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IDEAS AND TECHNICAL INNOVATIONS

Ultrasonic bone scalpel: utility in cervical corpectomy. A technical note

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Abstract

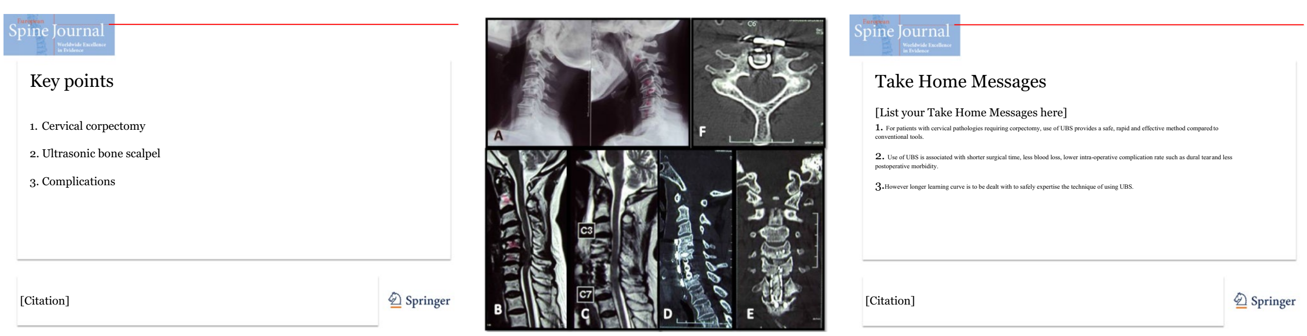
Purpose Anterior cervical corpectomy and fusion (ACCF) is a technically challenging surgery. Use of conventional instruments like high-speed burr and kerrison rongeurs is associated with high complication rates such as increased blood loss and incidental durotomy. Use of ultrasonic bone scalpel (UBS) in cervical corpectomy helps to minimize such adverse events.

Methods We performed a retrospective study based on the data of 101 consecutive patients who underwent cervical corpectomies with UBS for different cervical spine pathologies from December 2014 to December 2016. Total duration of surgery, time taken for corpectomy, estimated blood loss, and incidental durotomies were noted.

Results Total surgical time was 30–80 min (59.36 ± 13.21 min) for single-level ACCF and 60–120 min (92.74 ± 21.04 min) for double-level ACCF. Time taken for single-level corpectomy was 2 min 11 ± 10 s and 3 min 41 ± 20 s for double-level corpectomy. Estimated blood loss ranged from 20–150 ml (52.07 ± 29.86 ml) in single level and 40–200 ml (73.22 ± 41.64 ml) in double level. Four (3.96%) inadvertent dural tears were noted, two during single-level corpectomy and other two during double-level corpectomy.

Conclusions Use of UBS is likely to provide a safe, rapid, and effective surgery when compared to conventional rongeurs and high-speed burr. The advantages such as lower blood loss and lower intra-operative incidental dural tears were noted with the use of UBS.

Graphical abstract



Keywords Cervical corpectomy · Ultrasonic bone scalpel · Complications

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Introduction

Cervical corpectomy (ACCF) and fusion is a technically challenging procedure associated with excellent outcomes [1–7]. Use of the conventional instruments such as high-speed burr (HSB) and rongeurs may increase the rate of intra-operative and post-operative complications with inappropriate use [8]. Intra-operative complications such as prolonged operative time, excessive intra-operative bleeding from raw cancellous bony surfaces, inadvertent dural tear, injury to cord, and epidural venous plexus have been reported in the literature [9–19]. Introduction of ultrasonic bone scalpel (UBS) in spine surgery has not only allowed precise and controlled bone cutting, but also has minimized the chances of injury to the surrounding soft tissues [11, 12, 16, 20]. UBS has been used in various spinal surgeries such as laminectomy, laminoplasty, and deformity correction. The safety and efficacy of UBS in patients undergoing neurosurgical, oral, maxillofacial, and spinal surgeries have been published with good results [21–24]. There is limited data about the application of UBS in cervical spine surgery, and to the best of our knowledge, there is no published literature on its use in ACCF. Our purpose of this study is to report the surgical technique, advantages with newer technology, and intra-operative events with the use of UBS in ACCF.

Materials and methods

A retrospective review was performed in our tertiary care centre for all the cases of ACCF using UBS performed between December 2014 and December 2016. Cases with complete medical records were included in the study. Patient demographics, diagnosis, surgical procedure, number of levels of corpectomy, total duration of surgery, time taken for corpectomy (use of UBS), estimated blood loss, and incidental durotomies were noted. UBS (Misonix, Inc., Farmingdale, NY, USA) was used to perform cervical corpectomy in all cases.

