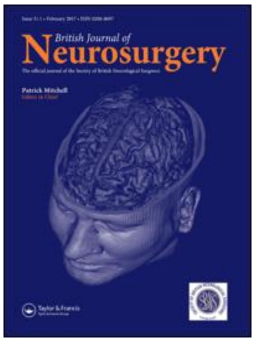

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ORIGINAL ARTICLE

Removal of calcified lumbar disc herniation with endoscopic-matched ultrasonic osteotome – Our preliminary experience

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ABSTRACT

Objective: To evaluate the clinical efficacy, practicability, and safety of an ultrasonic osteotome for percutaneous transforaminal endoscopic discectomy (PTED) in patients with calcified lumbar disc herniation (CLDH).

Methods: A total of 25 CLDH patients who underwent PTED at our department between December 2017 and August 2018 were analyzed retrospectively. Post-operative lumbar spine CT was used to evaluate residual calcification. Efficacy was evaluated by pre- and post-operative with the pain visual analog scale (VAS), Oswestry disability index (ODI), and the Modified MacNab Scale; the incidence of intra- and postoperative complications was also analyzed.

Results: All procedures were successfully completed and none of the patients was lost to follow-up. Postoperative CT verified the successful removal of calcified protrusions. VAS and ODI scores improved significantly after surgery. Based on the Modified MacNab scale, >90% patients achieved good or excellent outcomes. There were no complications such as dural tear and infection. Seven patients had varying degrees of postoperative dysesthesia. One patient experienced recurrence of herniation within 1 week after operation; successful recovery was achieved after repeat PTED.

Conclusions: Use of this ultrasonic osteotome for PTED facilitated effective removal of calcified disc protrusion, relieved nerve compression, and protected the adjacent neurovascular tissues. The instrument may help expand the indications for endoscopic surgery and avoid open surgery for some CLDH patients.

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Percutaneous transforaminal endoscopic discectomy; ultrasonic osteotome; calcified lumbar disc herniation; complication

Introduction

Percutaneous transforaminal endoscopic discectomy (PTED) offers the typical benefits of minimally invasive surgery.[1,2] Compared to open surgery, it is associated with lower postoperative visual analog scale (VAS) and Oswestry Disability Index (ODI) scores, improved patient satisfaction, shorter operating time, lesser blood loss, and shorter length of hospital stay.[3,4]

Surgical treatment of calcified lumbar disc herniation (CLDH) is considered one of the relative contraindications for endoscopic lumbar discectomy and most spine surgeons prefer traditional open surgery in these patients.[5] CLDH is quite common with reported prevalence rates of 5–6% of adults. Posterior longitudinal ligament calcification is known to be commoner in East Asian populations but this does not appear to be true of CLDH with Western and East Asian populations being similarly affected.[6,7]

The rapid advances in spinal endoscopic techniques and surgical equipment have improved the feasibility of endoscopic treatment of CLDH. However, endoscopic removal of calcified intervertebral disc tissue is typically challenging due to the inherent space constraints. In addition, use of high-speed drills during endoscopic removal of calcified tissue is associated with a high risk of damage to nerves and dural mater.[8,9]

Ultrasonic osteotomes are a type of instrument based on piezoelectric high-frequency mechanical vibration. They have selective bone-cutting properties with preservation of adjacent soft-tissue.[10,11] They have been applied in oral and maxillofacial surgery.[12] Most studies have them to be safe, precise, and selectivity for bone tissue as compared to drills.[13] Their use in spinal surgery is increasing.[14] In the past, there was a lack of availability of ultrasonic osteotomes compatible with endoscopic so their use for endoscopic treatment of CLDH is not well characterized. We evaluated the outcomes of PTED performed with ultrasonic osteotomes in patients with CLDH.

Materials and methods

Clinical data

Calcified discs can be classified from preoperative CT into: isolated (calcification <3 mm), half-moon type (calcification ≥3 and ≤10 mm), and continuous (calcification >10 mm).[15] We selected patients who qualified the following indications: (1) Low back pain radiating to one leg with/without numbness and Lasegue sign <70°. (2) Preoperative CT confirmed lumbar disc herniation (LDH) with >3mm calcification. (3) Presence of severe symptoms despite regular conservative treatment for >3 months or history of symptoms lasting >1 year that affected normal work and life.

