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Original Article

Awake spinal anesthesia facilitates spine surgery in poor surgical candidates: A case series

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ABSTRACT

Background. – Annually, hundreds of thousands of patients undergo surgery for degenerative spine disease (DSD). This represents only a fraction of patients that present for surgical consideration. Procedures are often avoided due to comorbidities that make patients poor candidates for general anesthesia (GA) and its associated risks. With increasing interest in awake surgery under spinal anesthesia (SA), the authors have observed that SA may facilitate spine surgery in patients with relative contraindications to GA. With this in mind, the authors set out to summarize the outcomes of a series of highly comorbid patients who received surgery under SA.

Methods. – Case logs of a single surgeon were reviewed, and patients undergoing spine surgery under SA were identified. Within this group, patients were identified with relative contraindications to GA, such as advanced age and medical comorbidities. For these patients, for whom surgery was facilitated by SA, the medical records were consulted to report demographic information and patient outcomes.

Results. – Ten highly comorbid patients were identified who received lumbar spine surgery for DSD under SA. Comorbidities included octogenarian status, obesity, and chronic health conditions such as heart disease. The cohort had a mean age of 75.5 and a mean American Society of Anesthesiologists Physical Status (ASA-PS) score of 3.1. The patients were predicted to have a 2.74-fold increase of serious complications compared to the average patient. There were no adverse events.

Conclusion. – For patients with symptomatic, refractory DSD and relative contraindications to GA, SA may facilitate safe surgical intervention with excellent outcomes.

1. Introduction

Lower back pain (LBP) and degenerative spine disease (DSD) are amongst the most common sources of disability in the world [1]. Every year, in the United States alone, hundreds of thousands of patients undergo spinal fusion for treatment of DSD [2]. Some studies, however, have shown that fewer than half of patients presenting with LBP and DSD are ultimately deemed appropriate surgical candidates [3]. Non-surgical candidacy can often be attributed to the fact that the presenting pathology does not warrant surgery. Mild pain, normal walking distance, and normal sitting tolerance are associated with receiving conservative, non-surgical management [4]. Not all patients, though, with severe LBP, associated radiculopathy, and radiographically significant DSD are candidates for spine surgery. In some cases, particular surgeries

Abbreviations: LBP, Lower back pain; DSD, Degenerative spine disease; GA, General anesthesia; SA, Spinal anesthesia; BMI, Body Mass Index; ASA-PS, American Society of Anesthesiologists Physical Status; LOS, Length of stay; PACU, Post anesthesia care unit; SD, Standard deviation; ACS, American College of Surgeons; NSQUIP, National surgical quality improvement program; IRB, Institutional review board; EBL, Estimated blood loss; AE, Adverse event; PONV, Post-operative nausea and vomiting; POCD, Postoperative cognitive decline; CHF, Congestive heart failure; HTN, Hypertension; HLD, Hyperlipidemia; PD, Parkinson's Disease; A-Fib, Atrial fibrillation; PE, Prior pulmonary embolism; CAD, Coronary artery disease; CAD, Prior myocardial infarction; CVA, Prior cerebrovascular accident; CI, Cognitive impairment.

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may be contraindicated due to patient anatomy or history. For example, total disc replacement may be contraindicated in patients with severe scoliosis or deficiency of posterior elements [5]. Sometimes, however, patients are considered poor surgical candidates due to the risks associated with general anesthesia (GA). While there are no absolute contraindications to GA when it is deemed necessary, this is not true in the elective setting. Medical comorbidities such as congestive heart failure as well as demographic factors such as advanced age may be considered as relative contraindications to GA [6].

An alternative to GA in spine surgery is the use of spinal anesthesia (SA) and subsequent 'awake' surgery. As awake spine surgery under SA has become more prevalent over recent years, it has become anecdotally apparent to the authors and others that patients who would traditionally be considered poor surgical candidates under GA have been able to receive successful awake spine surgery under SA with positive outcomes. SA's apparent ability to facilitate spine surgery in poor GA candidates has not been extensively studied. To the author's knowledge, however, there has been no study or case series demonstrating this phenomenon. To contribute to the sparse body of knowledge surrounding SAs ability to facilitate spine surgery in traditionally poor surgical candidates, the authors present the following case series of highly comorbid patients who were felt to have an improved risk profile receiving surgery under SA versus GA.

2. Methods

2.1. Cohort creation

The authors performed a single-center, single-surgeon, retrospective review of a prospectively collected database of patients undergoing lumbar spine surgery for degenerative spinal disease under awake SA at a major academic research institution. Patients who received surgery between June of 2020 and December of 2022 were considered for inclusion. For each of these patients, effort was made to find a demographically similar patient who received surgery under GA. It was discovered that some patients who received surgery under SA could not be compared to any patient undergoing GA. These patients possessed demographic characteristics, such as nonagenarian status, and medical comorbidities that made them ill-fit to undergo GA for elective surgery. It was, therefore, not possible to construct a meaningful control group. This cohort of patients, whose surgical candidacy was facilitated by the ability to receive awake surgery, was studied.

