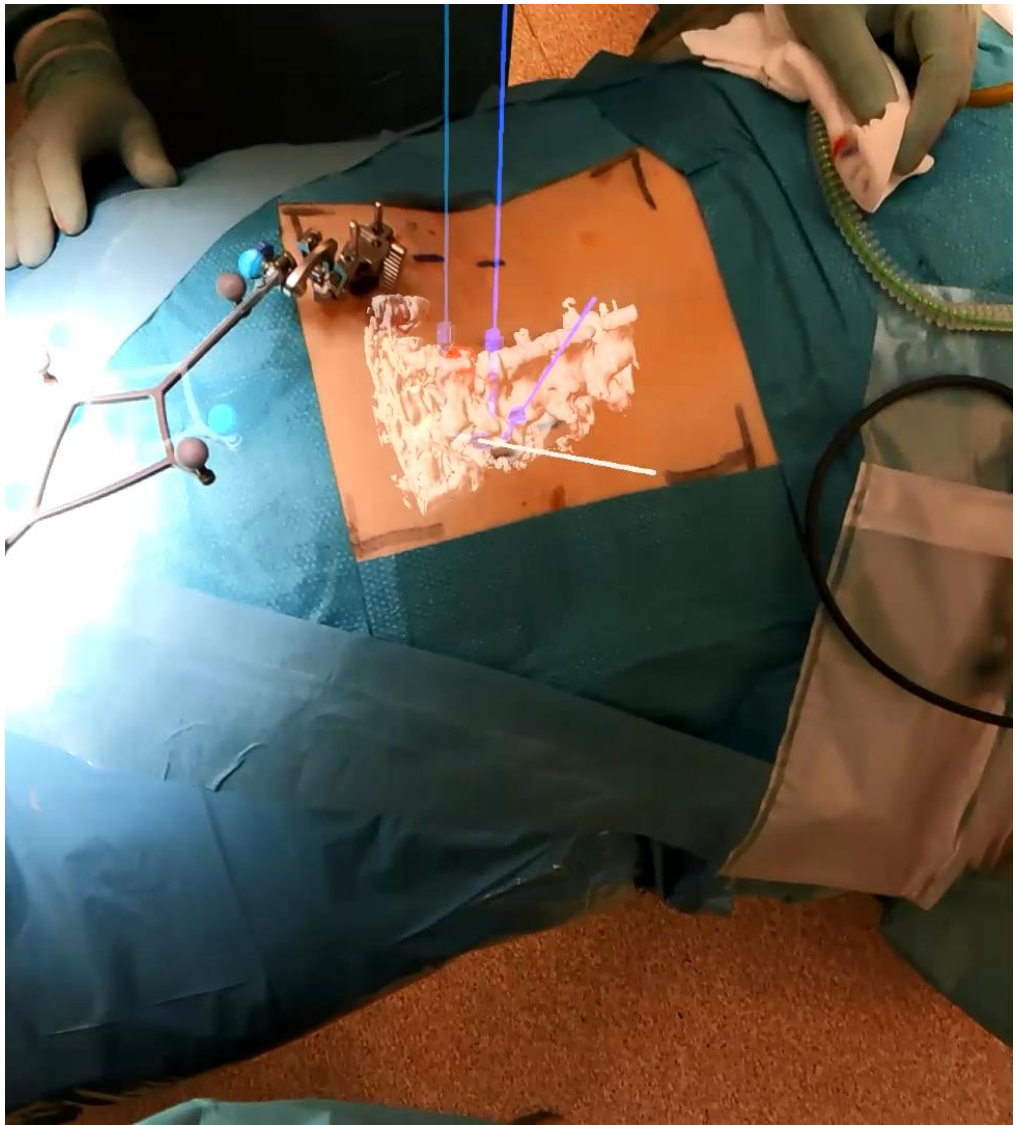
Mixed reality guided **TLIF**



