Case Report

Spatial Computing for preoperative planning and postoperative evaluation of single-position lateral approaches in spinal revision surgery

ABSTRACT

Spatial computing (SC) in a surgical context offers reconstructed interactive four-dimensional models of radiological imaging. Preoperative and postoperative assessment with SC can offer more insight into personalized surgical approaches. Spine surgery has benefitted from the use of perioperative SC assessment. Herein, we describe the use of SC to perform a perioperative assessment of a revision spinal deformity surgery. A 79-year-old wheelchair-bound male presented to the neurosurgery clinic with a history of chronic lumbar pain associated with bilateral lower extremity weakness. His surgical history is significant for an L2-L5 lumbar decompression with posterior fixation 1 year prior. On examination, there were signs of thoracic myelopathy. Imaging revealed his previous instrumentation, pseudoarthrosis, and cord compression. We perform a two-staged operation to address the thoracic spinal cord compression and myelopathy, pseudoarthrosis, and malalignment with a lack of global spinal harmony. His imaging is driven by a spatial computing and SC environment and offers support for the diagnosis of his L2-3 and L4-5 pseudoarthrosis on the reconstructed SC-based computed tomography scan. SC enabled the assessment of the configuration of the psoas muscle and course of critical neurovascular structures in addition to graft sizing, trajectory and approach, evaluation of the configuration and durability of the anterior longitudinal ligament, and the overlying abdominal viscera. SC increases the familiarity of the patient's specific anatomy and enhances perioperative assessment. As such, SC can be used to preoperatively plan for spinal revision surgery.

Keywords: Anterior lumbar interbody fusion, instrumentation, lateral lumbar interbody fusion, pseudoarthrosis, spatial computing, stereopsis, virtual reality

Galal A. Elsayed[1], Raj Swaroop Lavadi[1], Sangami Pugazenthi[2], Vinay Jaikumar[3], Rida Mitha[1], Daniel M. Hafez[2], John O. Ogunlade[2], Nitin Agarwal[1,4]

[1]Department of Neurological Surgery, University of Pittsburgh School of Medicine, [2]Department of Neurological Surgery, Washington University School of Medicine, St. Louis, Missouri, [3]Department of Neurosurgery, University of Buffalo, Buffalo, US, [4]Department of Neurological Surgery, University of Pittsburgh Medical Center, Pittsburgh, Pennsylvania, USA

Address for correspondence: Dr. Nitin Agarwal, Associate Professor, Neurological Surgery Director, Minimally Invasive Spine and Robotics Surgery, Associate Program Director, Neurosurgery Residency Program, Co-Director, Complex and Minimally Invasive Spine Deformity Fellowship, University of Pittsburgh School of Medicine, University of Pittsburgh Medical Center, Department of Neurological Surgery, 200 Lothrop Street, Suite B-400, Pittsburgh, PA 15213, USA.
E-mail: nitin.agarwal@upmc.edu

INTRODUCTION

Spatial Computing (SC) offers stereopsis to reconstructed, interactive, four-dimensional models of radiological imaging. In comparison to the use of computer monitors, SC allows surgeons to familiarize themselves with the patient's own anatomic variations and devise an operative trajectory by picking up a controller before a scalpel.[1] With preoperative SC assessment of a patient's anatomy, it is possible to reduce operative time and improve surgical technique in both open and minimally invasive spine approaches.[2] Herein, we present a case whereby SC offers preoperative planning and postoperative evaluation in a two-staged, single-position, lateral approach, spinal revision surgery.

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CASE REPORT

A 79-year-old wheelchair-bound male presented to the neurosurgery clinic with a 1-year history of chronic lumbar pain associated with bilateral lower extremity weakness in his proximal musculature. His surgical history is significant for an L2-L5 lumbar decompression with posterior fixation 1 year prior due to lumbar stenosis causing neurogenic claudication. Upon physical examination, the patient shows signs of proximal muscle weakness of the bilateral lower extremities and hyperreflexia within his patellar reflexes, with spastic weakness of the bilateral lower extremities.