Surgical technique

All the patients were operated under general anesthesia in supine position, with neck in slight extension. A standard left-sided anterior transverse or oblique incision (Smith Robinson approach) was used for the exposure. Superficial and deep meticulous dissection was performed keeping in mind adjacent vital structures (trachea, esophagus medially and carotid vessels laterally). We prefer to incise omohyoid (at C5–6–7 levels) and to repair it at the end of surgery to restore the anatomy, prevent post-operative hematoma and fibrosis. After the level identification on imaging, pins were introduced in the vertebra above and below the proposed corpectomy level. Pins were distracted using the distractor that aids in discectomy. Adjacent-level discectomies of the intended corpectomy were done. The vertebral endplates were scraped to remove the cartilage and bony endplate was preserved to prevent graft subsidence. Multiple small holes were made in the end plates to facilitate fusion between vertebral body and cage filled with bone graft. The landmarks of the vertebral body to be resected were marked. Lateral margins of vertebral body resection are defined by the medial border of uncovertebral joints. UBS was used to cut the vertebral body down through the posterior cortex to the level of Posterior Longitudinal Ligament (PLL). Care should be taken to limit the contact time between tip of the scalpel blade and dura to prevent thermal necrosis. Feeling of giveaway is considered as posterior endpoint of corpectomy. Straight osteotome was used to disengage the corpectomy fragment and was removed in toto using Allis forceps. Approximately 14–17 mm of vertebral body was excised and was used as a bone graft, as shown in Fig. 1. Any remnants of PLL were separated from dura using a 1 mm micro curette and removed in piecemeal using 1 mm/2 mm Kerrison rongeurs until the dura was adequately decompressed. Dural tears or avulsions were managed with the use of dura patch. If PLL ossification is noted on preoperative imaging, "floating technique" of PLL release was done [25]. A mesh cage filled with morselized cancellous bone was placed in the corpectomy defect over which anterior locking plate was fixed. Occasionally, one screw was placed through the plate into the cage to provide additional stability. All the patients were mobilized on second post-operative day depending on the neurological status. Drain was left for a longer duration in cases of dural leak and removed when the collection was less than 20 ml over a period of 24 h. Soft cervical collar was used intermittently and discontinued after 12 weeks.

UBS system has a hand piece that has interchangeable tips of different disposable sizes and geometry with a self-irrigation jet nozzle. The tip of the instrument oscillates in linear fashion at the ultrasonic frequency. It uses a piezoelectric transducer to convert electrical signal into a mechanical vibration. 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. The recurring impacts pulverize the non-compliant crystalline structure resulting in precise cut. The more compliant adjacent soft tissue is theoretically not affected by the ultrasonic oscillations [10, 14]. We have used 25 mm standard blunt blade (MXB-25) with a short extension (57 mm) and a silicon cover.

Results

A total of 101 patients were included in the study. Mean age of patients at surgery was 55.86 ± 16 years (range 8–84 years). 87 (86.13%) were male and 14 (13.87%) were female. Among the operated cohort, 84 (83.16%) were degenerative, 9 (8.91%) infective, 4 (3.96%) traumatic, and 4 (3.96%) were neoplastic. 70 (69.30%) had single-level corpectomy and 31 (30.69%) underwent double-level corpectomies. C6 (42.85%) was the most common level in single-level corpectomy group and C4–C5 (67.64%)

