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The Effectiveness and Safety of Ultrasonic Bone Scalpel Versus Conventional Method in Cervical Laminectomy: A Retrospective Study of 311 Patients

Bharat R. Dave, MS, MCh[1], Ajay Krishnan, MS[1], Ravi Ranjan Rai, MS[1], Devanand Degulmadi, MS[1], Shivanand Mayi, MS[1], and Mahendra Gudhe, MS[1]

Abstract

Study Design: Retrospective cohort study.

Objectives: The aim of this study was to compare the results of cervical laminectomy (CL) performed with ultrasonic bone scalpel (UBS) or conventional method (CM).

Method: This study comprised 311 CL performed by a single surgeon between January 2004 and December 2017. Group A (GpA) comprised 124 cases of CL performed using UBS, while Group B (GpB) comprised 187 cases of CL performed using CM. These 2 groups were compared in terms of demographic characteristics of patients, duration of surgery, estimated blood loss, and surgical complications.

Results: GpA included 112 males and 12 females, mean age being 61.18 years. GpB comprised 166 males and 21 females, mean age being 62.04 years. Mean duration of surgery, estimated blood loss, and length of hospital stay was 65.52/70.87 minutes, 90.24/98.40 mL, and 4.80/4.87 days in GpA and GpB, respectively. Six patients were reported to have dural injuries in each group. In GpA, 2 cases of C5 palsy and 1 nerve root injury was observed, while in GpB, 3 cases of C5 palsy and no nerve root injury was reported. One patient had developed transient neurological deterioration postsurgery in GpA as against 11 patients in GpB.

Conclusion: Neurological complications observed in CM leads to intensive care unit admission, additional morbidity, and additional expenditure, whereas UBS provides a safe, rapid, and effective means of performing CL, thereby decreasing the rate of surgical complications and postoperative morbidity.

Keywords

cervical, laminectomy, ultrasonic, myelopathy, retrospective study

Introduction

Cervical laminectomy (CL) is a commonly performed procedure for cervical spondylotic myelopathy (CSM) and ossified posterior longitudinal ligament (OPLL). Several techniques have been described for CL. The conventional method (CM) is to use the kerrison punch and Leksell rongeur to remove laminae piece meal or to make troughs on both sides of laminae using kerrison punch and then remove laminae en bloc. However, placing the kerrison footplate under the intact lamina in an already compromised spinal canal would cause further damage to the spinal cord.[1] There have been several reports in the literature regarding complications with CM, particularly dural injuries and mechanical injury to the cord.[2-4] Hirabayashi described the technique of laminoplasty using a high-speed burr (HSB),[5] and since then a HSB is being used for CL as

[1] Stavya Spine Hospital and Research Institute, Ahmedabad, Gujarat, India

Corresponding Author:
Ravi Ranjan Rai, Stavya Spine Hospital and Research Institute, Ahmedabad 380006, Gujarat, India.
Email: drravirai84@gmail.com

well. This offers the advantage of not penetrating the spinal canal while creating troughs; however, the last part of laminectomy needs to be completed by using kerrison rongeur, small curette or hook, which again involves entering the already narrow spinal canal. HSB has also been known to have complications of thermal injury, risk of entangling the soft tissues, risk of damage to cord, and is time consuming.[6,7] As against this, ultrasonic bone scalpel (UBS) might have the advantage of performing accurate, safe, and quick bony excision.[7,8]

The present study aims to focus on the technique used for CL by comparing the outcomes and complications of 2 different surgical techniques, that is, CM versus UBS, of a single-center consecutive patient series. The primary hypothesis is that UBS is safer and reduces the incidence of dural tear and spinal cord injuries. The secondary hypothesis is that UBS gives additional advantages of being precise, less time consuming, reduces LHS thereby reducing indirect cost, and improves outcome.