A thoracolumbar magnetic resonance imaging scan revealed thoracic central canal stenosis with concordant spinal cord compression and T2 signal hyperintensity at T10-11 and T11-12. His computed tomography (CT) scan of the lumbar spine suggested pseudoarthrosis at L2-3 and L4-5. His global spinal sagittal balance was affected by possible junctional kyphosis with concomitant concern for hardware failure secondary to osteolysis and pseudoathrosis. Due to the features suggestive of myelopathy and pseudoarthrosis with back pain, surgical management was explored. His imaging was exported into a spatial computing environment (Medicalholodeck AG)[3] and demonstrated a lack of bony bridging across L2-3 and L4-5, suggestive of pseudoarthrosis on the reconstructed CT scan.

SC offered preoperative assessment of thoracic myelopathy, the utility for surgical approach to a multi-level lateral interbody fixation procedure, the configuration of the psoas muscle and the lumbosacral plexus, trajectory planning, graft size/position, and configuration and evaluation of vital structures. The patient consented to the procedure. The patient underwent an initial decompression of T10 to T12 to relieve the spinal cord compression with the placement of screws from T9 to the pelvis with revision of the previous screw sites at L2-L5. After which, a lateral lumbar interbody fixation (LLIF) was performed from L2-3, L3-4, and L4-5 with a lateral anterior lumbar interbody fixation (ALIF) at L5-S1 with the assistance of a vascular surgeon for exposure. Finally, the patient underwent fixation dorsally with cobalt-chromium rods. After this instrumentation was placed, its position was confirmed with fluoroscopy. The patient had an uneventful postoperative course. Figure 1 is an artistic rendering depicting the feasibility to explore SC to create a perioperative plan. At 2 months postoperative follow-up, the patient no longer reports back pain and continues to regain strength in his lower extremities. Figure 2 compares the patient's preoperative and postoperative standing films. The following video link (https://www.youtube.com/watch?v=_QCL0yuaGWUandab_channel = GalalElsayed) reviews this information, presents a SC experience, and details the changes recorded in the spinopelvic parameters. The patient consented to the publication of these images.

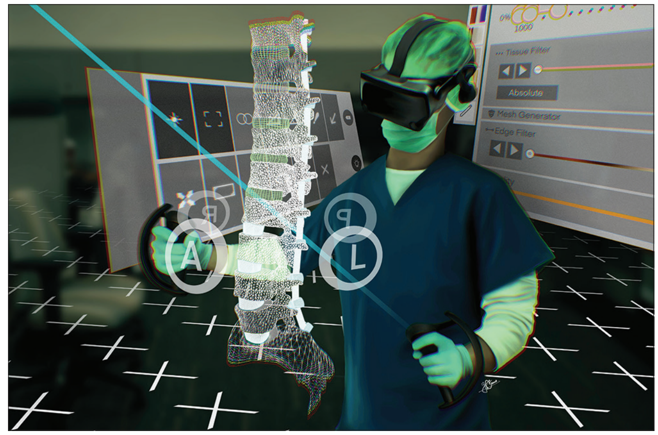

Figure 1: An illustrative rendering depicting a surgeon exploring virtual reality to create a perioperative plan. Of note, is the feasibility to access a perioperative planning environment in an office space. The instrumentation extends from T9-Pelvis

DISCUSSION

Herein, we present a case whereby SC offers preoperative assessment of thoracic myelopathy secondary to thoracic cord compression to evaluate arthrodesis in the setting of suspected pseudoarthrosis, and the utility for surgical approach to a multi-level lateral interbody fixation procedure, three-dimensional spinopelvic parameters, and the evaluation of the available operative corridor and trajectory to the L5-S1 disk space using a lateral anterior lumbar interbody fixation device. SC allows for assessing the configuration of the psoas muscle and the lumbosacral plexus in the decubitus position. In addition, preoperatively, SC supports trajectory planning and approach, graft sizing/position, evaluation of the configuration and durability of the anterior longitudinal ligament, evaluation of the segmental arteries, and the overlying abdominal viscera. This technology will maximize surgical accuracy, thereby limiting the occurrence of potential complications such as violation of the neurovascular structures. Postoperatively, SC offers the assessment of the interbody placement, the placement of the internal fixation devices, and the postoperative three-dimensional spinopelvic parameters.