Exclusions were: (1) Short duration of disease or mild symptoms and no obvious imaging findings; (2) Spinal space-occupying lesions, lumbar instability, severe lumbar spinal stenosis,

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Table 1. Baseline characteristics of the study population.

Age (years)	37.96 ± 2.31
Sex	–
M	16
F	9
Body mass index	25.25 ± 1.80
Involved segment	
L4/L5	14
L5/S1	11
Operative Time (minutes)	62.64 ± 6.11

lumbar tuberculosis, or other infection; (3) LDH without calcification or the length of calcified protrusion <3mm; and (4) Presence of coagulopathy, chronic cardiopulmonary disease, or poor general condition.

Twenty-five patients (14 inpatients and 11-day case operations) were selected between December 2017 and August 2018. Written informed consent was obtained. Clinical data are presented in Table 1. Preoperative and follow-up data were obtained from clinical records, physical examination, and telephonic interviews.

X-ray of lumbar spine was performed to assess spine morphology and stability. Lumbar CT and MRI were performed to assess the type of LDH, lumbar spinal stenosis, and calcification of the protruded tissue.

Technique

The full endoscopic surgical system (Joimax GmbH, Karlsruhe, Germany) and ultrasonic osteotome device (XD880A, SMTP, Beijing, China) (Figure 1) were used. The ultrasonic osteotome device consists of a host machine, a handpiece, and different types of disposable tips. It was designed to work within the confines of the working tube (φ7.5 mm) of the endoscopic system without causing damage to the lens or the lighting system. Tips with different lengths (220 or 300 mm) and diameters (φ3.6 or φ4.2 mm) were available. Cutting speed can be controlled by adjusting the operating parameters. The working frequency of the tip is 39 kHz. The maximum output power is 85W and the vertical amplitude of the tip is 120 μm at maximum power. Saline is pumped through the sterilized irrigation tube to the handpiece and the endoscopic tip.

The hand piece is held like a pencil. There is no lateral vibration so the tip does not injury adjacent tissue like spinal cord or nerve root even if the side of the tip touches them.

Surgical procedure (PTED)

Procedures were performed under local anesthesia with the patient prone. The skin entry point is approximately 12 cm lateral from the midline. After local anesthesia with 0.5% lidocaine (about 10 ml): (1) A needle is inserted from the skin entry point to the area of intervertebral foramen with fluoroscopic x-ray guidance, a 0.8mm guidewire is placed and the needle removed. (2) A dilator is inserted over the guidewire. (3) The working cannula is inserted. The ultrasonic osteotome is used to saw off the apex of the superior processus that forms the dorsal wall of the foramen, if necessary. (4) The position of the working cannula is checked by x-ray. (5) The endoscope is inserted. (6) The calcified protrusions are exposed (Figure 2(A)). (7) The ultrasonic osteotome is used to remove the calcified disc. (Figure 2(B)). (8) Dural pulsation and relaxation of the nerve root are seen to confirm decompression (Figure 2(C)).

Postoperative care

Patients were kept in bed for 6 h after surgery and were them mobilized. They were asked to avoid strenuous exercise and lumbar loading. Postoperatively, analgesics were administered PRN.

Efficacy evaluation

Outcomes were evaluated using the pre- and post-operative pain VAS score, ODI, and the Modified MacNab scale score. Removal of calcification was measured by comparing pre- and post-operative CTs (Measured by software of Image J).

Statistical analysis

Descriptive statistics were used for demographic data. Quantitative variables are presented as mean ± standard deviation (SD). Paired t-test was used to compare pre- and post-operative VAS and ODI scores. A p value less than .05 was considered statistically significant. All statistical analyses were performed using the SPSS version 21.0 software (IBM Corp., Somers, NY).