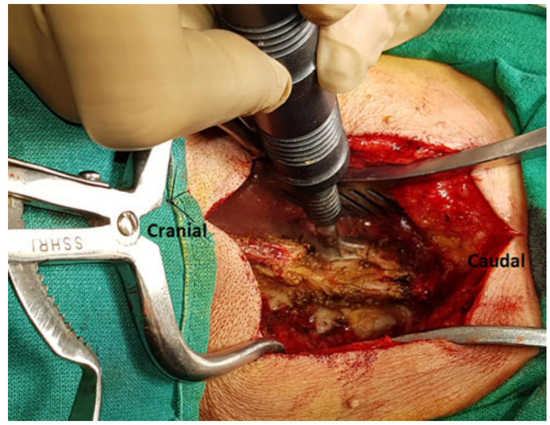

Figure 1. UBS being used to create precise cut for laminectomy.

Materials and Methods

This study was a retrospective observational study and did not require institutional ethical committee approval. We retrospectively evaluated all patients who had undergone CL between January 2004 and December 2017 at our institute for CSM and OPLL. Our indication for CL in CSM is clinically evident myelopathy with multilevel cervical stenosis, local kyphosis <13°, and spondylolisthesis <3.5 mm. Indication for CL in OPLL is clinically diagnosed myelopathy with multilevel stenosis, maintained cervical lordosis, and OPLL mass not crossing the K line. All patients who underwent CL during the above-mentioned period and with minimum 12-month follow-up and with available complete hospital records were included in the study. Exclusion criteria were the following: patients with infection, tumor, trauma, patients who needed anterior plus posterior procedure, and those previously operated. All patients were operated by a single surgeon (BRD). Patients were divided into 2 groups, depending on the technique used for laminectomy. CM was used for all CL performed till 2013 (GpB), and once we started using UBS in 2013, all subsequent patients (GpA) were operated using UBS (Misonix, Inc, Farmingdale, NY). Hospital records were used to document patients' demographic profile, duration of surgery, estimated blood loss (EBL), length of hospital stay (LHS), and surgical complications like dural tear, nerve root injury, and neurological deterioration. Objective validated Nurick grading was used to measure the outcome. Recovery rate based on Nurick grading was additionally calculated as per the following formula[9,10]: Preoperative grade − Postoperative grade/Preoperative grade × 100. The minimum follow-up period was 12 months.

Surgical Technique

After administration of antibiotic and induction of general anesthesia, the patient is positioned prone on bolsters, with head supported on a horse-shoe gel pad. The cervical spine is positioned in slight flexion for better exposure during decompression. After standard skin preparation and draping, longitudinal midline skin incision is made. Monopolar electrocautery is used to dissect down the ligamentum nuchae, expose the spinous processes, and paraspinal muscles lifted away through sub-periosteal dissection. A lateral view radiograph is obtained to confirm the level. Interspinous ligaments and ligamentum flavum at the cranial and caudal interlaminar spaces are incised at upper and lower margins of decompression. Then for GpA patients, UBS was used to make cuts on the laminae and consequent laminae removed en bloc. For GpB patients, Kerrison rongeur (1 mm or 2 mm) was used to create troughs on either side of laminae and then laminectomy was completed.

When using UBS, a precise cut is made at the laminofacet junction on either side. UBS is utilized to cut the bone of the laminae through the outer cortex as well as the inner cortex, through gentle sweeping motion, without putting undue pressure (Figure 1 and 2). It is essential to keep moving the device tip and not hold it too long at a particular spot, nor to push it deeper. A give-way sensation is felt when the bony cut is completed and that is the end point. Care needs to be exercised in severely compromised spinal canal and in which even the lateral recess is narrow. In these cases, a thin portion of inner cortex is left intact; UBS is used to cut most of the bone without penetrating into the canal at any point. The bony cut is then completed by introducing a thin osteotome through the incomplete bony trough and twisting it gently, thereby breaking the remaining inner cortex (Figure 3). Laminectomy is completed by lifting the cut laminae with the help of a nibbler/Leksell rongeur while separating any adhesions, if present, with the help of a penfield retractor or nerve hook (Figure 4).

