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ORIGINAL RESEARCH

Assessment of Safety and Efficacy of Full-Endoscopic Ultrasonic Bone Scalpel for Cervical Spondylotic Radiculopathy

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Objective: To evaluate the safety and efficacy of the endoscopic ultrasonic bone scalpel (EUBS) in percutaneous endoscopic cervical discectomy (PECD).

Methods: A retrospective analysis was conducted on data from 41 patients with cervical spondylotic radiculopathy (CSR) who underwent surgical treatment and were followed up at Xuzhou Central Hospital between January 2019 and June 2023. Among them, 22 patients were treated using EUBS and 19 using a high-speed drill (HSD). The two groups were compared in terms of operative time, bone fenestration time, frequency of surgical field blurring, length of hospital stay, complication rate, postoperative Visual Analog Scale (VAS) and Japanese Orthopaedic Association (JOA) scores, C2–7 Cobb angle, and intervertebral disc height at the operative level.

Results: The follow-up period ranged from 16 to 36 months. The bone fenestration time in the EUBS group was significantly shorter than that in the HSD group ($P < 0.05$), although no significant differences were observed in total operative time or frequency of surgical field blurring. The postoperative complication rate in the EUBS group was 0%, which was not statistically different from the 5.26% observed in the HSD group. Both groups showed significant improvements in VAS and JOA scores from three months post-surgery to final follow-up, with no significant differences between the groups. Similarly, no significant intergroup differences were found in C2–7 Cobb angle or intervertebral disc height at any time point.

Conclusion: The application of EUBS in PECD is safe and effective for treating CSR. It can reduce bone fenestration time and improve surgical efficiency.

Keywords: cervical spondylotic radiculopathy, percutaneous endoscopic cervical discectomy, endoscopic ultrasonic bone scalpel

Introduction

CSR is a degenerative condition of the cervical spine characterized by lateral disc herniation, facet joint degeneration, osteophyte formation, and other factors leading to nerve root compression. This compression manifests as radiating pain, numbness, or reduced mobility in the neck, shoulders, and upper limbs. CSR accounts for 60–70% of all cervical spondylosis cases.[1] For patients with CSR who do not respond to conservative treatments or whose symptoms progressively worsen, decompression surgery may be necessary. Anterior Cervical Discectomy and Fusion (ACDF) remains the standard surgical intervention for cervical spondylosis, widely recognized for its efficacy.[2] However, ACDF has several limitations, including restricted cervical spine movement, potential adjacent segment degeneration, and loss of intervertebral disc height. Additionally, complications associated with this approach—such as hoarseness, dysphagia, and abnormal breathing—remain significant challenges that cannot be

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entirely avoided.[3] In recent years, advancements in spinal endoscopic technology have revolutionized the treatment of cervical spondylosis, offering increasingly minimally invasive options. PECD presents several advantages over traditional surgical methods. It significantly reduces the risk of inadvertent injury to critical anterior cervical structures such as the trachea, esophagus, and laryngeal recurrent nerve. Furthermore, PECD eliminates the need for fusion and fixation, preserving the natural curvature of the cervical spine and maintaining segmental mobility. This technique also mitigates the likelihood of postoperative degeneration in adjacent vertebral bodies and helps maintain intervertebral disc height.[1,4]

In endoscopic spinal surgery, the HSD and laminectomy forceps are commonly employed to remove laminae and hyperplastic osteophytes. The HSD offers advantages such as low vibration, minimal impact, rapid speed, high precision, and a certain hemostatic effect on cancellous bone. However, its use poses challenges in maintaining stability, potentially leading to twisting of surrounding soft tissues and serious complications like vascular injury, nerve damage, or dural sac tears.[5] The UBS represents a novel osteotomy device that has gained traction in spinal surgery due to its strong bone selectivity, high grinding accuracy, low thermal damage, anti-scaling properties, and hemostatic capabilities.[6–8] At present, the EUBS has not yet been applied in clinical practice. To address this gap, this study aims to explore a novel ultrasonic bone scalpel system that can be used under endoscopic guidance (Figure 1), characterized by high precision and efficient osteotomy capability. The primary objective is to evaluate its safety and effectiveness in the treatment of patients with CSR undergoing PECD. We hope that this research will provide a safer and more effective therapeutic option for clinical application, thereby improving both the treatment outcomes and quality of life for patients suffering from CSR.