Results

Mean operative time was 62.64 ± 6.11 min. None of the patients was lost to follow-up. Post-operative CT showed removal of calcified tissue in the central and nerve root canal on the ipsilateral (imaging data of a typical case is shown in Figure 3). Comparing post-op with pre-op CTs (schematic is shown in Figure 3 and data are shown in Table 2) the removal rate on the symptomatic side was almost 100%, while the contralateral side range from 16% to 100% (average 54%). VAS and ODI scores improved significantly after surgery ($p < .05$) and improvements were maintained 6 months after surgery (Figure 4). Seven patients had varying degrees of postoperative dysesthesia. The number and extent of numbness decreased gradually by the first year of follow-up. None of the patients developed complications such as dural tear, intestinal injury, or infection. Reherniation appeared in one patient who recovered with another PTED. In one patient, we had a tip fracture. The calcification was particularly hard and the instrument was placed under what proved to be excessive lateral force. We removed the broken tip with nucleus pulposus forceps under the microscope. Fortunately, no nerve or dural injury occurred.

According to the Modified MacNab Scale, the curative effect was excellent in 20 patients, good in three patients, and acceptable in two patients. More than 90% patients achieved excellent and good curative effects.

Discussion

CLDH is a difficult type of LDH; morbidity rates reported in literature vary.[8,16] In China, CLDH gradually becoming more common maybe because of changes in lifestyle, though it is reported that popularity of Traditional Chinese Medicines (TCM), which tends to be surgically conservative, may have relevance to CLDH development as well.[17] The pathogenesis of the disease is still unclear. Compared with simple LDH, calcified herniations always exhibit extensive adhesions with anatomically contiguous tissues such as dural and nerve root. Open surgery to remove calcified tissue under direct vision has its advantages but may lead to large

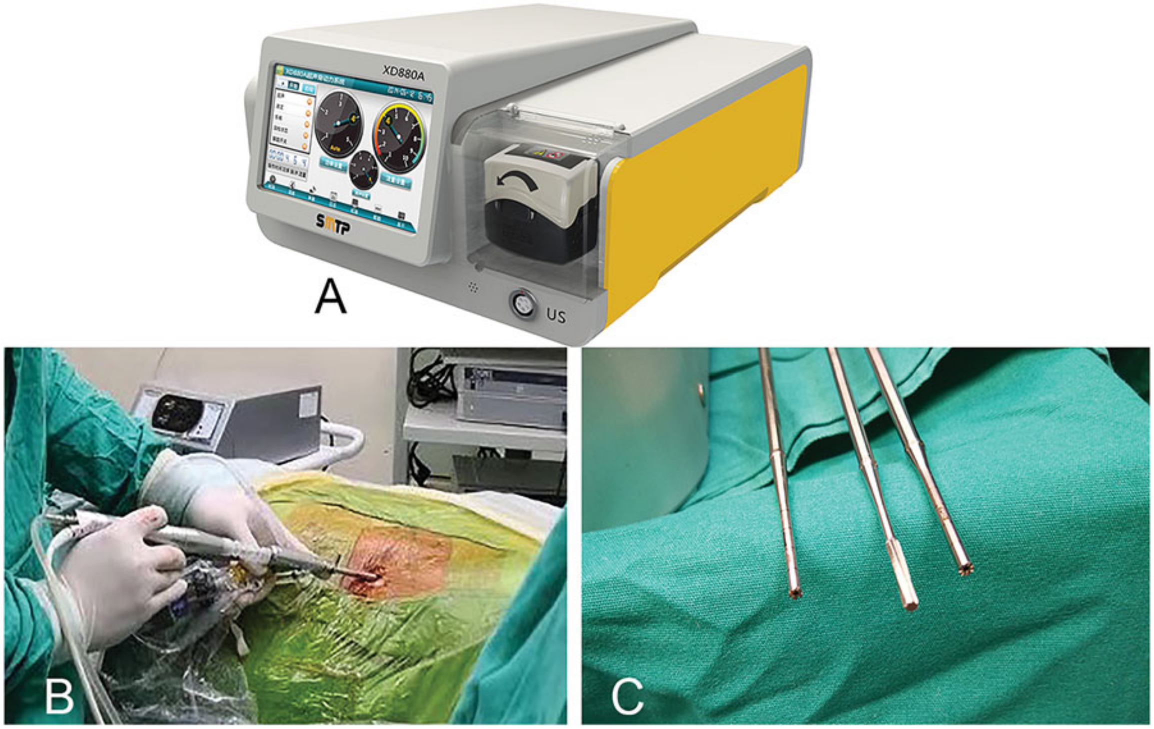

Figure 1. SMTP, XD880A (A: host with digital display could select the different modes and power levels, B: handpiece is the extension of the host and control the tips; C: different types of tips).