Homeostasis was achieved with gel foam and bipolar cautery. Adequacy of decompression was checked and levels confirmed under "C arm." Standard closure was performed in layers over a drain. All patients underwent magnetic resonance imaging (MRI) screening on the first postoperative day to ascertain the adequacy of decompression.

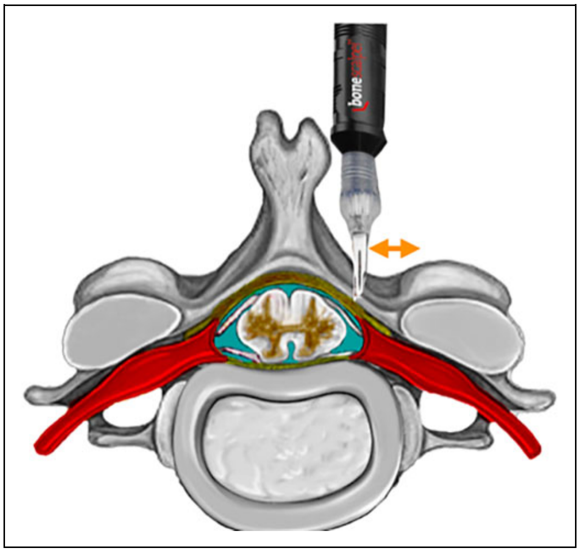

Figure 2. Axial cut illustration showing position of laminectomy cut at the lateral dural margin. This is usually 5 to 8 mm medial to facet margin. Specifically, it avoids direct injury of the roots and injury of the lateral gutter epidural plexus.

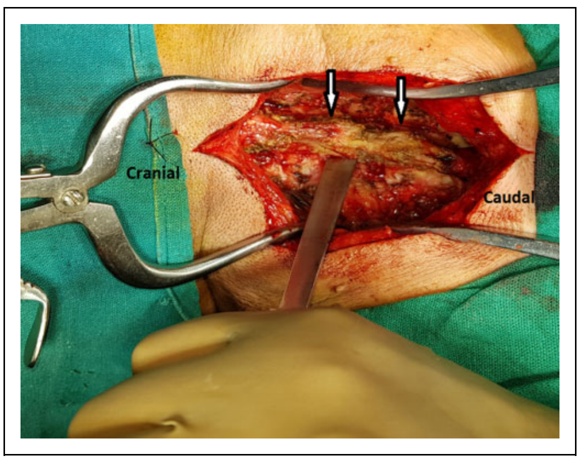

Figure 3. Osteotome being inserted into the cut created by UBS on the left side; it is twisted to break the remaining inner most cortex of the lamina. Arrow shows cuts created by UBS on right side.

Statistical Analysis

SPSS 20.0 software (SPSS Inc, Chicago, IL) was used for data analysis. We applied χ^2 test for evaluating the categorical data and Mann-Whitney *U* test for continuous data. Average values are presented in the tables as mean $\pm$ standard deviation. The difference was considered significant when *P* value was less than .05.

Results

A total of 414 CLs were performed at our institute between January 2004 and December 2017. Among these, 103 patients were excluded from the analysis since inclusion criteria were not satisfied in these cases. Patients who were excluded from the study were those lost to follow-up (n = 24), death within 1 year unrelated to surgery (n = 5), trauma (n = 15), tumor (n = 22), associated craniovertebral junction pathology (n = 15), spinal dysraphism (n = 1), and infection (n = 21). A total of 311 patients with minimum follow-up of 12 months were analyzed.

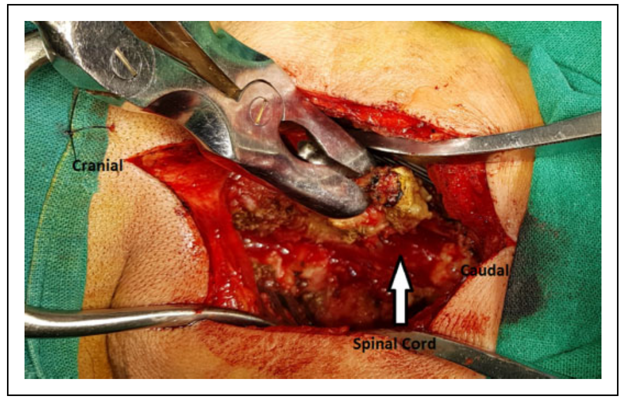

Figure 4. Bone nibbler holding the spinous process from caudal end and gently lifting the cut laminae to expose the underlying spinal cord.