Objects and Methods

Inclusion and Exclusion Criteria

Inclusion criteria: (1) single-segment CSR diagnosed by imaging; (2) patients with typical symptoms of unilateral cervical nerve root compression and consistent with imaging findings; (3) poor or ineffective conservative treatment (traction, physiotherapy, medication, etc.) after 8–12 weeks; (4) use of EUBS or HSD during PECD; (5) complete medical records and follow-up data. Exclusion criteria: (1) combined with cervical spondylotic myelopathy; (2) history of cervical spine surgery, trauma, tumor or tuberculosis; (3) combined with cervical segmental instability, spinal deformity, ossification of intervertebral disc; (4) cervical kyphosis ≥10°; (6) severe osteoporosis; (7) complicated by other systemic diseases or inflammation; (8) patients with severe mental illness who are unable to cooperate.

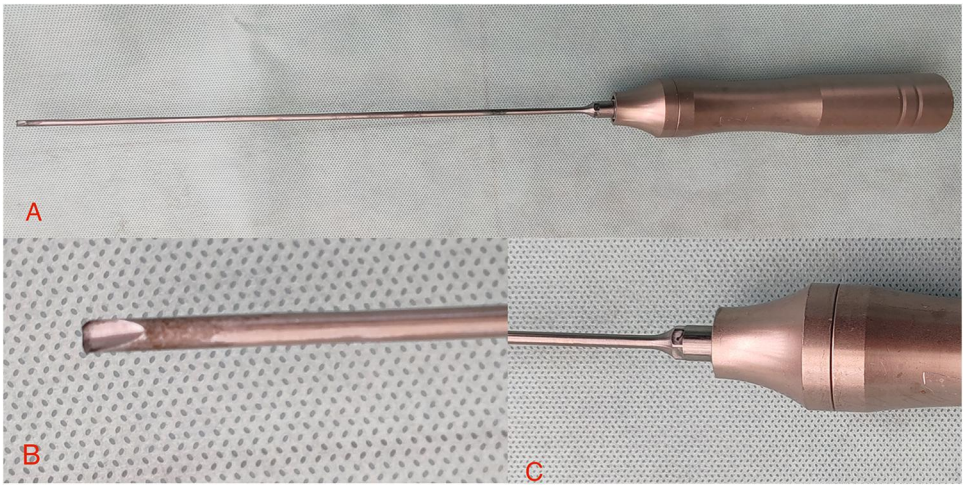

Figure 1 Structural Diagram of EUBS. (**A**) Overall appearance of the EUBS system. (**B**) Detailed view of the EUBS connecting rod and cutter head. (**C**) EUBS handle and generator unit.

General Information

This study retrospectively analyzed the clinical data of patients diagnosed and treated for cervical spondylotic radiculopathy (CSR) at Xuzhou Central Hospital from January 2019 to June 2023. A total of 41 patients met the inclusion criteria, comprising 24 males and 17 females. Patients were divided into two groups based on the surgical tool used during PECD. EUBS Group: Included 22 patients (13 males and 9 females) with a mean age of 57.68±14.27 years. HSD Group: Included 19 patients (11 males and 8 females) with a mean age of 56.11±13.34 years. Follow-up duration ranged from 16 to 36 months, with an average follow-up period of 25.5±5.0 months. Baseline characteristics did not significantly differ between the two groups, ensuring comparability. Detailed demographic information is summarized in Table 1.

Procedure of Surgery

To alleviate patient anxiety and pain during the procedure, preoperative psychological counseling was provided, along with sedatives (50 mg pethidine + 25 mg promethazine) to ensure a successful operation. Local anesthesia was administered, and patients were positioned prone on a plaster bed, with the head and chest supported and the neck slightly flexed forward to fully expose the posterior cervical region. The operative field was routinely sterilized and draped with sterile towels. A C-arm X-ray machine was used to locate the pathological intervertebral disc, and the surface projection of the "V" point —where the lamina gap intersects with the medial edges of the superior and inferior articular processes—was marked. Anesthesia was achieved by layer-by-layer infiltration of 10 to 20 mL of 0.4% lidocaine, centered on the "V" point and applied to the surface of the lamina. A 7 mm longitudinal skin incision was made, and a soft tissue dilator was inserted to sequentially dilate the soft tissues to the "V" point. Using the dilator, the soft tissues were dissected down to the "V" point. Under fluoroscopic guidance, a working cannula was then inserted through the dilator, confirming that the cannula's incision was accurately positioned within the "V" point area (Figure 2A).