Baseline demographic information was collected, including age, sex, Body Mass Indexes (BMIs), medical comorbidities, and American Society of Anesthesiologists Physical Status (ASA-PS). Perioperative, intraoperative, and postoperative data were collected, including operative time, time to ambulation, opioid utilization, and length of stay (LOS). Time to ambulation was defined as time from arrival in post anesthesia care unit (PACU) to earliest recorded ambulation. Length of stay was defined as time between the patient's admission to the hospital and time of discharge. Standard statistical tools including mean, standard deviation (SD), and percentage were used to describe the cohort. Estimated risk of adverse effects were calculated using the American College of Surgeons (ACS) National Surgical Quality Improvement Program (NSQUIP) Risk Calculator. This was performed to confirm that the studied patients did, in fact, possess a significantly higher risk of experiencing serious adverse effects (AEs) than the general population.

Institutional Review Board (IRB) approval was submitted to our ethics review committee and approved. Patient permission to publish deidentified data was not necessary, as this cohort study fell under the university's IRB's guidelines for "exempt" patient research. Individual patient identifiers were removed from case examples and associated imaging.

2.2. Spinal anesthesia technique

Adequate premedication was administered before induction of spinal anesthesia. Patients were placed in the sitting position, the skin was appropriately sterilized, and the lumbar region was draped. Spinal anesthesia was performed in the L3-L4 vertebral interspace. The skin was infiltrated with 1% lidocaine, followed by introduction of a spinal needle (*Quincke 25-gauge 90 mm)* into the dura mater (Fig. 1). After verification of free-flowing cerebrospinal fluid, 15 mg of 0.5% bupivacaine was injected at a rate of 0.1 mL/sec, with the orifice of the spinal needle facing cephalad. The cephalad extent of sensory blockade was assessed every 5 minutes after intrathecal injection using loss-to-pinprick sensation. Surgery was allowed to proceed after T6 sensory blockade had been established. The surgery may proceed in the standard manner with respect to positioning, technique, and hardware.

2.3. Anesthesia and anxiolytics during surgery

Within surgery, patients may be given anxiolytics and sedatives to the discretion of the surgeon and anesthesiologist based on the patient's comfort with the necessary surgical position and anxiety in the operating room as well as the relative risks of sedation based on the patients' medical comorbidities. The authors have noted, anecdotally, that certain surgeons frequently operate on patients who are fully alert and conversational, while others routinely keep their patients under conscious sedation, rendering them highly sedated yet still capable of maintaining their airway. A patient may be converted to GA in the standard manner if they are prohibitively uncomfortable or anxious. GA may also be induced in the event of an unexpectedly long procedure duration. SA can also be re-dosed if needed.

3. Results

3.1. Cohort demographics

10 patients (Table 1) were identified whose ability to undergo surgery was facilitated by spinal anesthesia. 4 of these patients received isolated spinal fusion procedures, 5 received isolated spinal decompressions, while 1 patient received a combination fusion and decompression. All surgeries were non-urgent, planned procedures. The cohort was 40.0% female with a mean (SD) age of 75.5 (11.95) years with and a range of 51 to 91. The mean (SD) BMI was 29.7 (4.9) kg/m^2. The mean (SD) ASA-PS was 3.1 (0.3). At presentation, all patients were on opioid-free medical management of their pain. Per the ACS NSQUIP Surgical Risk Calculator, the patients had a mean risk of major complication of 14.5% [7]. This is over 2.7 times higher than the risk associated with the average patient. This suggests that included patients could reasonably be deemed poor surgical candidates under normal circumstances. Demographics are summarized in Table 1.

3.2. Case presentation: spinal decompression

A 91-year-old woman with a BMI of 35.0 was referred from outside hospital following failed kyphoplasty approximately 2 months prior. In this time, her symptoms included lower back pain and lower extremity radiculopathy which were significantly impacting the patient's quality of life and confining her to a wheelchair. Past medical history was significant for coronary artery disease treated with bypass graft, heart failure with preserved ejection fraction,