Table 1. Demographic Variables in Both Groups. EBL and Surgery Duration is Lower in the UBS Group.

Variables	GpA	GpB	P^a
Total number of patients	124	187	NA
Age (SD) in years	61.18 (9.93)	62.04 (11.07)	.493
Male/female	112/12	166/21	
EBL in mL (SD)	90.24 (64.19)	98.4 (69.62)	.038
Surgery duration in minutes (SD)	65.52 (18.56)	80.87 (20.10)	.056
LHS in days (SD)	4.8 (1.57)	4.8 (2.44)	.623

Abbreviations: UBS, ultrasonic bone scalpel; SD, standard deviation; NA, not applicable; EBL, estimated blood loss; LHS, length of hospital stay.
[a] *P* value <.05 is significant.

GpA comprised 124 patients operated with UBS, and GpB comprised 187 patients operated with CM. Table 1 shows the demographic parameters and outcome measures of these 2 groups. Both groups were comparable in terms of average age, preoperative Nurick grade, mean duration of surgery, and hospital stay. Statistically significant difference was found in favor of UBS group in terms of lesser blood loss and better recovery rate (Table 2).

Table 3 shows complications observed in both groups. Both groups had equal number of dural injuries. All dural injuries were treated with primary repair or fat graft patch, water-tight closure, drain for 48 hours, and mobilization on the next day. There were no long-term sequel or complications observed due to dural tear. Nonsymptomatic palpable cerebrospinal fluid (CSF) collection was observed in 2 cases, which were managed conservatively. CSF fistula developed in 2 cases, which were sutured. Wound dehiscence due to superficial infection was reported in 2 patients. One patient in GpA had nerve root injury, which was in the initial cases of UBS because the osteotomy cut was made through the lamina with underlying

Table 2. Outcome Measures of Patients in Both Groups. Nurick Grade Recovery Rate Is Better in the UBS Group and Is Statistically Significant.

	Preoperative Nurick Grade (SD)	Postoperative Nurick Grade (SD)	Nurick Grade Recovery Rate (SD)
Ultrasonic bone scalpel: GpA	3.6 (0.97)	2.1 (0.88)	34.15 (13.34)
Conventional method: GpB	3.7 (0.98)	2.2 (0.97)	30.91 (13.06)
P	.950	.195	.035

Abbreviations: UBS, ultrasonic bone scalpel; SD, standard deviation; GpA, group A; GpB, group B.

Table 3. Surgical Complications

	GpA	GpB	*P*
Dural injuries	6	6	.66
C5 palsy	2	3	.99
Nerve root injuries	1	0	.39
Major neurological deterioration	1	11	.04

Abbreviations: GpA, group A; GpB, group B.

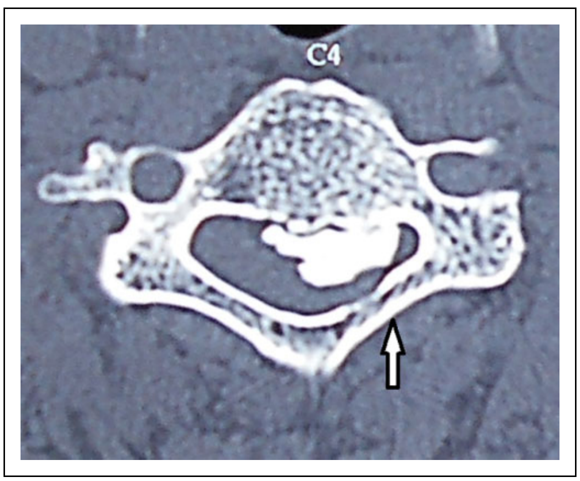

Figure 5. This is the case in which nerve root was inadvertently injured with UBS. Figure shows axial CT scan cut with extensive OPLL causing narrowing of the lateral recess.