After removing the dilator, the spinal endoscope was inserted, and the procedure was performed under continuous saline irrigation to maintain clear visualization. Forceps and radiofrequency electrodes were used to meticulously remove soft tissue from the facet joint surface, fully exposing the lower edge of the superior facet joint, the upper edge of the inferior facet joint, and the inner side of the joint between the superior and inferior facet joints, commonly referred to as the "V" point. In the EUBS group, an endoscopic ultrasonic bone cutter was employed to position the blade tip on the facet joint surface and partially remove bone tissue around the "V" point for decompression; the cutting force was adjusted to be just sufficient for the bone cutter to easily penetrate the bone (Figure 2B). The procedure was halted when the inner layer of the facet joint cortex was cut through, indicated by a hollow sensation felt during the operation, at which point the bone block was excised using forceps. The lateral ligament was then removed externally to expose the lateral edge of the dural sac and the nerve root (Figure 2C and E). Following the course of the nerve root, an EUBS is used in conjunction with a bone forceps (1 to 2 millimeters in size) to carefully remove 1 to 3 millimeters of the lateral mass, ensuring not to exceed one-third of the facet joint. Subsequently, a small amount of bone from the superior margin of the pedicle of the lower vertebra is also removed. This procedure aims to further enlarge the space surrounding the cervical nerve roots. Radiofrequency ablation was employed to separate the nerve root from the dural sac, and the

Table 1 Basic Characteristics of Patients

Characteristic	EUBS	HSD	T Value	P Value
Sex (male/female)	22 (13/9)	19(11/8)		
Age (years)	57.68±14.27	56.11±13.34	0.828	0.413
Segments				
C3-C4	2	0		
C4-C5	3	1		
C5-C6	8	8		
C6-C7	7	10		
C7/T1	2	0		
Follow-up period (month)	18.56±3.31	17.56±2.97	0.916	0.366

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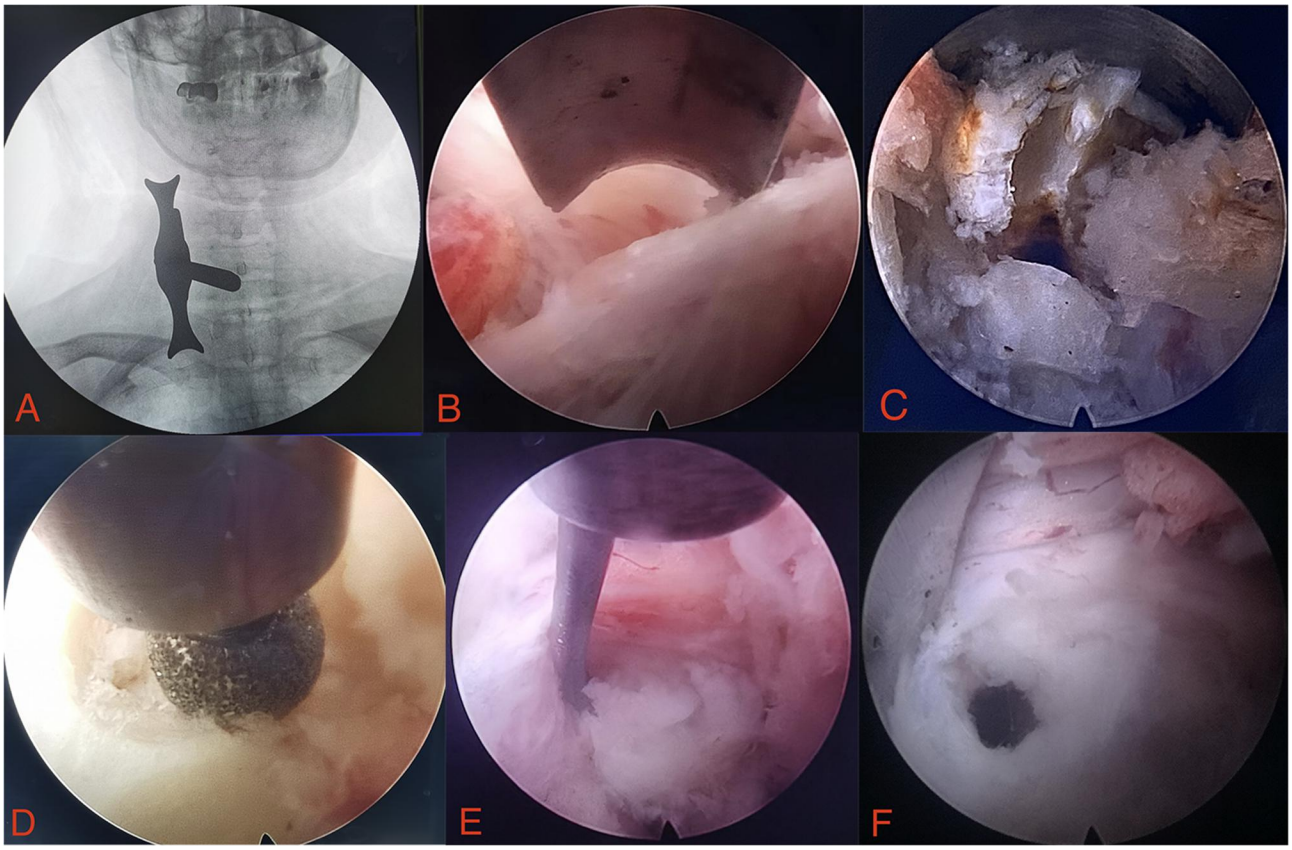