By using a SC platform, one can visualize the patient's thoracic cord compression from disc degeneration, ligamentous buckling, facet hypertrophy from degenerative arthropathy, and dilation of the epidural venous vasculature signifying congestion from compression. An evaluation is also possible of his previous instrumentation, his L2-3,

Figure 2: Standing radiographs (AP and lateral views, respectively) from the preoperative (a and b), and the 2-month postoperative (c and d) periods. Preoperative imaging demonstrates mild dextrocurvature of the thoracolumbar spine centered at L1, mild anterior sagittal imbalance, instrumented posterior spinal fusion of L2-L5, and moderate multilevel degenerative changes of the thoracolumbar spine. Postoperative imaging demonstrates posterior instrumented fusion from T9 to the pelvis and anterior fusion from L2-S1

L4-5 pseudoarthroses, his supine surgical anatomy and alignment, the operative approach for the lateral position ALIF, his pre-and postoperative three-dimensional spinopelvic parameters, the operative corridor and approach along the lumbosacral plexus, and the trans-psoas corridor for the L2-3, L3-4, and L4-5 LLIF approach from any given angle with depth perception from binocular vision.

Identification of the major great vessels (i.e. the aorta and inferior vena cava) and the bifurcation of the iliac artery/veins as landmarks relative to the disc space of interest is required when performing an ALIF. Identification of the iliolumbar vein is personalized with the use of three-dimensional reconstruction and the depth perception offered by stereopsis in VR technology. In an LLIF, the psoas major is a landmark for subsequent dissection. Using SC, along with the guidance of adjunctive electromyography, we are able to predict and discern the extent of dissection and exposure of the psoas major required, without disturbing the lumbosacral plexus.[5]

We envision future inter/intra-rater reliability studies to validate the use of stereopsis and SC for standardizing radiological protocols for surgical approaches to spinal pathologies. Furthermore, we envision the future use of standardized lumbosacral plexus imaging protocols suited for stereopsis and SC to help accelerate the pace of surgical innovation to decrease the incidence of peripheral neuropathies from LLIF approaches.[6] Success in the development of the previously mentioned ideas will sustain and encourage spine surgery innovation for the years to come as spatial computing and SC become more commonplace.[7]

Stereopsis and SC can offer surgeons increased familiarity with the patient's specific anatomy and enhance the perioperative assessment. In this case, SC was successfully used to plan for a two staged spinal revision surgery which in part safely employed the use of a minimally invasive anterolateral approach to the spine.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient has given his consent for his images and other clinical information to be reported in the journal. The patient understands that his name and initials will not be published and due efforts will be made to conceal his identity, but anonymity cannot be guaranteed.

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Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Piromchai P, Ioannou I, Wijewickrema S, Kasemsiri P, Lodge J,

Kennedy G, *et al.* Effects of anatomical variation on trainee performance in a virtual reality temporal bone surgery simulator. J Laryngol Otol 2017;131:S29-35.
2. Yuk FJ, Maragkos GA, Sato K, Steinberger J. Current innovation in virtual and augmented reality in spine surgery. Ann Transl Med 2021;9:94.
3. Available from: https://www.medicalholodeck.com/en/. [Last accessed on 2023 Apr 05].
4. Parenteau CS, Lau EC, Campbell IC, Courtney A. Prevalence of spine degeneration diagnosis by type, age, gender, and obesity using Medicare data. Sci Rep 2021;11:5389.
5. Lu S, Chang S, Zhang YZ, Ding ZH, Xu XM, Xu YQ. Clinical anatomy and 3D virtual reconstruction of the lumbar plexus with respect to lumbar surgery. BMC Musculoskelet Disord 2011;12:76.
6. Lykissas MG, Aichmair A, Hughes AP, Sama AA, Lebl DR, Taher F, *et al.* Nerve injury after lateral lumbar interbody fusion: A review of 919 treated levels with identification of risk factors. Spine J 2014;14:749-58.
7. Godzik J, Farber SH, Urakov T, Steinberger J, Knipscher LJ, Ehredt RB, *et al.* "Disruptive technology" in Spine surgery and education: Virtual and augmented reality. Oper Neurosurg (Hagerstown) 2021;21:S85-93.