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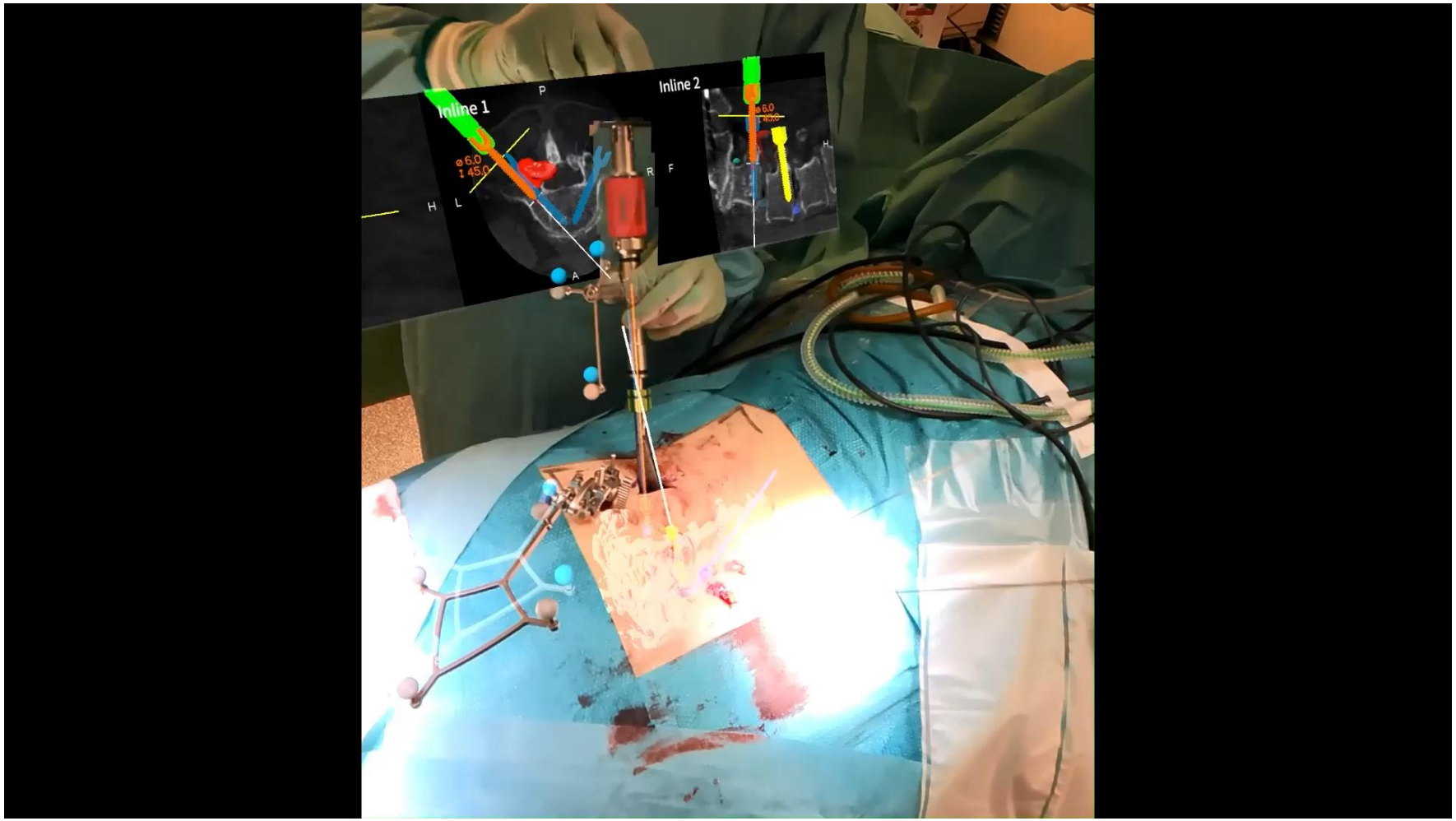