Figure 2 Surgical Procedures. (**A**) C-arm X-ray fluoroscopy for precise positioning and insertion of the working cannula. (**B**) Placement of the EUBS on the bone surface of the lamina in preparation for osteotomy. (**C**) Ongoing EUBS osteotomy process, demonstrating the fragmented bone post-osteotomy. (**D**) Utilization of HSD to remove bone surrounding the "V" point and establish the surgical window. (**E**) Exploration and release of the axilla of the nerve root through nerve dissection, exposing the free nucleus pulposus. (**F**) Removal of the protruding nucleus pulposus, relieving nerve compression, and ensuring well-perfused blood vessels on the surface of the nerve root.

working cannula was positioned in the subdural space under the nerve root via a tongue-shaped incision. The nerve root was explored and decompressed using a nerve retractor. Loose and mobile nucleus pulposus material was extracted with a nucleus probe, and a curette was used under microscopic guidance to thoroughly search for and remove any remaining loose nucleus pulposus within the disc.

In the HSD group, a high-speed drill was used to remove the outer cortex and cancellous bone of the lamina and articular process, followed by excision of the inner cortex with a bone forceps (Figure 2D). The lateral ligamentum flavum was then incised to expose the lateral margin of the dural sac and the nerve roots. Utilizing a combination of the HSD and bone forceps, 1–3 mm of the lateral mass adjacent to the nerve root was carefully removed, ensuring that no more than one-third of the articular process was resected. A small amount of bone from the upper inner margin of the inferior vertebral pedicle was also removed to further expand the subdural space for the nerve root. Separate the nerve root from the dural sac, position the working cannula beneath the nerve root, and carefully explore and release the area under the nerve root. Remove any free or loosely detached nucleus pulposus, and inspect the intervertebral disc to determine whether any nuclear remnants remain (Figure 2F).

Under microscopic observation, adequate decompression of the nerve root was confirmed, with restored surface blood circulation and good vascular perfusion, and no local hemorrhage was noted. All instruments were carefully withdrawn, and the incision was sutured. During the procedure, it is important to continuously monitor and inquire about the patient's pain responses and limb mobility in real-time. Postoperatively, both groups of patients received appropriate pharmacological treatments as needed, including analgesics, anti-inflammatory agents for swelling reduction, and neurotrophic medications to support nerve recovery. Patients were fitted with cervical collars for protective immobilization for 4 weeks and underwent guided cervical rehabilitation exercises under medical supervision.

Observational Evaluation Indicators

Surgical indicators, including the total operation time, the osteotomy time (specifically, the time required for bone removal around the V point), the frequency of surgical field blurring (defined as instances where blood exudation caused more than 1 seconds of blurred vision), the length of hospital stay, and postoperative complications, were meticulously recorded and compared; clinical efficacy was evaluated through the VAS for assessing neck and shoulder pain severity preoperatively, 3 months postoperatively, and at the last follow-up, and the JOA score for neurological status of the spinal cord also assessed preoperatively, 3 months postoperatively, and at the final follow-up; radiographic parameters included the C2-7 Cobb Angle, which measured the angle between the lower endplates of C2 and C7 to reflect the physiological curvature of the cervical spine, and the average intervertebral disc height of the surgical segment, defined as the mean distance between the anterior and posterior edges of the upper and lower endplates on lateral X-ray films of the cervical spine, with an intervertebral disc height less than 5 mm indicative of cervical segmental instability,[9] and to minimize measurement error, two independent radiologists not involved in the surgery conducted separate measurements, with the final results calculated as the average of these two assessments.

Statistical Methods

Data were analyzed using SPSS 25.0 software measurement data conforming to a normal distribution were represented as mean±standard deviation ($\bar{x} \pm s$). Between-group comparisons were conducted using independent samples t-tests, while within-group comparisons utilized paired samples t-tests. Count data were expressed as frequencies and percentages, with between-group comparisons analyzed using chi-square tests. All tests were two-tailed, with a significance level set at α=0.05.

Results

All operations on 41 patients were successfully completed without any serious complications such as vascular, nerve, or spinal cord injuries. In the EUBS group, the mean total operation time was 105.31±26.17 minutes, the mean duration of bone fenestration was 48.54±10.51 minutes, the mean number of surgical field blurring incidents was 7.86±2.43, and the mean length of hospital stay was 6.82±2.44 days. In the HSD group, the mean total operation time was 118.95 ±33.27 minutes, the mean duration of bone fenestration (window opening time) was 57.89±15.66 minutes, the mean number of surgical field blurring incidents was 9.15±2.81, and the mean length of hospital stay was 7.26±2.77 days. The duration of bone fenestration was significantly lower in the EUBS group compared to the HSD group (P<0.05). However, there was no significant difference in the length of hospital stay between the two groups (P=0.559) (Table 2).

