Awake spinal surgery: simplifying the learning curve with a patient selection algorithm

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OBJECTIVE There is a learning curve for surgeons performing “awake” spinal surgery. No comprehensive guidelines have been proposed for the selection of ideal candidates for awake spinal fusion or decompression. The authors sought to formulate an algorithm to aid in patient selection for surgeons who are in the startup phase of awake spinal surgery.

METHODS The authors developed an algorithm for selecting patients appropriate for awake spinal fusion or decompression using spinal anesthesia supplemented with mild sedation and local analgesia. The anesthetic protocol that was used has previously been reported in the literature. This algorithm was formulated based on a multidisciplinary team meeting and used in the first 15 patients who underwent awake lumbar surgery at a single institution.

RESULTS A total of 15 patients who underwent decompression or lumbar fusion using the awake protocol were reviewed. The mean patient age was 61 ± 12 years, with a median BMI of 25.3 (IQR 2.7) and a mean Charlson Comorbidity Index of 2.1 ± 1.7 ; 7 patients (47%) were female. Key patient inclusion criteria were no history of anxiety, 1 to 2 levels of lumbar pathology, moderate stenosis and/or grade I spondylolisthesis, and no prior lumbar surgery at the level where the needle is introduced for anesthesia. Key exclusion criteria included severe and critical central canal stenosis or patients who did not meet the inclusion criteria. Using the novel algorithm, 14 patients (93%) successfully underwent awake spinal surgery without conversion to general anesthesia. One patient (7%) was converted to general anesthesia due to insufficient analgesia from spinal anesthesia. Overall, 93% ($n = 14$) of the patients were assessed as American Society of Anesthesiologists class II, with 1 patient (7%) as class III. The mean operative time was 115 minutes (± 60 minutes) with a mean estimated blood loss of 46 ± 39 mL. The median hospital length of stay was 1.3 days (IQR 0.1 days). No patients developed postoperative complications and only 1 patient (7%) required reoperation. The mean Oswestry Disability Index score decreased following operative intervention by 5.1 ± 10.8 .

CONCLUSIONS The authors propose an easy-to-use patient selection algorithm with the aim of assisting surgeons with patient selection for awake spinal surgery while considering BMI, patient anxiety, levels of surgery, and the extent of stenosis. The algorithm is specifically intended to assist surgeons who are in the learning curve of their first awake spinal surgery cases.

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WHEN properly selected surgical candidates undergo spinal fusion, significant improvements in patients' quality of life can be achieved.¹ The concept of Enhanced Recovery After Surgery (ERAS) is a multimodal approach to patient care that has been extensively studied and implemented in a variety of surgical subspecialties, including spinal fusion operations.^{2,3}

Accordingly, in an effort to reduce morbidity associated with open fusion techniques, the development of “awake” minimally invasive spinal surgical techniques has been promoted.⁴ Introduced in 1986, Zigler et al. described a series of 34 patients who successfully underwent posterior cervical spine fusion under local anesthesia.⁵ Since this time, in conjunction with minimally invasive approaches,

ABBREVIATIONS ASA = American Society of Anesthesiologists; GETA = general endotracheal anesthesia; IONM = intraoperative neurophysiological monitoring; MIS = minimally invasive surgery; ODI = Oswestry Disability Index; TLIF = transverse lumbar interbody fusion.

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multiple studies have been conducted to demonstrate the efficacy and feasibility of spine fusions under regional spinal anesthesia.^{6–8}

In 2016, Wang and Grossman described the successful use of awake spine surgery for minimally invasive surgery (MIS)—transverse lumbar interbody fusion (TLIF). While this study pioneered the recent use of conscious sedation in lumbar spine fusion, limitations included a surgical cutoff time of 120 minutes.¹ Notably, in an effort to address the limitations present in the previous studies evaluating awake spinal surgery, Chan et al. demonstrated an effective, comprehensive, and reproducible anesthesia protocol that adequately controlled patient pain throughout the perioperative period while avoiding complications.⁹ In the study by Wang and Grossman, the anesthetic protocol relied only on local anesthetic with conscious sedation and, notably, did not utilize spinal anesthesia.¹ In contrast, Chan et al. employed a combination of liposomal long-acting local anesthetic agents, a spinal anesthetic, and conscious sedation in an effort to extend operative limits to > 2 hours.⁹ While increased operative time is not frequently necessary for one-level MIS-TLIFs, expansion of operative time limits in turn allows for the expansion of interventions utilizing awake anesthetic techniques. Given the increased applicability of awake spine surgery using novel anesthetic techniques, a more comprehensive discussion regarding ideal patient selection is critical.