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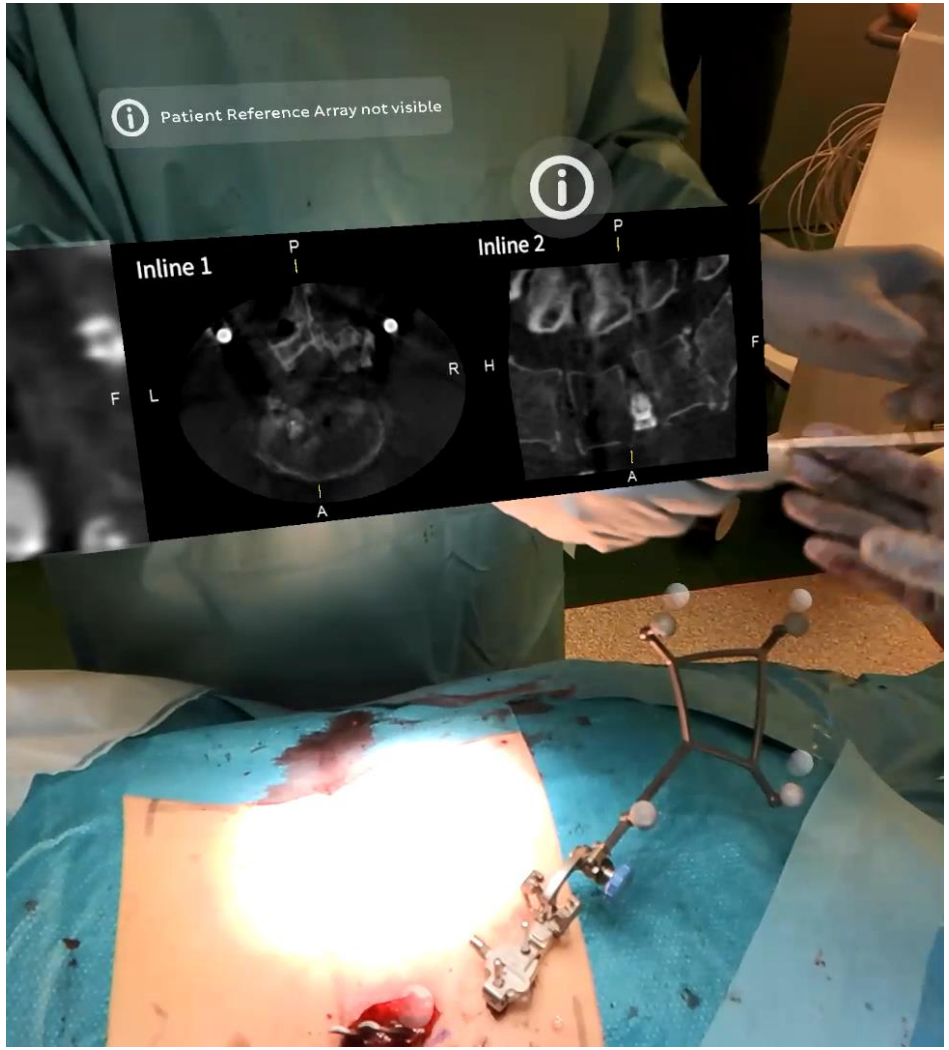