Both groups demonstrated significant improvements in VAS scores, and JOA scores at 3 months postoperatively and at the final follow-up (all $P < 0.05$), with further significant improvements observed at the final follow-up compared to 3 months postoperatively (all $P < 0.05$). There were no statistically significant differences in VAS scores between the two groups at baseline, 3 months postoperatively, and at the final follow-up (all $P > 0.05$). While there was no significant difference in JOA scores between the two groups at baseline and at the final follow-up (both $P > 0.05$). These results are summarized in Table 3.

Table 2 Comparison of Perioperative Data Between the Two Groups (s Mean ± Standard Deviation)

Parameter	EUBS	HSD	P Value
Operative time (min)	105.31±26.17	118.95±33.27	p=0.15
Osteotomy time(min)	48.54±10.51	57.89±15.66	p<0.05
Using RFE (times)	7.86±2.43	9.15±2.81	p=0.12
Drainage fluid (mL)	13.00±5.95	19.81±2.56	<0.001
LOS (d)	6.82±2.44	7.26±2.77	p=0.58
Cost (1000 RMB)	30.52±3.53	30.69±9.26	p=0.89

Abbreviations: RFE, radiofrequency electrode; LOS, length of stay.

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Table 3 Comparison of VAS and JOA Scores Between the Two Groups

Index	Time	EUBS	HSD	T Value	P Value
VAS	Preop	6.77±0.87	5.63±1.64	2.90	0.010
	Post-op	1.73±0.81	1.68±0.58	0.22	0.826
	Postop 3m	0.86±0.54	1.52±0.51	−3.62	0.002
	Postop 6m	0.54±0.11	0.73±0.45	−1.14	0.268
	Postop 12m	0.45±0.11	0.63±0.49	−1.07	0.297
	P value	<0.05	<0.05		
JOA	Preop	11.27±1.16	12.15±1.06	−2.96	0.008
	Post-op 3d	14.09±1.11	14.52±0.70	−2.48	0.023
	Postop 3m	15.09±1.10	14.84±0.69	0.57	0.578
	Postop 6m	15.77±0.81	14.57±3.37	01.30	0.209
	Postop 12m	16.27±0.70	16.15±0.76	0.236	0.816
	P value	<0.001	<0.001		

Abbreviations: Preop, preoperative; post-op, postoperative; VAS, visual analogue scale score; JOA, Japanese Orthopaedic Association score.

The C2-7 Cobb angles of both groups were significantly higher at 3 months postoperatively and at the last follow-up compared to preoperative values (all $P < 0.05$), with no significant differences observed between the two groups (all $P > 0.05$). Additionally, there were no significant differences in the average height of the intervertebral disc between the two groups at 3 months postoperatively and at the last follow-up (both $P > 0.05$). These findings are summarized in Table 4.

No significant complications were observed in the EUBS group. In the HSD group, one patient experienced hypoesthesia and decreased muscle strength in the affected upper limb postoperatively, which resolved after three months of neurotrophic drug treatment. The incidence of complications did not differ significantly between the two groups (χ^2=1.187, P=0.276).

Discussion

Since the introduction of endoscopic posterior cervical decompression and discectomy for cervical disc herniation, endoscopic posterior cervical surgery has emerged as an advanced, safe, and effective minimally invasive spinal technique.[10–12] This approach is characterized by minimal surgical trauma, rapid postoperative recovery, and outcomes comparable to those of traditional surgery. Percutaneous endoscopic technology has gained widespread application in treating cervical spondylosis,[13,14] particularly benefiting patients with CSR characterized by lateral disc extrusion compressing nerve roots.[15]

Currently, the primary tools used by surgeons for handling bony structures such as the lamina and articular processes during endoscopic posterior cervical surgery include HSD and bone forceps. While bone forceps can effectively dissect bone, they often lead to excessive intraoperative bleeding, increase the surgeon's workload, and contribute to surgeon fatigue. Moreover, the irregularity of bone resection and prolonged resection time can negatively impact postoperative healing.[16] Although HSD reduce the surgeon's workload, their use is complicated by a challenging grip due to the high counterforce generated by the rotating drill head and significant local heat generation, which may pose risks to surrounding blood vessels and nerves.[17]

Table 4 Comparison of Imaging Measurements Between the Two Groups

Index	Time	EUBS	HSD	T Value	P Value
CA	Preop	12.91±6.8	12.98±6.7	0.11	0.912
	Postop 6m	14.97±4.8	15.02±4.8	0.10	0.920
	Postop 12m	16.01±4.9	16.28±4.5	−0.18	0.855
DH	Preop	5.31±1.2	5.39±1.2	−0.30	0.764
	Postop 6m	5.23±1.0	5.28±1.1	−0.26	0.797
	Postop 12m	5.18±1.0	5.23±1.2	−0.39	0.697

Abbreviations: CA, Cervical curvature; DH, disc height.