OPLL mass and dural calcification (Figure 5). This patient had developed dural tear in the lateral recess with nerve root injury. Dural tear was repaired. The patient was found to have left C5 palsy that did not recover till 2-year follow-up. There were 2 patients in the UBS group and 3 patients in CM group who developed postoperative C5 palsy, which developed between 5 days and 4 weeks after surgery, and all of them recovered in 6 months. The incidence of transient neurological deficit immediately postoperatively was significantly higher, 5.8% (n = 11) in the CM group as against 0.8% (n = 1) in the UBS group. All these patients required prolonged intensive care unit (ICU) stay, steroid administration, and delayed rehabilitation. All patients with transient neurological deficit recovered only to their preoperative neurological status. Complex regional pain syndrome developed in many patients (40%) with neurological deficit or long-standing cervical myelopathy; this was managed conservatively. Symptomatic pneumo-cranium was observed in 2 patients and non-symptomatic in 2 patients. Urinary tract infection developed in 17 patients. Urinary catheterization was required to be kept for more than 3 weeks in 20 patients.

Discussion

Cervical myelopathy is a clinical description of signs and symptoms resulting from cervical spinal cord compression. It is commonly observed in elderly patients as a result of degenerative changes in the cervical spine. Radiologically, the compression of spinal cord is commonly caused by anterior bulging, calcified or herniated intervertebral disc, bony osteophytes, or degenerative spondylolisthesis.[11] OPLL is another major cause of cervical myelopathy. The choice of optimal surgical approach and technique remains debatable. Available options are anterior decompression and fusion, posterior approaches, or combined anterior plus posterior approach. Decision making depends on various factors such as host biology, host bone quality, kyphosis, coexisting axial neck pain, number of motion segments involved in cord compression, location of pathology, and the desire to preserve or limit motion.[12] Posterior approach is preferable in multilevel disease, cervical lordosis maintained, local kyphosis $<13°$, and cases with difficult anterior exposure. Laminectomy alone is an established treatment option for CSM. Although several authors have reported high incidence of post-laminectomy kyphosis,[13,14] this does not appear to cause symptoms or neurological abnormalities[15,16] and hence is being commonly performed. Laminectomies being an indirect decompression method, at least 3 or 4 consecutive laminae are removed to achieve adequate decompression. Posterior fusion is added to the laminectomy in cases where there is loss of cervical lordosis, instability on flexion extension radiographs, or laminoforaminotomy is required to decompress the cervical roots.

Complications associated with posterior cervical decompression surgery include infection, dural tear, epidural hematoma, incomplete decompression, incomplete resolution or progression of symptoms, axial neck pain, nerve root injuries, and spinal cord injuries. Postoperative neurological deterioration is one of the dreaded complications of CL with a rate of 1.8% to 10% observed in some major studies.[17-20] Majority of these were associated with further injury to spinal cord with progressive myelopathy. In our experience with CL, we observed a high rate (5.88%) of postoperative neurological deterioration with CM in GpB. As against this, postoperative neurological deterioration was observed in only 1 patient (0.8%) in GpA. All these cases that developed neurological deterioration required postoperative ICU care had extra cost implications, delayed postoperative period, delayed recovery, and rehabilitation. Such major complication subjects the surgeon as well as the patient and caregivers to excessive mental and financial stress, along with bringing a bad name to spine surgery as such. The reason for this postoperative deterioration was postulated to be due to acute cord dilatation that occurs secondary to decompression; it was considered as inevitable and unpredictable complication of cervical spine decompressive surgery. However, with the use of newer instruments like UBS and high speed drill/burr, this complication has been observed to be minimal.[21,22] A recent biomechanical study by Lin et al[1] supports this clinical observation and concludes, "In the setting of a stenotic spinal canal, spine surgeons should consider using the burr to perform laminectomy to minimize the degree of canal encroachment." However, such a biomechanical study with UBS is lacking.