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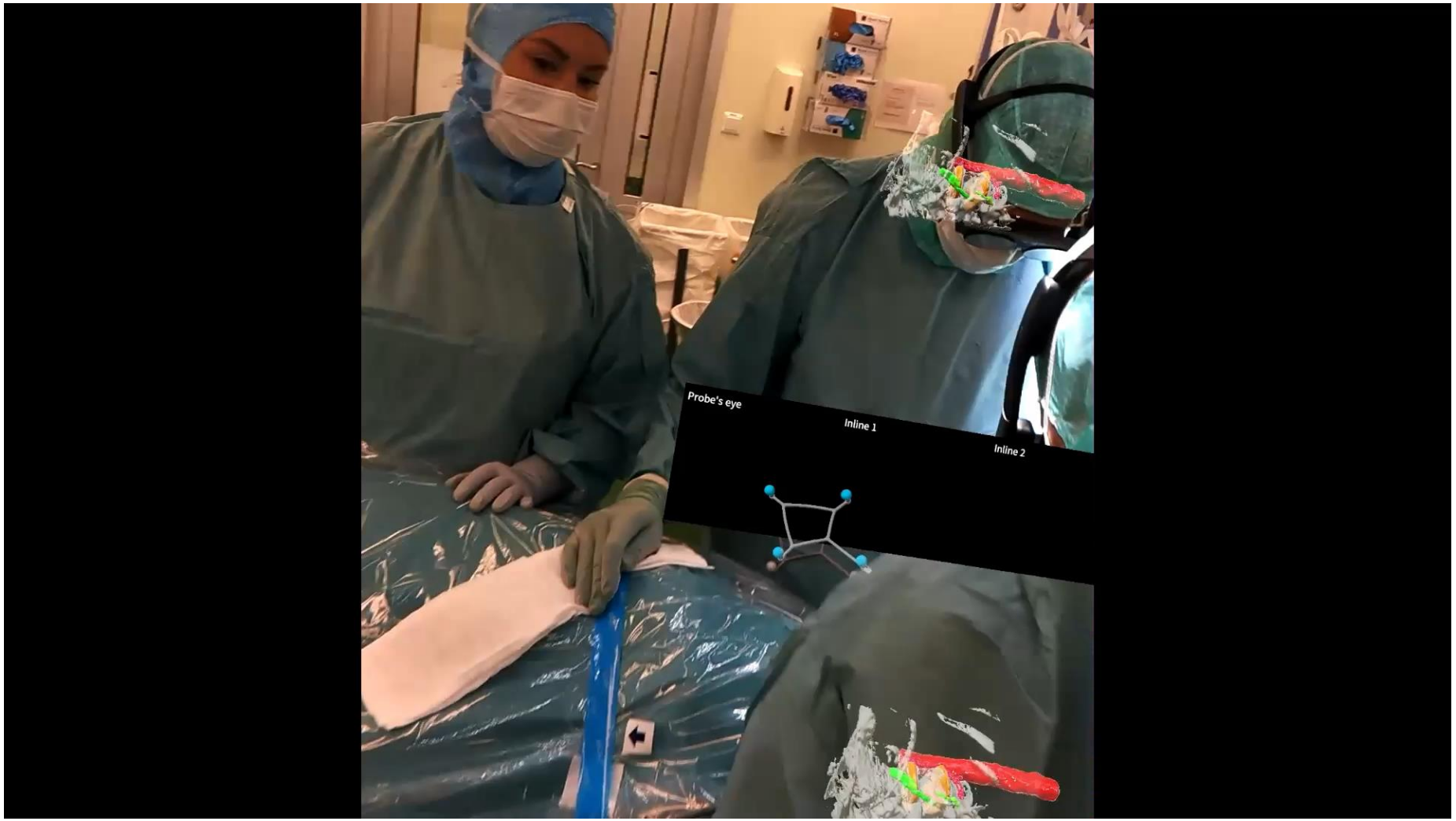

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Original Article

AO SPINE

Augmented Reality-Assisted Spine Surgery: An Early Experience Demonstrating Safety and Accuracy with 218 Screws

Global Spine Journal
2023, Vol. 13(7) 2047–2052

DOI: 10.1177/21925682211069321
journals.sagepub.com/home/gsj
Sage

Fenil R. Bhatt, BS[1], Lindsay D. Orosz, MS PA-C[2], Anant Tewari, BS[2], David Boyd, MD[3], Rita Roy, MD[2], Christopher R. Good, MD FACS[1], Thomas C. Schuler, MD[1], Colin M. Haines, MD[1], and Ehsan Jazini, MD[1]

Table 3. Accuracy Grading.