The UBS represents a novel instrument for bone resection. It converts electrical signals into mechanical energy via an ultrasonic transducer, amplifies this energy through an amplitude converter, and induces vibration at ultrasonic frequencies in the cutting head. This process fragments bone tissue into fine particles, achieving precise bone resection.[18] The resulting cuts are clean, with minimal bone fragmentation and destruction, ensuring accurate and controlled cutting.[19,20] Importantly, the UBS selectively targets bone tissue while causing minimal damage to surrounding vascular and neural structures.[21]

Based on the design and working principle of the UBS, numerous studies have confirmed its safety and effectiveness in spinal surgery. Karaoglu et al[22] conducted PECD on 27 patients with unilateral single-level CSR, reporting significant symptom improvement in all patients. However, three patients experienced transient numbness and discomfort in the affected limb. Jiang et al[23] treated 36 patients with single-level CSR using PECD, achieving good outcomes in 33 cases and transient forearm numbness in two patients. Onen et al[24] performed cervical laminectomy on 46 patients with cervical spinal stenosis, where the UBS group took an average of 2.2 minutes to remove a single lamina, significantly faster than the 7.4 minutes required by the HSD group. All patients showed significant symptom improvement without any major nerve injuries. Tsai et al[25] utilized the UBS in endoscopic lumbar discectomy for removing the upper and lower laminae of adjacent vertebrae and the junction of the transverse process, achieving an average operation time of 74.4 minutes and a surgical success rate of 95%, further proving the safety and effectiveness of the UBS in endoscopic surgery.

Given its successful application in various spinal surgeries, including laminectomy, facetectomy, and total laminectomy, the safety and effectiveness of EUBS represent a new focus for spine surgeons.[26–28] This study designed a novel EUBS technique and applied it to endoscopic vertebral decompression for CSR patients, comparing it with HSD and achieving promising results.

In this study, the VAS and JOA scores of all 41 patients showed significant improvement postoperatively compared to preoperative values. The clinical efficacy of the EUBS group (Figure 3) was comparable to that of the HSD group (Figure 4), with no apparent differences observed. The improvements became more pronounced over time, demonstrating sustained effects.

In this study, the EUBS demonstrated significant advantages in reducing osteotomy time. After using the high-speed drill (HSD) to remove the hard lateral cortical bone and part of the cancellous bone of the lamina, the medial cortical bone is subsequently excised using laminectomy forceps. This approach minimizes the risk of HSD-induced damage to nerves and the dura mater. However, the insertion of forceps into the spinal canal can potentially stimulate or compress