Despite its increasing popularity and established feasibility, clear evidence-based recommendations for patient selection have not been established.^{7,8,10} This study outlines a patient selection algorithm for the implementation of awake spinal surgery to assist surgeons in their learning curve.

Methods

This algorithm was established following multidisciplinary meetings involving neurosurgeons, anesthesiologists, nurses, and physiotherapists at the University of California, San Francisco. A retrospective review was performed to study the outcomes and establish the efficacy of our algorithm and selection criteria. All patients who underwent awake lumbar spinal surgery at the University of California, San Francisco, were included in this study.

Patient Selection

This algorithm has been created for patients undergoing either spinal decompression or spinal fusion (Fig. 1). Regardless of the intended spinal intervention, candidates should not have a history of anxiety, sleep apnea, conditions compromising the airway, poorly controlled pulmonary disease (baseline room air oxygen saturation < 95%), poorly controlled cardiac disease, high risk for aspiration, a BMI > 30 kg/m², or a spinal pathology above the level of the conus medullaris. Patients with preexisting cardiac disease were not universally excluded due to the importance of the awake technique in this patient population. All candidates should be evaluated by the anesthesia team prior to intervention for preoperative clearance given the

necessary prone position compounded with the lack of a protected airway. Furthermore, candidates should not have a prior history of lumbar spinal surgery at the level of the spinal anesthetic for administration purposes.

Decompression

In patients undergoing spinal decompression, the proposed surgical intervention should preferably be restricted to 1 to 2 levels in those with only moderate stenosis. If the patient has radiological evidence of facet cysts, avoiding awake spinal interventions is recommended due to the high risk of CSF leaks. Patients with herniated discs may still be appropriate candidates for awake decompression if there are no clinical signs of cauda equina syndrome. For experienced surgeons, patients with severe stenosis and those requiring 3 levels of decompression may be candidates for awake surgery per the surgeon's preference.

Fusion

For patients undergoing spinal fusion, our algorithm proposes that the intended operative intervention should be restricted to individuals undergoing a single-level fusion with moderate stenosis (Fig. 1). In situations with an experienced surgeon, this can be increased to individuals undergoing fusion at two levels with severe stenosis. However, similar to awake spinal decompressions, caution must be used in cases involving severe stenosis or facet cysts given the high risk of CSF leaks. In all cases, if the patient presents with stenosis or disc herniation at the level of the conus medullaris or higher, awake spinal instrumentation should be avoided given the increased risk of neurological deficits along with increased difficulty in getting access for a spinal anesthetic.

Anesthetic Protocol

Our anesthesia protocol for awake, minimally invasive spinal surgery has been previously described by Chan et al. in 2019 and is reviewed here, as follows (Fig. 2).⁹ Preoperatively, patients are administered acetaminophen (1000 mg orally) and gabapentin (600 mg orally). Gabapentin is not administered if the patient is > 70 years of age or has chronic kidney disease with a glomerular filtration rate of < 60 mL per minute. For the intraoperative phase, preprocedural sedation is administered intravenously by the anesthesiologist with midazolam (ideally < 2 mg) and fentanyl (ideally < 100 µg). Lumbar spinal anesthesia is achieved via intrathecal injection of 15 mg of isobaric bupivacaine (3 mL of 0.5% bupivacaine) and 10 µg to 25 µg of fentanyl 1 space above or below the operative level. While alert, the patients position themselves prone on the Jackson table with guidance from the operating room staff (Fig. 3). General sedation should be titrated to a Ramsay Sedation Scale score of 2 to 3 using 25 µg/kg to 50 µg/kg per minute of propofol with 2 µg/kg per minute of ketamine. Alternative sedative options include dexmedetomidine guttae or a combination of fentanyl and midazolam administered intravenously. Sedatives should be provided with the goal of sedation but with limited opiate administration. During the operative phase, each in-