Variable	Value
Total AR screws graded for accuracy	208
Gertzbein–Robbins grade A	187 (89.9)
Gertzbein–Robbins grade B	11 (5.3)
Gertzbein–Robbins grade C	6 (2.9)
Gertzbein–Robbins grade D	0 (.0)
Gertzbein–Robbins grade E	0 (.0)
Modified G-R (S2AI) grade A	4 (1.9)
Modified G-R (S2AI) grades B-E	0 (.0)

Values represent the number of patients (%) or mean ± SD.
AR: Augmented reality, *G-R:* Gertzbein–Robbins, *S2AI:* S2-alar-iliac.

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Technology

AO SPINE

Global Spine Journal
2020, Vol. 10(2S) 22S-33S

DOI: 10.1177/2192568220907896
journals.sagepub.com/home/gsj
SAGE

Evolving Navigation, Robotics, and Augmented Reality in Minimally Invasive Spine Surgery

Ibrahim Hussain, MD[1,*], Murat Cosar, MD[1,*], Sertac Kirnaz, MD[1], Franziska A. Schmidt, MD[1], Christoph Wipplinger, MD[1], Taylor Wong, BA[1], and Roger Härtl, MD[1]

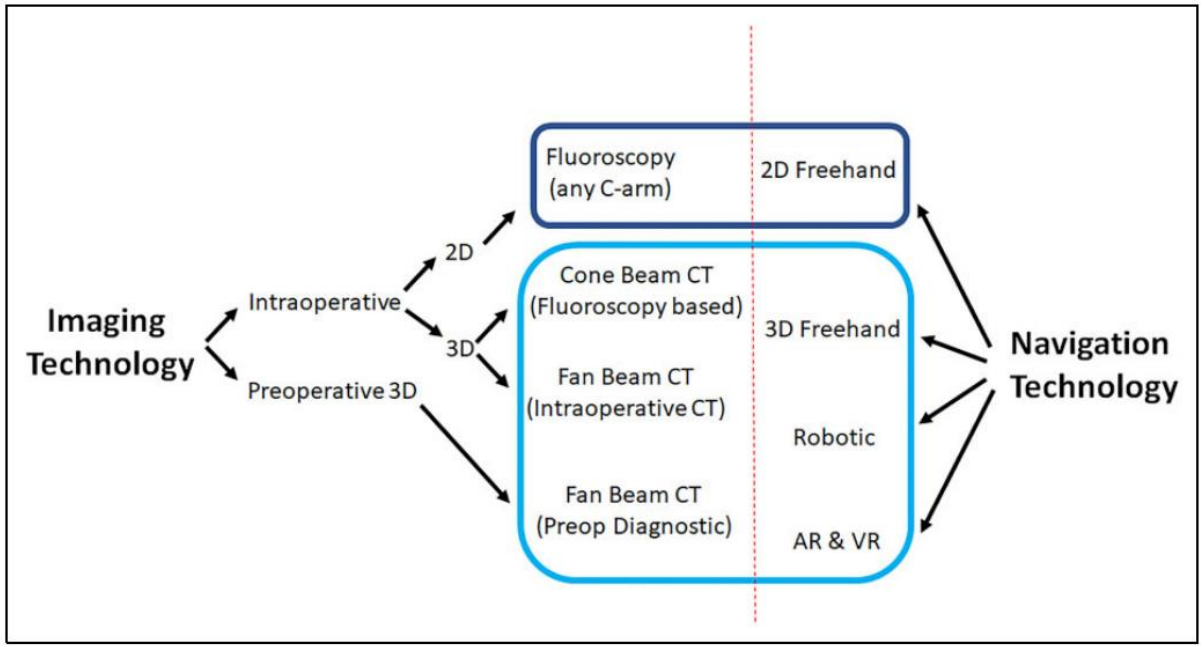

Table 1. Relative Comparison of Operative Factors in 2-Dimensional Versus 3-Dimensional Minimally Invasive Spine Surgery.