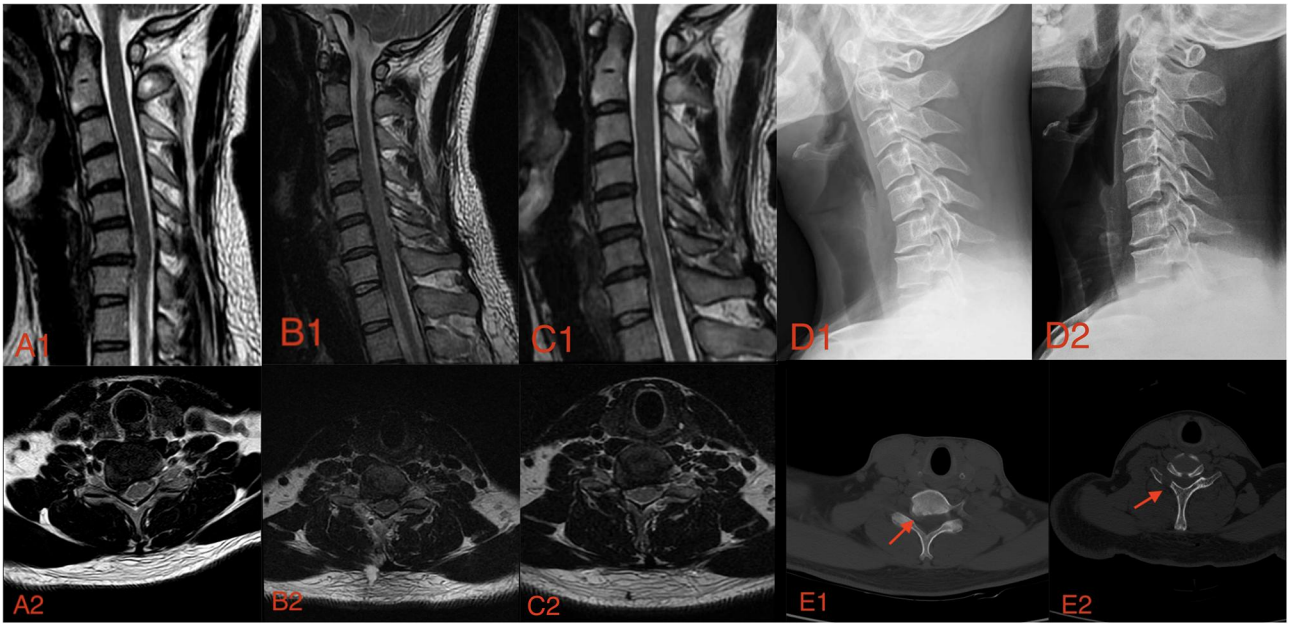

Figure 3 Preoperative and postoperative radiographic images of a 52-year-old male patient with C6/7 CSR, who underwent PECD using an EUBS. (**A1** and **A2**) Preoperative cervical MRI demonstrating C6/7 disc herniation compressing the left nerve root. (**B1** and **B2**) Sagittal and axial MRI views at 3 months post-operation showing removal of the protruding nucleus pulposus, with no obvious compression of the nerve root. (**C1** and **C2**) At 12 months post-operation, sagittal and axial MRI results remain consistent with those at 3 months, indicating sustained good recovery. (**D1** and **D2**) Lateral X-ray films reveal preoperative cervical kyphosis, which improved to a Cobb angle of 14.6°at 12 months post-operation. (**E1**) Preoperative cervical CT in the transverse plane shows intervertebral disc herniation (red arrow). (**E2**) Postoperative follow-up CT image in the axial plane, showing partial laminectomy with adequate foraminal decompression (red arrow).

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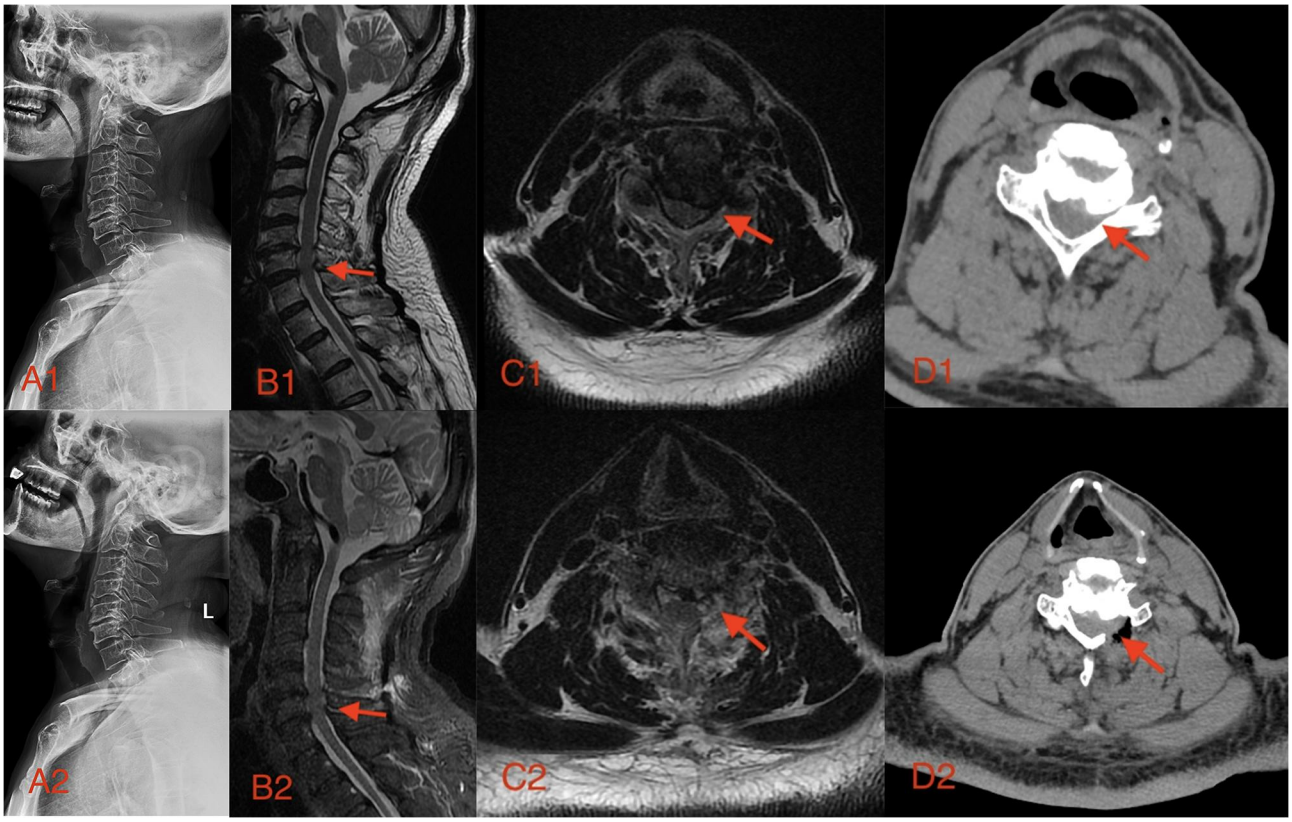