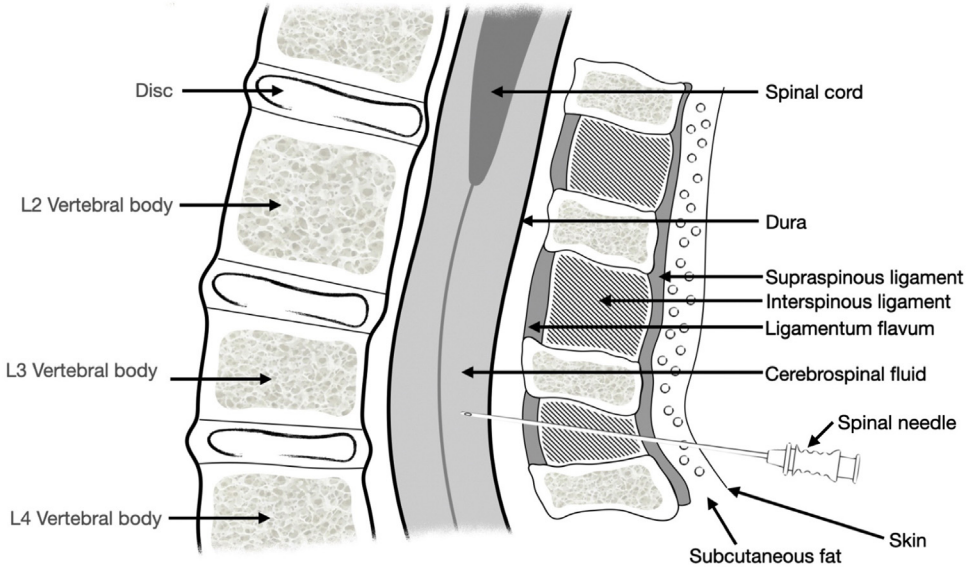

Fig. 1. Relevant anatomy and needle trajectory in spinal anesthesia. Figure courtesy of author Jeffrey Gadsden.

Table 1
Studied patients and major medical comorbidities.

Patient	Surgery	Age, (Years)	Sex (M/F)	BMI (kg/m^2)	Major Comorbidities	ASA	Patient's risk of serious AE	Average person's risk of serious AE	AEs	EBL (mL)	Procedure duration (min)
1	L5-S1 Fusion	64	M	34.8	Obesity, CHF	3	14.6%	6.2%	None	<50 mL	199
2	L4-L5 Fusion	72	M	25.9	PD, A-Fib	3	18.2%	6.6%	None	<50 mL	175
3	L4-L5 Fusion	85	F	30.7	PE	3	14.7%	6.6%	None	<50 mL	132
4	L4-S1 Decomp	77	M	24.5	HLD, PD	3	12.1%	4.9%	None	<50 mL	77
5	L4-L5 Fusion + L2-L4 Decomp	87	M	31.8	Obesity, CHF, HTN, HLD	3	22.7%	6.6%	None	<50 mL	152
6	L5-S1 Decomp	73	M	30.2	Obesity, HTN	3	12.2%	6.6%	None	<50 mL	152
7	L4-L5 Decomp	51	F	34.5	CAD, MI, CHF, PE, CVA	3	8.0%	3.0%	None	<50 mL	106
8	L4-L5 Decomp	83	F	20.1	HTN, A-Fib	3	7.4%	3.0%	None	<50 mL	66
9	L4-L5 Fusion	72	M	29.4	CAD, HTN, CVA (3 ×), CI	3	17.8%	6.2%	None	<50 mL	175
10	L5-S1 Decomp	91	F	35.0	CAD, CHF, HTN, Pulmonary HTN, Carotid Stenosis	4	16.9%	3.0%	None	<50 mL	80
Avg.		75.5	40% F	29.7		3.1	14.5%	5.3%		<50 mL	131.4

CHF: Congestive heart failure; EBL: Estimated blood loss, HTN: Hypertension, HLD: Hyperlipidemia, PD: Parkinson's disease, A-Fib: Atrial fibrillation, PE: Prior pulmonary embolism; CAD: Coronary artery disease, MI: Prior myocardial infarction; CVA: Prior cerebrovascular accident (Stroke), CI: Cognitive impairment.

pulmonary hypertension, bilateral carotid artery stenosis, and prior deep vein thrombosis requiring daily warfarin. Assigned ASA-PS was 4, signifying presence of systemic disease that is a constant threat to life.

Imaging revealed extrusion of kyphoplasty graft material into the spinal canal, with corresponding cord compression (Fig. 2).

Following discussion with both the patient and expert colleagues, it was determined that L5-S1 decompression would be the necessary for relief of symptoms. The ACS NSQUIP calculator predicted a 16.9% chance of serious AE, over five times the 3.0% predicted in the average patient. Due to the patients age, cardiopulmonary comorbidities, and markedly increased likelihood of AE per the ACS, plans were made to undergo decompression under awake SA. The decision to use SA over GA was made as it may reduce the perioperative complications associated with this patient's condition, as is described in the discussion (section 4.3) below.