The use of ultrasonic aspirator was first reported in 1947[23] for removal of dental plaques, and neurosurgical applications were reported in 1978.[18] However, its use in spine surgeries became evident only during the last decade. Ultrasonic devices have been described to generate vibrational forces to create localized tissue disruption. This property has been utilized in neurosurgery and spine surgery as ultrasonic aspirators and dissectors for removal of tumors and bone. UBS is an advancement of this technology. It has a narrow cutting blade that oscillates longitudinally. Micro-movements are produced at the frequency of 22.5 kHz with an excursion ranging from 30 to 300 µm depending on amplitude setting and blade geometry.[7] The recurring impacts pulverize the noncompliant crystalline structure resulting in a precise cut with minimal bone debris. It also has a self-irrigation system that provides lubrication and cooling at the working site to reduce the thermal injury. As the elastic property of soft tissue is higher than osseous structures, soft tissues are spared from damage by the ultrasonic cutting blade. UBS potentially provides a method of precise bone cutting while reducing the risk of injury to duramater and neural elements.[24,25]

Literature on UBS shows several advantages including decreased risk of mechanical injury, reduced thermal injury, and reduction in osseous bleeding, which improves visibility in the surgical field and provides significant reduction in surgical time.[26,27] In our experience, along with all the above-mentioned advantages, we have found UBS to be invaluable in cases with severe cord compression. The device tip allows the surgeon to create a precise cut of the laminae, without any undue pressure on the cord and without entering the already compromised spinal canal. It has significantly reduced the risk of transient neurological deficit occurring due to inadvertent cord injury during CL and this has been the biggest advantage of UBS. In the present study, the neurological recovery was significant in both groups, but was better in GpA (Figure 6). The overall outcome in our group of UBS is comparable but little lower than in other studies.[9] So the primary hypothesis that UBS reduces the incidence of neurological worsening and improves the outcome is very obvious and statistically significant.

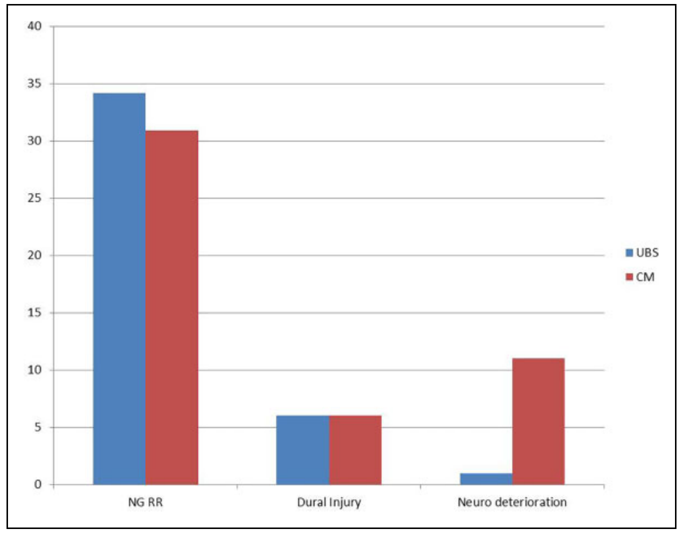

Figure 6. Comparison of outcomes in terms of Nurick grade recovery rate (NG RR), dural injuries, and neurological deterioration among both groups.

The use of UBS has boosted our confidence in dealing with cases of severe cord compression. There is a word of caution though. The use of UBS is not completely safe and without complications. Cases with dural calcification warrant extra care while using UBS, because UBS can cut through the calcified dura and damage the neurological tissue. It is also advisable to carefully read the axial section of MRI preoperatively and assess the lateral part of canal where the cut of UBS is anticipated. In those cases where the lateral part of spinal canal is too narrow due to ossified posterior ligamentum flavum, UBS can cause nerve root/dural injuries if the device tip penetrates the inner cortex of lamina, as observed in one of our initial cases. In such cases, it is recommended to use UBS to cut only through the outer cortex of lamina and leave the thin strip of inner lamina intact, which is subsequently broken by twisting action through an osteotome (Figure 3) or bone nibbler.