Figure 4 A male patient diagnosed with CSR at the C6/7 level underwent PECD using a HSD. (**A1** and **A2**) are preoperative and postoperative cervical X-rays, showing no significant change in cervical lordosis. (**B1**) Sagittal T2-weighted MRI images, The red arrow indicates the preoperative pathological segment C6/7. (**B2**) Sagittal T2-weighted MRI images, The red arrow indicates the postoperative pathological segment C6/7. (**C1**) Axial T2-weighted MRI images, The red arrow shows the preoperative C6/7 segment with left foraminal stenosis. (**C2**) Axial T2-weighted MRI images, The red arrow shows the postoperative C6/7 segment with successful decompression of the left foramen. (**D1**) Axial cervical CT scan showing preoperative left C6/7 foraminal stenosis, indicated by the red arrow. (**D2**) Axial cervical CT scan showing postoperative decompression of the left C6/7 foramen, with the red arrow marking the successfully treated level.

spinal nerves, thereby increasing the risk of nerve injury. In contrast, the EUBS does not require substantial downward pressure during bone removal, resulting in lower physical strain for the operator compared to the high-speed drill. Additionally, the risk of nerve injury is reduced with the use of EUBS.[16]

During the operation, continuous saline irrigation was employed to lower the tip temperature of the UBS device, making it challenging to accurately calculate the intraoperative bleeding volume. Therefore, we quantified intraoperative bleeding by counting the number of blurred fields In this study, the number of blurred fields in the EUBS group was similar to that in the HSD group, indicating no significant difference in reducing intraoperative bleeding between the EUBS and HSD. This similarity may be attributed to the imprecise method of statistical estimation used. Interestingly, during the operation, it was observed that the bleeding volume at the fracture ends was significantly reduced when using the EUBS device, likely due to its thermal and cavitation effects which induce local hemostasis. However, no significant difference was noted between the two groups overall, possibly because the bleeding volume included not only the fracture ends but also venous plexus bleeding, a major source of intraoperative hemorrhage. Lin et al[29] reported a significant reduction in intraoperative bleeding with UBS compared to traditional bone cutting tools. Conversely, a recent cohort study by Bradley Anderson MS et al[30] found that UBS did not reduce expected intraoperative bleeding volume or durotomy compared to traditional tools. These discrepancies may depend on the surgeon's familiarity with the technique and other surgical factors. Therefore, whether EUBS can effectively reduce bleeding requires further verification through prospective studies.

The prolonged length of hospital stay observed in our study (median >6 days) may be attributed to several factors. First, postoperative monitoring is generally more extended in our institution due to limited access to community-based rehabilitation services. Second, some patients experienced delayed mobilization or minor complications such as transient nerve root irritation, which required additional observation.[31] Lastly, local healthcare policies encourage inpatient

recovery for at least several days following spinal procedures, differing from practices in countries with well-established outpatient rehabilitation systems.

In summary, this study demonstrates that the application of EUBS in PECD surgery is safe and effective. Compared to HSD, EUBS significantly shortens fenestration time, making it worthy of clinical promotion. As a retrospective study, this research has limitations such as a small sample size and short follow-up period. Long-term efficacy and broader applicability need to be further verified through large-sample, long-term prospective studies.

Data Sharing Statement

The data presented in this study are available on request from the corresponding author.

Ethics Approval and Consent to Participate

This study was conducted in accordance with the principles of the Declaration of Helsinki. Ethical approval was obtained from the Medical Ethics Committee of Xuzhou Central Hospital (Approval No.: XZXY-LK-20220727-064). All participants provided written informed consent prior to their inclusion in the study.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

Guangwang Liu reports a patent "An Ultrasonic Bone scalpel Designed for Endoscopic Minimally Invasive Surgical Applications (ZL 2024 2 0138156.5)". All authors declare that they have no other conflicts of interest in this work.

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