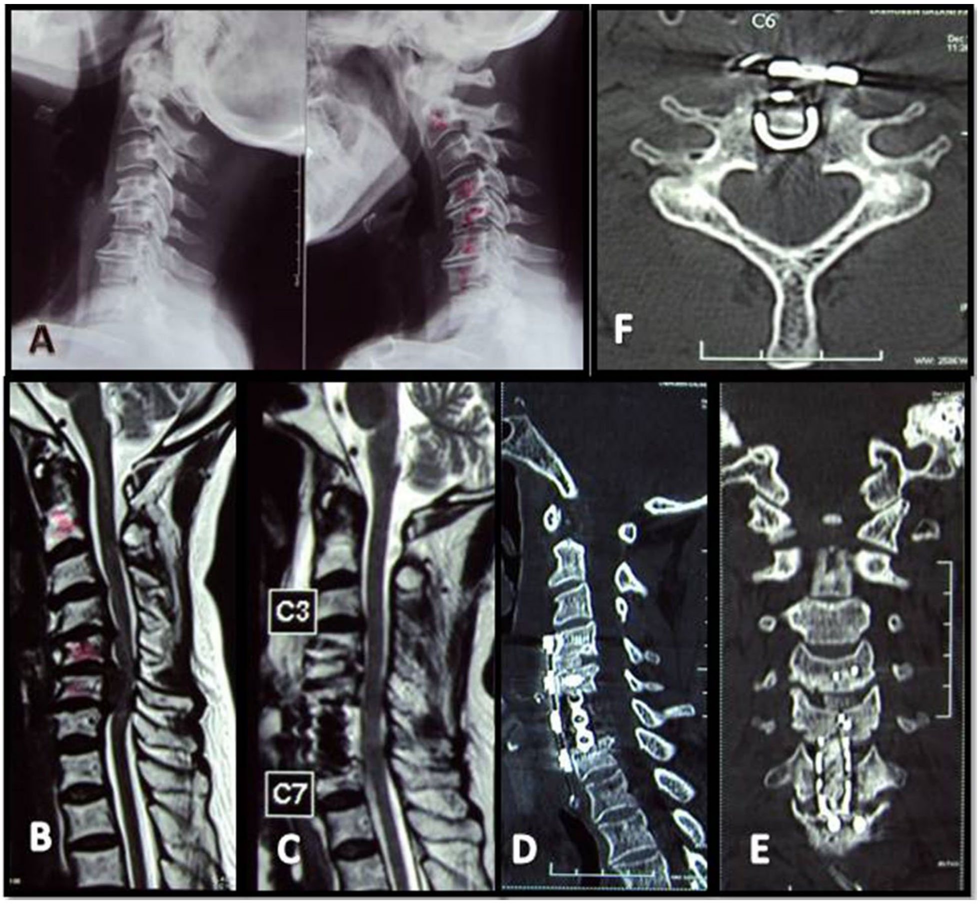

Fig. 1 **a** Preoperative flexion and extension images of cervical spine showing loss of lordosis. **b** Preoperative sagittal MRI image showing a discogenic stenosis at C4–5 and a large inferiorly migrated disc behind C6 vertebral body with significant compression on the cord. **c** Post-operative sagittal MRI image showing complete decompression of the cord at the affected levels. **d** Post-operative sagittal CT image showing C4–5 inter body bone graft obtained from C6 corpectomy and a mesh cage with bone graft placed between C5–7 with an anterior plate extending from C4–7. **e**, **f** Post-operative coronal and axial CT images showing the lateral margins of vertebral body resection

in double-level group. Total surgical time was 30–80 min (59.36 ± 13.21 min) for single-level corpectomy and 60–120 min (92.74 ± 21.04 min) for double-level corpectomy. Time required for single-level corpectomy (use of UBS) was 2 min 11 ± 10 s and 3 min 41 ± 20 s for double-level corpectomy. Estimated blood loss ranged from 20–200 ml (58.60 ± 35.1 ml); 20–150 ml (52.07 ± 29.86 ml) in single-level group; and 40–200 ml (73.22 ± 41.64 ml) in double-level group. We noted four (3.96%) inadvertent dural tears, two during single-level corpectomy, and two during double-level corpectomy.

Discussion

Spinal pathologies such as degeneration, infection, trauma, and neoplastic involvement are treated by decompression with or without fusion [1–7]. ACCF is a commonly performed surgery for anterior decompression of cervical spine. Surgical technique of ACCF has evolved over past few decades. Despite various technical advances, ACCF is not devoid of intra-operative complications and post-operative morbidity especially in cases of calcified disc, kyphotic deformity, and hypertrophic posterior longitudinal ligament (HPLL) or ossified posterior longitudinal ligament (OPLL) [26–29]. Use of conventional tools such as kerrison rongeurs and HSB is associated with high risk of increased intra-operative bleeding, prolonged operative time, incidental durotomy, injury to cord, and epidural vessels [18]. Spinning and increased heat production with burr is reported to cause damage to adjacent soft tissue [10, 30]. In light of potential complications, efforts have been made to introduce a safe and effective bone cutting system [12, 21, 31, 32].

Introduction of UBS for spinal surgery added an advantage of performing a controlled, precise, and narrow bone cuts. Corpectomy bone obtained is useful as a bone graft for fusion. The use of ultrasonic vibration for cutting of bone was developed several decades ago [23, 24]. An ultrasonic bone aspirator was first used in 1947 for the removal of dental plaques [23]. After 1950, ultrasonic bone cutter gained widespread use in osteotomies in the field of dentistry and oral-maxillofacial surgery [10, 24]. In 1978, UBS was used for the first time in neurosurgical procedure. Since then, UBS has been used for skull base surgery for several years and is recently introduced in spine surgery [18, 20, 32, 33]. In this study, we discuss the surgical technique of using UBS for ACCF. The advantages of using UBS are precise and narrow bone cuts in the vertebra that reduce intra-operative blood loss by reduction in exposure of bleeding cancellous bone for a longer time and also by air–water cavitations' effect [12]. Corpectomy using UBS helped in reducing the overall surgical time and in preventing further complications. Due to inherent property of elasticity, soft-tissue damage is noted to be minimal as it can withstand high amount of impact energy generated due to UBS vibration [9, 10, 20, 21]. Thermal damage to dural sac is taken care by the constant irrigation that is a part of UBS system (self-irrigation jet nozzle).