There have been favorable literatures on the use of high speed drill/burr for CL.[2-4] Nevertheless, there is a risk of instrument slippage and causing mechanical or thermal damage to neural tissue.[6,8] In addition to this, there is excessive bleeding and the procedure is time consuming.[8,26-28] In the present study, the EBL and duration of surgery were significantly low in GpA, and the observed bone end bleed and epidural bleed were also low (Figure 7). The LHS and overall complications were low as well. All these factors indirectly reduced the cost and improved outcome, and therefore can be considered as secondary gains of UBS.

Limitations of the Study

This being a retrospective study has its inherent limitations. The comparison was with CM and UBS group rather than the current standard HSD and UBS. There was no randomization as well. The UBS experience was on the time line of the surgeon in his later career. This, by itself, would have contributed to

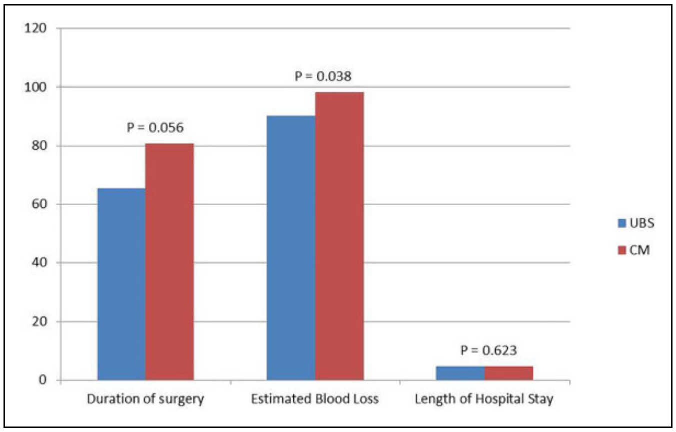

Figure 7. Comparison of the duration of surgery, estimated blood loss, and length of hospital stay among both groups.

better outcome. Like any instrument or technique, using UBS also has a learning curve, and a higher complication rate is expected in the initial few cases. This factor was not taken into account while analyzing the data.

The outcome of both groups in the present study is less as compared to other large series. This may be either due to the surgical technique or due to the fact that in our series, more patients presented with higher (4 or 5) Nurick grade preoperatively. Moreover, there is heterogeneity of the cohort, and cases in our series included both CSM and OPLL. They are varied pathologies and outcomes cannot be generalized. Additionally, the presentation of our patients was very late, with severe radiological grades, thereby worsening prognosis. The scoring system used was conventional Nurick grade. A better scoring system like mJOA (Modified Japanese Orthopaedic Association) with additional Neck Disability Index would have given more objective assessment. Also, other factors were not objectively graded, which may have implication on outcomes such as radiological grade, smoking, age, diabetes mellitus, comorbidities, and so on.

Low cost though mentioned as a secondary gain is more logical rather than actual measurement. It would require actual analysis as multiple parameters are involved in short- and long-term cost analyses. Biomechanical studies with UBS are lacking. Thermal and pressure damages are known to occur with both HSD and UBS, but there is no objective method described so far to quantify these damages. So experience plays a major role here, as with any other technology.

Conclusion

CL performed with CM and UBS provides comparable results in terms of mean duration of surgery, EBL, and recovery rate. However, postoperative neurological deterioration was observed in CM in a significant number of cases, which necessitated ICU admission, additional morbidity, and additional expenditure. UBS, when used carefully, provides a safe and effective means of decompression through laminectomy in cervical cord compressive pathologies. Larger comparative studies with standard HSD is needed to define outright the superiority of UBS, which is likely.

Declaration of Conflicting Interests

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ORCID iD

Ajay Krishnan, MS https://orcid.org/0000-0001-9808-2371
Ravi Ranjan Rai, MS https://orcid.org/0000-0002-0873-6907

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