The procedure took 80 minutes. Estimated blood loss (EBL) was 15 mL, and there were no intraoperative complications. The patient was discharged to home 23.9 hours after surgery for a total hospital length of stay of 31 hours. The patient utilized 24.1 MME of inpatient postoperative opioids. The patient had no perioperative complications and no unplanned admissions. On her six-week postoperative visit, she reported significant improvement in her back pain and radiculopathy. Furthermore, the patient who was previously wheelchair bound, regained the ability to walk with only cane assistance.

3.3. *Case presentation: spinal fusion*

A 72-year-old man with a BMI of 29.4 presented to the clinic with chief complaints of lower back pain with associated bilateral lower extremity radiculopathy. The symptoms made it incredibly difficult for the patient to stand or ambulate, causing a significant impairment in quality of life. He had a history notable for coronary artery disease and 3 prior strokes complicated by cognitive dysfunction. Assigned ASA-PS was 3, signifying severe systemic disease.

Flexion/extension imaging revealed anterolisthesis of L4 on L5 (Fig. 3). Cross sectional imaging revealed multilevel degenerative disease, with the most extreme canal stenosis at the L4-L5 level (Fig. 4).

Following discussion with the patient, it was determined that L4-L5 fusion would be necessary for relief of symptoms. The ACS NSQUIP calculator predicted a 17.8% chance of serious AE, nearly three times the 6.2% predicted in the average patient. Due to the patient's cardiac comorbidities, fragile cognitive status, and markedly increased risk of AE per the ACS, plans were made to undergo fusion under awake SA. The decision to use SA over GA

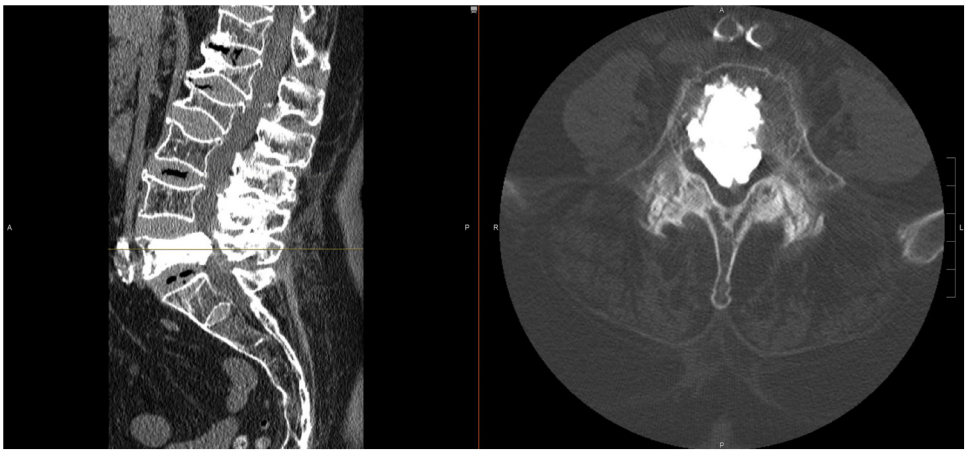

Fig. 2. Preoperative sagittal (L) and axial (R) CT demonstrating kyphoplasty graft material extruding into canal space causing cord compression at the L5-S1 level.