Factor	2D Navigation	3D Navigation
Upfront economic burden	+	+++
Surgical revision rates	+++	+
Pedicle screw accuracy	+	+++
Operative time	++	+
Flexibility of utilization	+	+++
Radiation exposure to patient	++	+++
Radiation exposure to staff	++	0
Overall economic health care burden	+++	++

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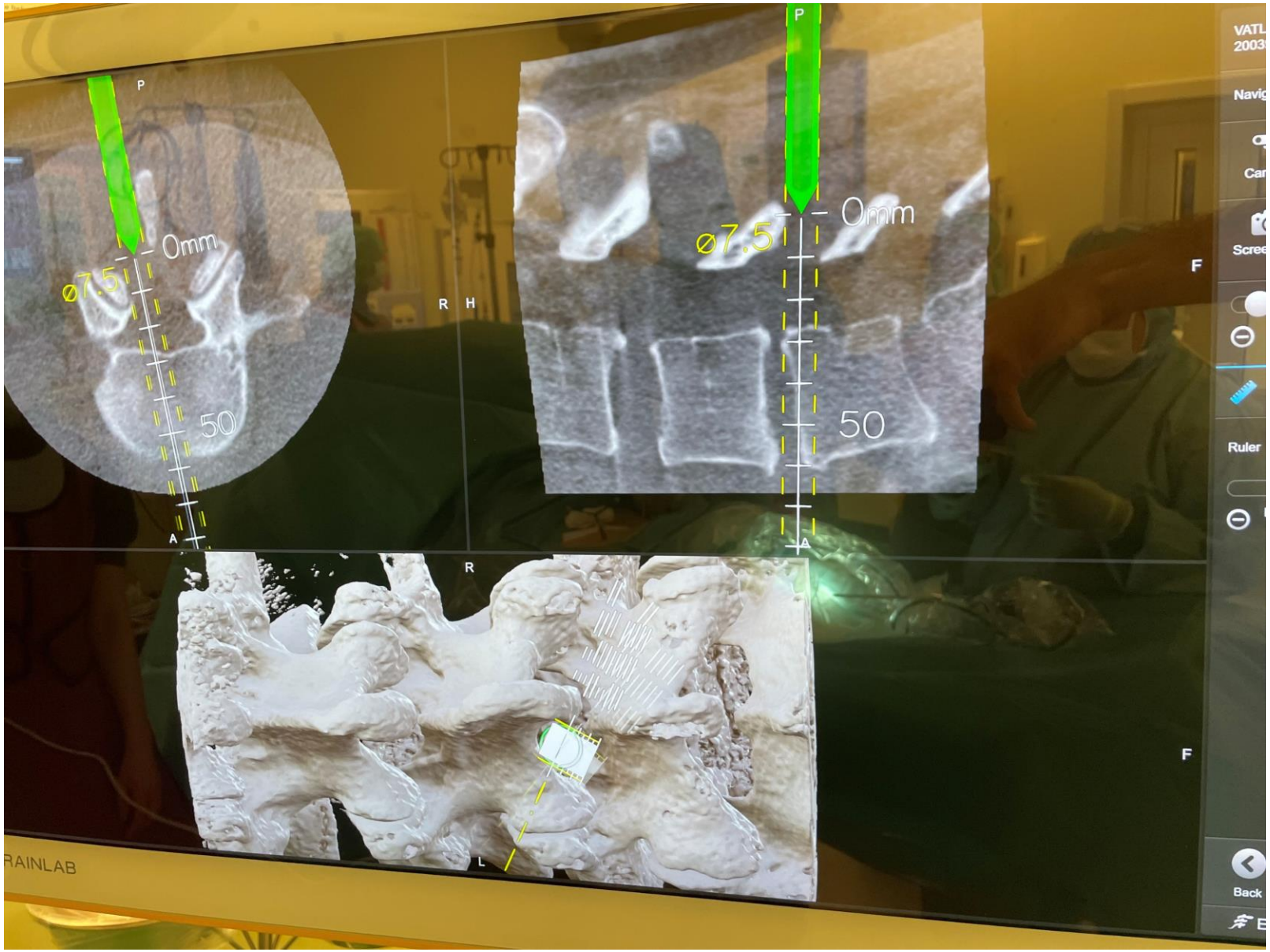