Incidence of inadvertent dural tear following ACCF with conventional instruments ranges from 0 to 21% in the literature [15, 18, 25, 34]. CSF leak due to inadvertent dural injury leads to potential complications such as formation of pseudo-meningocele, airway compromise and meningitis [6, 35–37]. Sarkar S et al. reported an incidence of 4.3% incidental durotomies in his series of 468 patients operated by cervical corpectomy using conventional techniques. OPLL and skip corpectomies were associated with increased risk in their study [15]. The incidence of dural tear has been reported to be similar or even lower with the use of UBS [16, 17]. In a study by Bydon et al., pediatric cases of achondroplasia operated with UBS and HSB were compared and dural injury was reported in nine (45%) cases with HSB [23]. One can very well argue that in cases of ACCF using UBS, the chances of dural tear/avulsions are present while lifting up the corpectomy fragment as in toto removal of resected vertebral body is a blind procedure. This can be taken care by careful pre-op planning, gradual lifting of the vertebra and using 1 mm kerrison punch to disengage and dislodge the resected vertebra. In the present study, we noted four (3.96%) inadvertent dural tears, two in single-level corpectomy, and the other two in double-level corpectomy cases. These patients were managed conservatively using dura patch intra-operatively or keeping the drain for longer duration in peri-operative period.

Blood loss during ACCF may be excessive with conventional tools due to exposed cancellous bony surfaces for longer time and also increases with the number of corpectomies [27]. Several previous studies have reported that UBS significantly reduces blood loss in comparison with conventional tools [11, 19]. The proposed mechanism behind the reduction in blood loss from bone ends using UBS is air–water cavitations' effect that assists in closing the smallest blood vessels and also helps in rinsing away any blood from the larger vessel [12]. Li et al. in a comparative study of 47 patients of cervical laminoplasty with conventional burr and UBS reported significantly lower blood loss in UBS group [11]. Sanborn et al. in his lab study on ovine models concluded that operating time in experimental models was significantly lower [9]. Hu et al. reported reduction in osseous bleeding from cut ends due to local haemostatic effect with the use of UBS as compared to conventional methods [10]. Bartley CE et al. reported 30–40% reduction of blood loss from cut ends with use of UBS in 20 patients with adolescent idiopathic scoliosis [13]. Onen et al. reported results of his comparative study in 46 patients of cervical myelopathy operated with laminectomy. Mean blood loss of 180 ml was noted in UBS group (23 patients) when compared to 380 ml in HSB group (23 patients) [14]. In our study, we noted a lower amount of blood loss with the use of UBS. Though we cannot assess the actual blood loss from the cut bone ends and epidural blood loss separately, on the whole, the estimated blood loss in our study was likely to be lower.

Recent systematic review by Tetreault L reported that longer operative time was associated with increased peri-operative complications [38]. Variable results were reported with respect to the duration of surgery with the use of UBS and conventional techniques [9–11, 14, 16, 19]. Duration of surgery is dependent on various factors and also initial learning phase with a newer instrument. Our average total duration of surgical time was noted to be shorter in comparison with studies with conventional instruments.

We report the results of largest case series in the use of newer modality UBS in cervical corpectomy surgery. However, our study has few limitations. Ours is a retrospective study without a control group. Though we did not discuss about the clinical results in our study, the results are in process of collection and will be published in the upcoming studies. For any superiority studies, cost analysis becomes an important consideration for general application which was not done in our study. Well-designed prospective comparative studies will be necessary to ascertain the real benefits and also future use of UBS in other parts of spine.

Conclusion

For patients with cervical pathologies requiring corpectomy, the use of UBS is likely to provide a safe, rapid and effective method compared to conventional tools. The use of UBS is associated with shorter surgical time, less blood loss, and lower intra-operative complication rate such as dural tear and less post-operative morbidity. However, longer learning curve is to be dealt with to safely expertise the technique of using UBS.

Compliance with ethical standards

Conflict of interest All the authors declare that they have no conflicts of interest.

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