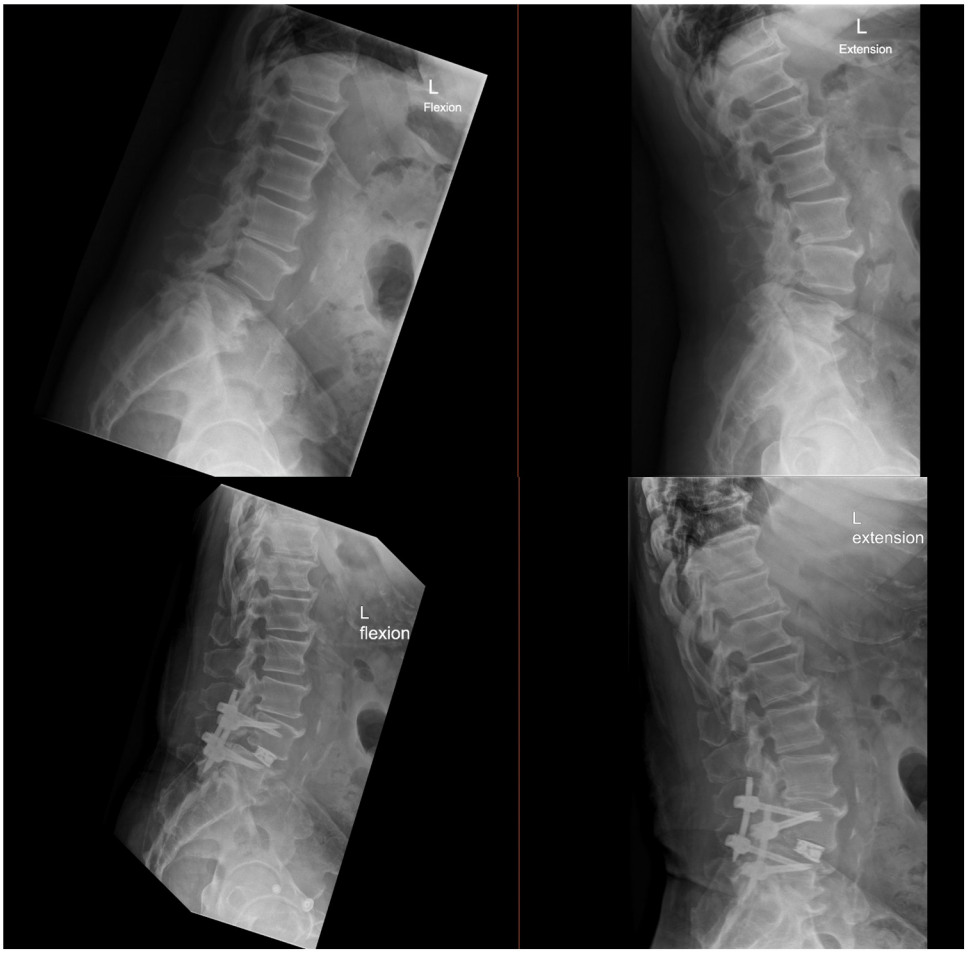

Fig. 3. Preoperative (top) and postoperative (bottom) flexion/extension X-Rays.

was made as it may reduce the perioperative complications associated with this patient's condition, as is described in the discussion (section 4.3) below.

The procedure took 261 minutes. There were no operative complications, and EBL was 100 mL. The patient was able to ambulate 4.3 hours after surgery and was discharged 3.5 hours later for a total hospital length of stay of 12 hours. The patient required no inpatient postoperative opioids. The patient had no perioperative complications and no unplanned admissions. On his six-week postoperative visit, he reported significant improvement in his back pain and radiculopathy. At his three-month postoperative visit, the patient described all of his symptoms as being completely gone.

4. Discussion

4.1. Spine surgery incidence and candidacy

While the exact prevalence of all degenerative spine disease is not known, and likely underreported, it is a tremendous source of morbidity and disability in the adult population. The prevalence

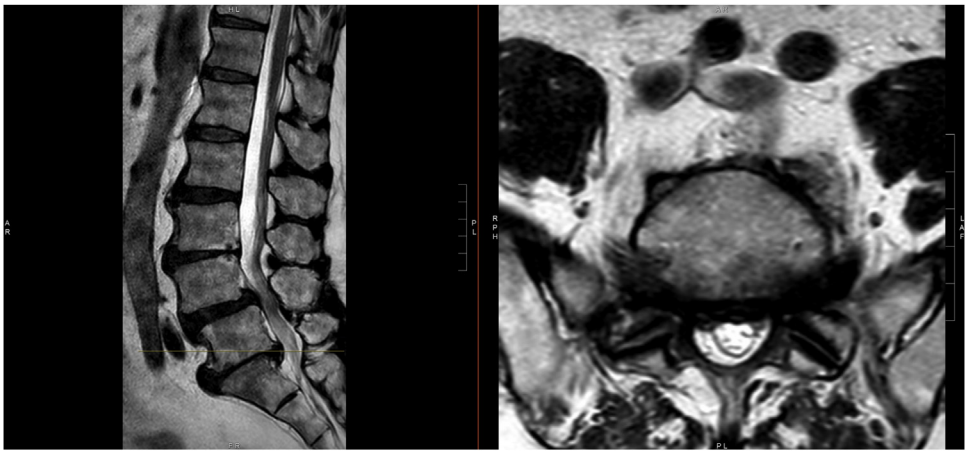

Fig. 4. Sagittal (L) and Axial (R) Preoperative T2-weighted MRI.

of degenerative spine disease can be roughly described as 40% in patients over 40 and 80% in patients over 80 [1]. While nonsurgical treatment may be effective for many of these patients, a significant portion of patients will ultimately be unresponsive to conservative, nonsurgical management [1]. As a result, hundreds of thousands of patients in the United States alone receive surgery for management degenerative spine disease [2]. Surgery may be avoided due to low disease severity or complicating spinal pathologies. Perioperative evaluation of surgical patients, however, is often heavily influenced by anesthesiologists, who give particular attention to the likelihood of cardiopulmonary adverse events (AEs) [8]. In this sense, candidacy for spine surgery is often a matter of GA candidacy. This suggests that SA, by circumventing the need for GA, expands spine surgery candidacy to include patients with relative contraindications to GA. The series of patients above demonstrates this phenomenon. It is worth noting, however, that SA is not without relative contraindications, and should be considered for patients who can tolerate the necessary positioning associated with the surgery and do not have prohibitive levels of anxiety. Anxiety, in the authors' experience, is the most common reason for which a patient denies surgery under SA in favor of GA. While there are few absolute contraindications to SA, however, it should be avoided in patients with active infections at the needle injection site. Weighing these factors against the risks associated with GA requires thoughtful conversation between the patient, surgeon, and anesthesiologist alike.