FIG. 1. Patient selection flowchart for awake lumbar spinal surgery. Individuals with no history of anxiety, sleep apnea, airway compromise, pathology below the conus medullaris, or facet cysts with a BMI < 30, maximal moderate central spinal stenosis, and 1 to 2 intended surgical levels are ideal candidates for awake intervention. *Adequate space for the spinal anesthetic to enter the intradural compartment must be available—hence the need for an experienced surgeon. †Requires an experienced surgeon due to increased risk of a CSF leak.

cision or percutaneous screw tract is infiltrated with 10 mL of liposomal bupivacaine (20 mL or 1.3% liposomal bupivacaine diluted with 20 mL of normal saline to a total volume of 40 mL). In the event of inadequate analgesia after 2 hours, reinjection of 1 mL of 0.5% bupivacaine on the surgical field using a 24-gauge pencil-point spinal needle can be used.

Apart from analgesia, during the operative phase, blood pressure support and nausea prophylaxis are important to manage. The mean arterial pressure should be maintained at a minimum of 65 mm Hg, or 80% of the patient's baseline mean arterial pressure, via fluid boluses, phenylephrine guttae, or ephedrine. Intravenous dexamethasone and

Zofran (4 mg) are frequently used for nausea prophylaxis. For diabetic patients, dexamethasone is held.

During the postoperative phase, analgesia can be attained via the use of acetaminophen (1000 mg every 4 hours around the clock), gabapentin (300 mg 3 times a day), and oxycodone (5 mg every 3–4 hours, as needed for moderate pain). For severe pain that is unresponsive to oral analgesics, hydromorphone (0.2–0.4 mg intravenously every 3–4 hours, as needed) is appropriate, although avoidance is ideal. Patient-controlled analgesia should be avoided in these cases. Nausea is managed postoperatively with Zofran (4 mg intravenously every 6 hours, as needed). If the patient is unable to void independently in the postan-

FIG. 2. Anesthesia protocol for awake spinal surgery utilized at the University of California, San Francisco. Modified from Chan A, et al. *Neurosurg Focus*. 2019;46(4):E16,⁹ published with permission. ATC = around the clock; BID = twice per day; CKD = chronic kidney disease; GFR = glomerular filtration rate; ggt = guttae; IV = intravenously; MAP = mean arterial pressure; PACU = post-anesthesia care unit; PCA = patient-controlled analgesia; PO = by mouth; PT = physical therapy; PRN = as needed; TID = three times per day; q3h = every 3 hours; q4h = every 4 hours; q6h = every 6 hours.

thetia care unit, the bladder scan should be checked and a straight catheter implemented, as needed. Patients are encouraged to partake in physical therapy on the day of surgery, with a goal of discharge within 24 hours of surgery.

Statistical Methodology

Descriptive statistics for continuous variables were reported as median (IQR) or mean ± SD and categorical variables as frequencies. The quantile-quantile plot and Shapiro-Wilk test were used to assess the normality of distributions. All statistical analyses were conducted using R version 3.6.2 (The R Project).

Results

Using the proposed patient selection algorithm, 15 patients underwent minimally invasive decompression or lumbar fusion using the established awake protocol (Fig. 1) at the University of California, San Francisco (Table 1). The mean patient age was 61 ± 12 years with a median BMI of 25.3 (IQR 2.7), and 7 patients (47%) were female. The mean Charlson Comorbidity Index was 2.1 ± 1.7 with a mean preoperative Oswestry Disability Index (ODI) score of 17 ± 8.1. Fourteen patients (93%) were assessed as American Society of Anesthesiologists (ASA) class II, and 1 patient (7%) as class III.

FIG. 3. Illustrative example of the patient position and spinal anesthetic technique for awake lumbar spine surgery. Spinal anesthetic is introduced 2 levels above the intended operative level (e.g., spinal anesthetic at L2–3 for an operation at L4–5). S = sacrum. Copyright Praveen V. Mummaneni. Published with permission.

Fourteen patients (93%) successfully underwent awake spinal surgery without requiring conversion to general anesthesia. One patient (7%) was converted to general endotracheal anesthesia (GETA) due to insufficient analgesia from the spinal anesthetic. No perioperative complications were present in our study cohort, although 1 patient (7%) required reoperation due to the need for additional decompression and fusion. The mean operative time was 115 ± 60 minutes, with a mean estimated blood loss of 46 ± 39 mL. The median postoperative hospital length of stay was 1.3 days (IQR 0.1 days). The mean ODI score decreased following operative intervention by 5.1 ± 10.8 . The mean follow-up period was 1.1 ± 0.9 years.