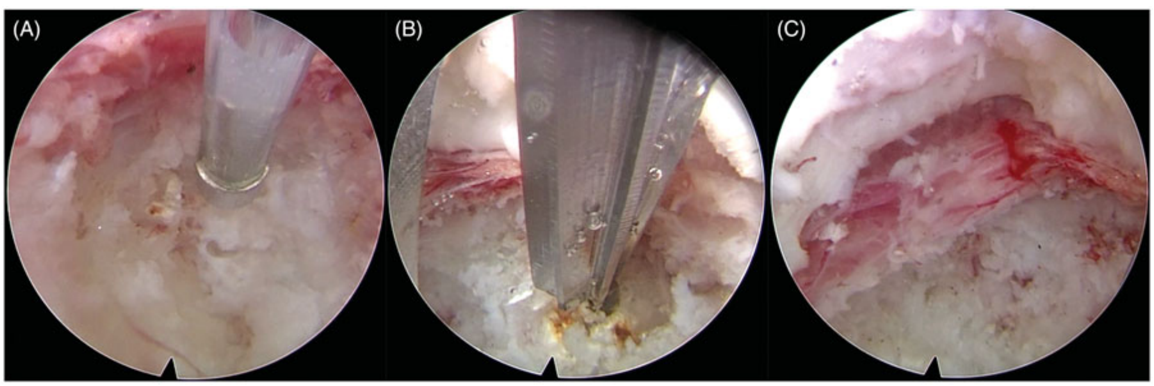

Figure 2. Endoscopic image showing ongoing ultrasonic osteotome of the calcified intervertebral discs. (A: expose the calcified protrusion; B: remove the calcification with ultrasonic osteotome; C: calcification is effectively removed).

amount of bleeding and a high risk of neural damage, leading to slow recovery.

It is relatively difficult to remove calcified intervertebral disc tissue *via* endoscopy because of limited operation space. In addition, surgeons need more skill and experience as calcified protrusions tend to extensively adhere to the surrounding tissues.[18] Technological developments, particularly the ultrasonic osteotome have made endoscopic CLDH feasible.

Some studies have found CLDH to be associated with spinal stenosis, which complicates transforaminal discectomy.[1,19] Dabo *et al.*[17] reported good results of percutaneous endoscopic interlaminar discectomy (PEID) for treatment of CLDH, which were comparable with those of ordinary LDH; however, the incidence of postoperative dysesthesia in the calcified group was relatively higher than that in the non-calcified group. The ultrasonic osteotome lessen this problem.

The ultrasonic osteotome for PTED offers several advantages over traditional surgical tools. (1) Tissue selectivity: due to differences in tissue density and elastic properties, ultrasonic osteotome only cuts the bone tissue, which significantly reduces the risk of injury to nerves and dural mater.[20] (2) Anti-rolling: As HSDs spin, they risk soft tissues, swabs, patties, etc., becoming wrapped around them causing wider damage, particularly in deep and narrow surgical fields. Ultrasonic osteotomes carry no such risk.[21] None of our patients experienced any intraoperative spinal cord or root injury. (3) Easy to handle: the tissue selectivity and anti-rolling characteristics ensure easy operation. The tip of the device is more stable at low amplitudes of handle vibration during osteotomy and does not produce rotational torque.[22,23] (4) Its cavitation effect reduces local bleeding, which keeps the field clear[24] making it especially suitable for CLDH with a restricted endoscopic surgical field and in those with unclear