4.2. General anesthesia-associated complications

The potential complications associated with GA are numerous, and well described by Michelle Harris and Frances Chung [9]. Perhaps the most common AE associated with GA is postoperative nausea and vomiting (PONV). PONV has a prevalence ranging from 10% to 80% depending on the risk category of the individual, with canonical risk factors being female sex, nonsmoking status, and a history of PONV or motion sickness [10]. Although PONV is not a life-threatening complication, the same cannot be said for all complications of GA.

Amongst the most feared GA associated AEs are cardiac complications. These arise as both inhaled anesthetics and propofol alike are known to have cardiac depressant and smooth muscle relaxant effects, which can cause significant hypotension [11]. In this sense, it is often safer from a hemodynamic perspective to perform cases under local anesthesia, particularly for patients with significant baseline cardiovascular comorbidities; this has been shown in the setting of spine surgery [12]. Improved hemodynamic stability minimizes risk of hypoperfusion-related complications ranging from acute kidney injury to myocardial ischemia to brain injury. For instance, it has been found that SA, compared to GA, reduces risk of renal insufficiency [13]. Perhaps the most feared cardiac complication of GA is myocardial infarction [14]. Other cardiac AEs include heart failure and new onset arrhythmia, which may both occur after surgery under GA [15]. It is, however, not clear to what extent this perioperative morbidity can be attributed GA, rather than the stress of surgery itself. Anesthesia-related cardiac arrest may also occur and is more common in patients of advanced age [16].

GA, accompanied by endotracheal intubation, has also been implicated in the development of pulmonary complications. The most common pulmonary complication associated with GA is atelectasis, which accounts for approximately 70% of postoperative hypoxemia; it is also a risk factor for the development of further pulmonary pathologies such as pneumonia [17]. The lungs are also at risk of injury at time of induction via aspiration, which is the most common source of GA-associated pulmonary mortality [18]. GA, when compared to SA, may also indirectly impact incidence of pulmonary emboli, as GA has been shown to increase hospital length of stay, thereby prolonging immobility, when compared to SA [19]. Neurological complications may also occur and are often correlated strongly with patient demographics such as age [20]. One broad category of neurologic AEs seen after surgery is postoperative cognitive dysfunction (POCD), an acute postoperative decline in cognition and attention. POCD, while often apparently short-lived, should not be taken lightly, as it is associated with the eventual development of more serious cognitive impairment, such as Alzheimer's dementia [21]. It is certainly worth noting, however, that GA is not necessarily the causative factor precipitating POCD. The noteworthy REGAIN trial, in fact, found no significant differences between delirium incidence in GA and SA patients [22]. This trial, however, studied hip surgery patients; it is not clear if these results can be extrapolated to spine fusion patients, as this entire patient population demonstrated significant morbidity and mortality.

GA may also lead to direct drug reactions such as anaphylaxis or malignant hyperthermia.

4.3. High risk populations

Particular patient populations are at increased risk for GA associated AEs. To understand patients that are at increased risk, one needs only to look at the ASA-PS, which has been in use for over 60 years to quantify patients' pre-anesthesia medical comorbidities to help predict perioperative risk [23]. Anesthesia risk may be

increased in the setting of diabetes, heart disease, hypertension, kidney disease, lung disease, obesity, sleep apnea, or neurological disorders including such epilepsy or prior stroke [24].

Many of these comorbidities are associated with advanced age and obesity [25,26]. It is not surprising, then, that these conditions are common in the DSD population, as DSD is more common in patients with advanced age and BMIs [27]. This creates the unfortunate situation where many patients who could benefit the most from surgical management of DSD are relatively contraindicated due to AEs associated with GA. This, however, may no longer be the case. In recent years, there has been a growing movement to perform certain spine surgeries under SA with the patient fully awake, thereby circumventing the need to put patients under general anesthesia [19]. There is also evidence suggesting that SA potentially improves outcomes for patients receiving surgical treatment of DSD [28].

SA, therefore, may facilitate surgical management of DSD in patients who would otherwise be unable to receive surgery due to their relative contraindications to GA, thereby expanding spine surgery candidacy. To highlight this, we presented the preceding cases in which traditionally poor surgical candidates received successful surgical management of DSD under awake SA.