Discussion

In several surgical fields, the emphasis of quality improvement efforts has been centered on enhancing a patient's recovery following surgery, often through minimally invasive techniques. Neurosurgery, specifically spine surgery, is no exception, with various minimally invasive techniques being pioneered to reduce postoperative complications, hospital length of stay, and pain. An extension of minimally invasive spine surgery is the advent of awake spinal fusions utilizing conscious sedation

and regional spinal anesthesia to reduce the complications and costs associated with general anesthesia. A growing number of studies have demonstrated the clinical benefits of operating with patients under regional anesthesia, which include decreased intraoperative blood loss, fewer intraoperative complications associated with general anesthesia, and improved postoperative pain control.^{4,8,9,11,12} Beyond clinical benefits, recent cost-benefit analyses have demonstrated that the use of conscious sedation with spinal anesthesia instead of general anesthesia decreased the total cost for lumbar discectomy and laminectomy by 40% due to a combination of factors, including shorter operative times and duration of anesthesia, and lower estimated blood loss.¹³

The results of the current study demonstrate the feasibility and efficacy of spinal anesthesia with conscious sedation for lumbar spinal operations given appropriate patient selection. To date, spinal anesthesia with conscious sedation is being increasingly used for select patients undergoing less-extensive lumbar spinal operations.⁸ Only 1 patient in our cohort had to convert intraoperatively to a GETA protocol due to insufficient analgesia from the spinal anesthetic. One patient required reoperation due to persistence of symptoms because of neural foraminal ste-

TABLE 1. Patient characteristics

Age (yrs)	BMI (kg/m ²)	No. of Levels	Decompression or Fusion	Conversion to GETA	Reop
37	30.9	1	Decompression	No	No
52	25.1	1	Decompression	No	No
56	21.0	1	Decompression	Yes*	No
63	25.8	1	Decompression	No	Yes†
75	23.1	1	Decompression	No	No
78	17.0	1	Decompression	No	No
42	23.8	2	Decompression	No	No
64	25.8	2	Decompression	No	No
75	21.6	2	Decompression	No	No
52	24.1	1	Fusion	No	No
62	25.4	1	Fusion	No	No
64	25.3	1	Fusion	No	No
68	29.1	1	Fusion	No	No
76	26.5	1	Fusion	No	No
60	28.9	2	Fusion	No	No

* The patient was converted to GETA intraoperatively due to insufficient analgesia from the spinal anesthetic.

† The patient required reoperation because of persistence of symptoms from neural foraminal stenosis due to scoliosis. The patient secondarily underwent awake MIS-TLIF.

nosis due to scoliosis, and the patient underwent another awake MIS-TLIF. Ultimately, while limited in size, none of the patients in our cohort experienced any complications related to the spine surgery in the perioperative period. From an intraoperative standpoint, the mean operative time was 115 ± 60 minutes, comparable to prior reports of awake spine surgery cases (113.5 ± 6.3 minutes).^{1,9}

From the perspective of postoperative recovery, patients who underwent awake spinal instrumentation have demonstrated enhanced recovery compared with those who underwent standard awake operations in both our cohort and recent literature. The use of conscious sedation avoids the adverse effects and complications associated with general anesthesia such as memory loss, nausea, mental confusion, and sensorimotor function impairment.^{1,9,14} The avoidance of general anesthesia increases the number of patients eligible for surgical intervention. Individuals who have been deemed high-risk surgical candidates from an anesthesia perspective ($\geq$ ASA class II) may be candidates for spinal intervention that avoids the risks associated with general anesthesia.¹⁵ Another benefit of utilizing conscious sedation with regional spinal anesthesia is its lasting effect on pain during the immediate postoperative period. Poorly controlled postoperative pain is a common complaint in the first 3 days following spinal fusion and decompression. The presence of liposomal bupivacaine provides a prolonged period of local, regional anesthesia, which has the potential to decrease the patient's reliance on opioid pain medications during recovery.^{1,16} Furthermore, with improved postoperative pain control, patients have an increased tolerance for physical therapy and rehabilitation exercises, which allow for a more rapid recovery. As demonstrated, patients in this cohort who underwent awake spinal surgery reported a mean ODI improvement of 5.1 ± 10.5 . While Wang and Grossman demonstrated a

more robust ODI decrease in the awake cohort (-28.7), this was likely due to the higher preoperative mean ODI of 42 compared with 17 in the current study cohort.¹