Spine

SPINE Volume 45, Number 22, pp E1507–E1515

HEALTH SERVICES RESEARCH

Patients' and Physicians' Knowledge of Radiation Exposure Related to Spine Surgery

Michelle C. Scott, MD,[a] Anoop R. Galivanche, BS,[b] Elbert J. Mets, BA,[b] Neil Pathak, MD,[b] Joseph B. Kahan, MD, MPH,[b] Patrick J. Burroughs, BS,[b] Arya G. Varthi, MD,[b] Lee E. Rubin, MD,[b] and Jonathan N. Grauer, MD[b]

TABLE 1. Literature Values for Inpatient and Outpatient Imaging Modalities

Imaging Modality	Effective Dose, mSv	Effective Dose, mSv (Mean ± Std)	Equivalent No. of Chest Radiographs* (Mean ± Std)
Cervical spine			
Radiograph (AP)	0.04[3],0.05[4],0.06[4],0.12[5]	0.07 ± 0.04	2.25 ± 1.20
Radiograph (lateral)	0.01[4], 0.02[5], 0.03[4], 0.06[3]	0.03 ± 0.02	1.00 ± 0.72
Fluoroscopy (anterior cervical fusion)	0.012[6], 0.015[6], 0.02[6], 0.04[7], 0.07[8]	0.03 ± 0.02	1.05 ± 0.81
CT (traditional)	2.8[6], 3.0[9], 4.6[2,10]	3.47 ± 0.99	115.56 ± 32.89
CT (O-Arm)	1.56[11], 2.19[12]	1.88 ± 0.45	62.50 ± 14.85
Lumbar spine			
Radiograph (AP)	0.21[13], 0.27[13], 0.28[4], 0.41[3], 0.50[3], 0.53[13], 0.55[13], 0.69[13], 0.70[4], 1.09[13], 1.61[13], 2.2[5]	0.75 ± 0.60	25.11 ± 20.03
Radiograph (lateral)	0.14[13], 0.20[3], 0.29[13], 0.31[13], 0.32[13], 0.34[13], 0.35[13],0.46[13] 0.56[13], 1.50[3]	0.45 ± 0.39	14.90 ± 12.95
Fluoroscopy (posterior lumbar fusion)	0.20[12], 0.26[12], 0.26[12], 0.32[12] 0.52[14], 0.75[12], 0.83[12]	0.45 ± 0.26	14.95 ± 8.51
CT (traditional)	3.20[15], 3.40[15], 3.40[15], 3.60[15], 4.10[15], 4.10[15], 4.30[15], 4.90[16], 5.0[15], 8.10[16], 9.0[16], 12.0[5], 19.15[2,10]	6.48 ± 4.64	216.02 ± 154.79
CT (O-arm)	2.35[17], 3.20[18],3.20[19], 5.57[12], 9.38[20]	4.74 ± 2.86	158.00 ± 95.27
CT (Airo)	5.90[17]	—	196.67

0.03 mSv = 1 Chest radiograph.

TABLE 2. Background Radiation Values

Radiation Exposure	Effective Dose, mSv	Effective Dose, mSv (Mean ± Std)	Equivalent No. of Chest Radiographs*
Approximate round-trip flight from New York to London	0.098[21], 0.10[22]	0.099 ± 0.001	3.30 ± 0.03
Approximate background radiation exposure annually	3.0[22], 3.60[23]	3.30 ± 0.42	110 ± 14
Approximate annual dose received of the International Space Station	150.00[24], 170.00[22], 230.30[25]	183.43 ± 41.80	6114 ± 1393
Atomic bomb survivors	200.00[22], 200.00[26]	200	6667

0.03 mSv = 1 Chest radiograph.