4.4. Limitations

A major limitation of this case series was its study design as a single surgeon, single institution, retrospective case series. With this, there exists risk for bias, as well as a lack of a control group of patients undergoing comparable procedures under GA. Creation of a control group was attempted by searching for spine surgery patients of similar age, BMI, ASA score, and comorbidity burden. This, however, could not be done, as elderly and highly comorbid patients preferentially received surgery under SA to avoid the GA-associated complications above. Another limitation was the low sample size of 10 patients. The authors, however, feel that awake spine surgery under SA is a safe, well-validated treatment strategy. The authors, therefore, present this cohort not to validate the method, but rather, to demonstrate the concept of SA's utility in facilitating operative management in highly comorbid patients who cannot safely undergo GA for an elective procedure.

4.5. Adoptability

While it may also be reasonable to hypothesize that these outcomes can only be attained by a surgeon who is well trained in awake spine surgery, research suggests that awake surgery is easily adopted by otherwise competent surgeons [29]. This suggests a low barrier to adoption of this exciting technique that may both improve patient outcomes and expand surgical candidacy in highly comorbid patients.

5. Conclusions

Many patients who require spine surgery have demographic characteristics and medical comorbidities that make them poor candidates for GA; this serves as a barrier to comprehensive care for their DSD. Awake spine surgery under SA, circumvents this obstacle, thereby expanding surgical candidacy. SA is associated with excellent patient outcomes in this cohort of patients. We conclude, therefore, that SA can facilitate spine surgery for highly comorbid DSD patients that were previously deemed poor surgical candidates.

Human and animal rights

The authors declare that the work described has been carried out in accordance with the Declaration of Helsinki of the World Medical Association revised in 2013 for experiments involving humans as well as in accordance with the EU Directive 2010/63/EU for animal experiments.

The authors declare that the work described has not involved experimentation on humans or animals.

Informed consent and patient details

The authors declare that this report does not contain any personal information that could lead to the identification of the patient(s) and/or volunteers.

Disclosure of interest

The authors declare the following financial or personal relationships that could be viewed as influencing the work reported in this paper:

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References

[1] Artificial discs for lumbar and cervical degenerative disc disease -update: an evidence-based analysis. Ont Health Technol Assess Ser 2006;6:1–98.
[2] Martin BI, Mirza SK, Spina N, Spiker WR, Lawrence B, Brodke DS. Trends in Lumbar fusion procedure rates and associated hospital costs for degenerative spinal diseases in the United States, 2004 to 2015. Spine (PhilaPa 1976) 2019;44:369–76, http://dx.doi.org/10.1097/brs.0000000000002822.
[3] Kim HJ, Park JY, Kang KT, Chang BS, Lee CK, Yeom JS. Factors influencing the surgical decision for the treatment of degenerative lumbar stenosis in a preference-based shared decision-making process. Eur Spine J 2015;24:339–47, http://dx.doi.org/10.1007/s00586-014-3441-5.
[4] Yang MMH, St-Pierre GH, DuPlessis S. Patient predictors of surgical candidacy in elective spine disorders. Can J Neurol Sci 2019;46:96–101.
[5] Huang RC, Lim MR, Girardi FP, Cammisa Jr FP. The prevalence of contraindications to total disc replacement in a cohort of lumbar surgical patients. Spine (PhilaPa 1976) 2004;29:2538–41, http://dx.doi.org/10.1097/01.brs.0000144829.57885.20.
[6] Smith G, D'Cruz JR, Rondeau B, Goldman J. General Anesthesia for Surgeons. In: StatPearls. StatPearls Publishing. Copyright © 2022. Treasure Island (FL): Stat Pearls Publishing LLC; 2022.
[7] McNelis J, Castaldi M. The National Surgery Quality Improvement Project" (NSQIP): a new tool to increase patient safety and cost efficiency in a surgical intensive care unit. Patient Saf Surg 2014;8:19, http://dx.doi.org/10.1186/1754-9493-8-19.