Despite its benefits, awake spinal surgery is not without complications. An individual's tolerance and the safety of the procedure are important considerations when selecting candidates for any intervention involving only conscious sedation. Patients with a history of anxiety are likely not ideal candidates for any awake procedure. Previous studies reporting the use of conscious sedation during spinal instrumentation have described the need to revert to general anesthesia during the intraoperative phase because of severe anxiety.¹¹ This is a known risk and must be discussed with the patient and surgical team prior to the start of the procedure. Patients who have a history of airway compromise or obstructive sleep apnea or who are morbidly obese are poor candidates for any awake procedure due to the lack of a protected airway in an individual in the prone position (Fig. 2). However, awake spine surgery is particularly interesting to patients with preexisting cardiac disease who may be otherwise precluded from undergoing spinal surgery due to unacceptable anesthesia risks.

Regarding specific procedure-related contraindications, individuals with facet cysts or those who have spinal pathology at the level of the conus medullaris should not be treated in an awake procedure given the high risk of neurological impairment. Given the need for spinal anesthesia, if a patient has had a prior spine surgery with or without hardware placement at the level of the intended spinal anesthetic placement level, awake intervention is likely not feasible due to the increased scar tissue and difficulty in anesthetic induction. Additionally, the introduction of intrathecal spinal anesthesia can be complicated by the presence of severe central stenosis, further requiring an experienced surgeon. Any feature that confers an

increased risk of CSF leaks such as facet cysts should lead to surgery under GETA since repair of these complications increases the operative time and may complicate the timing between maximal awake anesthetic capabilities. While our cohort did not experience any complications during the intraoperative phase, complications for surgeons to be aware of include CSF leaks and nerve injury. Intraoperative CSF leaks can be effectively managed via suturing the defect along with using a dural glue to augment closure. Furthermore, no infections were experienced in this cohort, and incisions were closed using nylon sutures. An important limitation of the awake technique is that the use of spinal anesthesia and conscious sedation, while effective in managing intra- and postoperative pain, prevents patient and surgeon assessment of neurological function during the procedure. This is compounded by the absence of intraoperative neurophysiological monitoring (IONM) in our algorithm. However, avoiding IONM decreases both operative time and patient discomfort. Furthermore, recent studies evaluating IONM have demonstrated a lack of benefit for smaller procedures such as the minimally invasive 1- to 2-level TLIFs described in this report.¹⁷

Despite the strengths of our study, there are several limitations. Given the retrospective nature of this study, there is an inherent risk of bias, especially when assessing the utility of the algorithm on previous cases. However, this was addressed through assessment of the algorithm impact by multiple fellowship-trained, board-certified spine surgeons. Beyond the neurosurgical team, an awake intervention requires close collaboration with the anesthesia team. Due to its novelty, many institutions and anesthesiologists may not have protocols for awake surgical interventions along with limited comfort in supervising these interventions. Hopefully, through the establishment of evidence-based guidelines along with a patient selection algorithm, it will be easier to adopt awake procedures. Finally, this algorithm is not a comprehensive guide, as each patient must be evaluated individually; however, it provides a guide for surgeons and for future work expanding on our results.

Conclusions

Herein, we propose an easy-to-use algorithm for the selection of ideal candidates for awake lumbar spine fusion and decompression. The algorithm is intended to aid surgeons who are in the learning curve of their first awake spine surgeries. The benefits of awake spine surgery may include decreased operative time, intraoperative complications related to general anesthesia, postoperative pain, length of hospital stay, and total costs. The proposed patient selection process considers relevant spinal pathology, a history of anxiety, BMI, compromising airway diseases, and surgeon experience. The ideal candidates for any awake spinal intervention are those without a history of anxiety, airway compromising conditions, or a lumbar spinal pathology below the level of the conus medullaris. Furthermore, spinal fusions should be limited to 1 to 2 levels and decompressions to a maximum of 3 levels. Further studies with larger cohorts are critical to determine the full utility of awake lumbar spine surgery.

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