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

Vijay Letchuman, BA,¹ Nitin Agarwal, MD,¹ Valli P. Mummaneni, MD,² Michael Y. Wang, MD,³ Saman Shabani, MD,¹ Arati Patel, MD,¹ Joshua Rivera, BS,¹ Alexander F. Haddad, MD,¹ Vivian Le, MPH,¹ Joyce M. Chang, MD,² Dean Chou, MD,¹ Seema Gandhi, MD,² and Praveen V. Mummaneni, MD, MBA¹

¹Department of Neurological Surgery, University of California, San Francisco; ²Department of Anesthesiology, University of California, San Francisco, California; and ³Department of Neurosurgery, University of Miami, Miami, Florida

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.

https://thejns.org/doi/abs/10.3171/2021.9.FOCUS21433

KEYWORDS awake; spine; fusion; decompression; anesthesia
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 guttate or a combination of fentanyl and midazolam administered intravenously. Sedatives should be provided with the goal of sedation but with limited operative administration. During the operative phase, each in-
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 guttæ, 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 postanes-
In the intraoperative setting, the bladder scan should be checked and a straight catheter implemented, as needed. Patients are encouraged to participate 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.
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. 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.

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. 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-
nal confusion, and sensorimotor function impairment.

1,9,14

With general anesthesia such as memory loss, nausea, men

The avoidance of general anesthesia increases the number of pa-

tients eligible for surgical intervention. Individuals who have been
deemed high-risk surgical candidates from an anesthesia perspec-
tive (≥ ASA class II) may be candidates for spinal intervention that
avoids the risks associated with general anesthesia such as memory loss, nausea, men-
tal confusion, and sensorimotor function impairment.1,9,14

The avoidance of general anesthesia increases the number of pa-
tients in our cohort experienced any complications related to the spine surgery in the perioperative peri-

od. 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).15

From the perspective of postoperative recovery, pa-
tients who underwent awake spinal instrumentation have
demonstrated enhanced recovery compared with those who
underwent standard awake operations in both our co-

tort and recent literature. The use of conscious sedation
avoids the adverse effects and complications associated
with general anesthesia.

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 that avoids the risks associ-
ated with general anesthesia provides a prolonged period of local, reg-

ional 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 reha-

bilitation 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 stud-
ies reporting the use of conscious sedation during spinal
instrumentation have described the need to revert to gen-
eral anesthesia during the intraoperative phase because of
severe anxiety.11 This is a known risk and must be dis-
cussed 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 mor-
bidly 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 contraindica-
tions, individuals with facet cysts or those who have spi-
nal 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 an-
esthesia, 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 dif-
ficulty in anesthetic induction. Additionally, the introduc-
tion of intrathecal spinal anesthesia can be complicated
by the presence of severe central stenosis, further requir-
ing an experienced surgeon. Any feature that confers an

| 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.

The patient secondary underwent awake MIS-TLIF.
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.7

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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**Disclosures**

Dr. Agarwal: royalties from Thieme Medical Publishers. Dr. Wang: patent holder with DePuy Synthes, Stryker, Spineology, and Medtronic; and direct stock ownership in ISD, Kinetiometrics, and Medical Device Partners. Dr. Chou: consultant for Globus and Orthofix; and royalties from Globus. Dr. P. V. Mummaneni: has served as a consultant for DePuy Spine, Globus, and Stryker; has direct stock ownership in Spinility/ISD; has received royalties from DePuy Spine, Thieme Publishers, and Springer Publishing; and has received support from ISSG, NREF, NIH, and AO Spine for non–study-related clinical or research effort.

**Author Contributions**

Conception and design: Agarwal, Gandhi, PV Mummaneni. Acquisition of data: Rivera, Le. Analysis and interpretation of data: Letchuman, Agarwal, VP Mummaneni, Wang, Shabani, PV Mummaneni. Drafting the article: Letchuman, Agarwal, Shabani, PV Mummaneni. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Agarwal. Statistical analysis: Letchuman. Administrative/technical/material support: Agarwal, PV Mummaneni. Study supervision: Agarwal, PV Mummaneni.

**Correspondence**

Nitin Agarwal: University of California, San Francisco, CA. nitin.agarwal@ucsf.edu.