[8] O'Donnell FT. Preoperative evaluation of the surgical patient. Mo Med 2016;113:196–201.
[9] Harris M, Chung F. Complications of general anesthesia. Clin Plast Surg 2013;40:503–13, http://dx.doi.org/10.1016/j.cps.2013.07.001.
[10] Apfel CC, Läärä E, Koivuranta M, Greim CA, Roewer N. A simplified risk score for predicting postoperative nausea and vomiting: conclusions from cross-validations between two centers. Anesthesiology 1999;91:693–700, http://dx.doi.org/10.1097/00000542-199909000-00022.
[11] Tsikas D, Jordan J, Engeli S. Blood pressure-lowering effects of propofol or sevoflurane anaesthesia are not due to enhanced nitric oxide formation or bioavailability. Br J Clin Pharmacol 2015;79:1030–3, http://dx.doi.org/10.1111/bcp.12568.
[12] Lee JK, Park JH, Hyun SJ, Hodel D, Hausmann ON. Regional anesthesia for lumbar spine surgery: can it be a standard in the future? Neurospine 2021;18:733–40, http://dx.doi.org/10.14245/ns.2142584.292.
[13] Warren J, Sundaram K, Anis H, Kamath AF, Mont MA, Higuera CA, et al. Spinal anesthesia is associated with decreased complications after total knee and hip arthroplasty. J Am Acad Orthop Surg 2020;28:e213–21, http://dx.doi.org/10.5435/jaaos-d-19-00156.
[14] Devereaux PJ, Xavier D, Pogue J, Guyatt G, Sigamani A, Garutti I, et al. Characteristics and short-term prognosis of perioperative myocardial infarction in patients undergoing noncardiac surgery: a cohort study. Ann Intern Med 2011;154:523–8, http://dx.doi.org/10.7326/0003-4819-154-8-201104190-00003.
[15] Sellers D, Srinivas C, Djaiani G. Cardiovascular complications after non-cardiac surgery. Anaesthesia 2018;73(Suppl 1):34–42, http://dx.doi.org/10.1111/anae.14138.
[16] Braz LG, Módolo NS, do Nascimento Jr P, Bruschi BA, Castiglia YM, Ganem EM, et al. Perioperative cardiac arrest: a study of 53,718 anaesthetics over 9 yr from a Brazilian teaching hospital. Br J Anaesth 2006;96:569–75, http://dx.doi.org/10.1093/bja/ael065.
[17] Ferreyra G, Long Y, Ranieri VM. Respiratory complications after major surgery. Curr Opin Crit Care 2009;15:342–8, http://dx.doi.org/10.1097/MCC.0b013e32832e0669.
[18] Cook TM, Woodall N, Frerk C. Major complications of airway management in the UK: results of the Fourth National Audit Project of the Royal College of Anaesthetists and the Difficult Airway Society. Part 1: anaesthesia. Br J Anaesth 2011;106:617–31, http://dx.doi.org/10.1093/bja/aer058.
[19] Perez-Roman RJ, Govindarajan V, Bryant JP, Wang MY. Spinal anesthesia in awake surgical procedures of the lumbar spine: a systematic review and meta-analysis of 3709 patients. Neurosurg Focus 2011;51:E7, http://dx.doi.org/10.3171/2021.9.Focus21464.
[20] Evered L, Scott DA, Silbert B, Maruff P. Postoperative cognitive dysfunction is independent of type of surgery and anesthetic. Anesth Analg 2011;112:1179–85, http://dx.doi.org/10.1213/ANE.0b013e318215217e.
[21] Fong TG, Inouye SK. The inter-relationship between delirium and dementia: the importance of delirium prevention. Nat Rev Neurol 2022;18:579–96, http://dx.doi.org/10.1038/s41582-022-00698-7.
[22] Neuman MD, Feng R, Carson JL, Gaskins LJ, Dillane D, Sessler DI, et al. Spinal anesthesia or general anesthesia for hip surgery in older adults. N Engl J Med 2021;385:2025–35, http://dx.doi.org/10.1056/NEJMoa2113514.
[23] Mayhew D, Mendonca V, Murthy BVS. A review of ASA physical status - historical perspectives and modern developments. Anaesthesia 2019;74:373–9, http://dx.doi.org/10.1111/anae.14569.
[24] Scharwächter WH, Keet SW, Stoecklein K, Loer SA, Boer C. Health risk factors in the anesthesia population. J Clin Anesth 2016;32:33–9, http://dx.doi.org/10.1016/j.jclinane.2015.11.017.
[25] Ansari S, Haboubi H, Haboubi N. Adult obesity complications: challenges and clinical impact. Ther Adv Endocrinol Metab 2020;11, http://dx.doi.org/10.1177/2042018820934955, 2042018820934955.
[26] Jaul E, Barron J. Age-related diseases and clinical and public health implications for the 85 years old and over population. Front Public Health 2017;5:335, http://dx.doi.org/10.3389/fpubh.2017.00335.
[27] 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, http://dx.doi.org/10.1038/s41598-021-84724-6.
[28] Garg B, Ahuja K, Sharan AD. Awake spinal fusion. J Clin Orthop Trauma 2020;11:749–52, http://dx.doi.org/10.1016/j.jcot.2020.06.003.
[29] West JL, De Biase G, Bydon M, Bojaxhi E, Mendhi M, Quiñones-Hinojosa A, et al. What is the learning curve for lumbar spine surgery under spinal anesthesia? World Neurosurg 2022;158:e310–6, http://dx.doi.org/10.1016/j.wneu.2021.10.172.