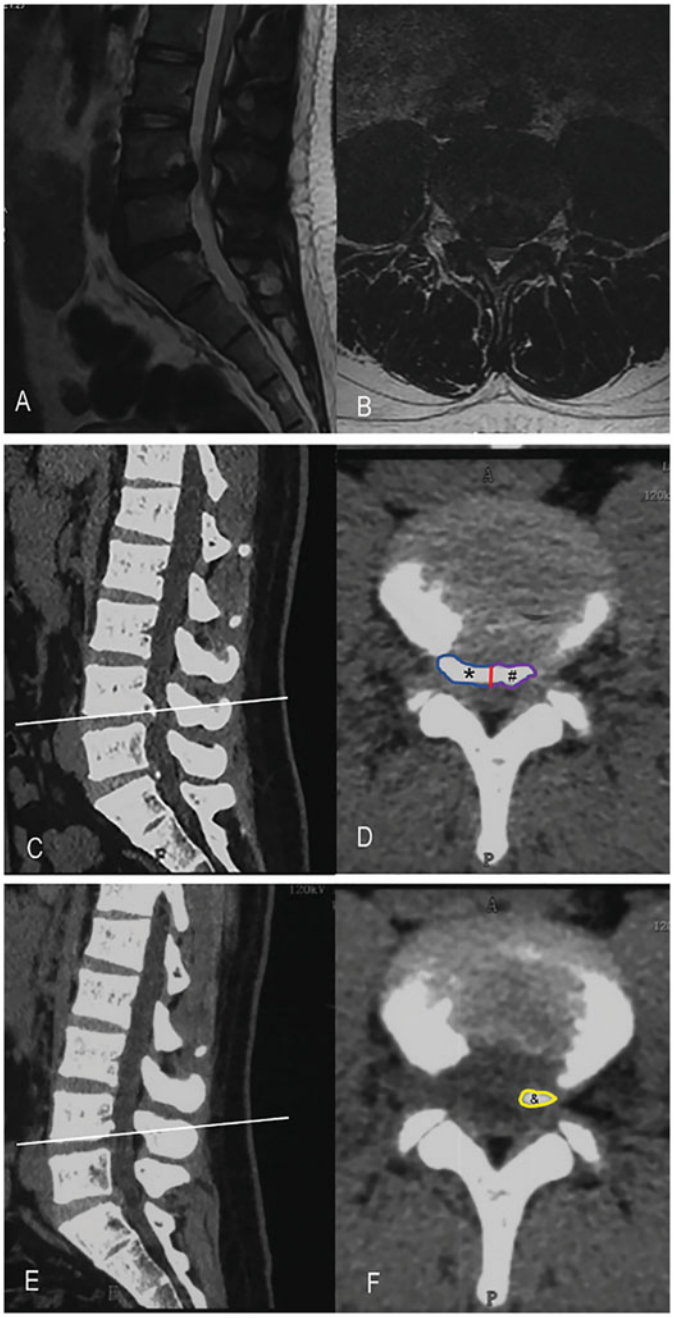

Figure 3. A 23-year-old man with low back pain which radiated to right lower limb since more than 6 months. Preoperative MRI and CT show calcification of L4/5 herniated intervertebral disc which has compressed the right nerve root (A, B, C, and D). CT obtained 3 months after surgery showed efficient decompression of the nerve root and successful removal of the calcified lesion (E and F). *Calcification at symptomatic side. #Calcification at contralateral. &Residual calcification.

Table 2. Assess the removal of calcification with axial CT image.

Calcification's area (mm^2)	Preoperative	Postoperative	Removed	Removal rate (%)
Ipsilateral	34.0 ± 12.6	4.0 ± 1.9	33.6 ± 12.3	99.2 ± 3.9
Contralateral	27.2 ± 13.6	15.1 ± 10.8	14.5 ± 25.1	54.3 ± 25.1

anatomy or anatomical variations. (5) This technique requires less expertise than that required with the drilling technique.[25] (6) There is no drill *vs.* sucker problem. Using a drill next to the sucker risks a drill strike putting metal shavings in the wound that then obscure later MR scans.

In our study, postoperative CT showed that intervertebral foramen were wider than that before surgery confirming that the surgical objective of decompression had been achieved. Both VAS and ODI scores were significantly decreased after surgery.

In our experience, calcified herniated discs are hard and inelastic. As soft fragments cannot be removed *via* a narrow space, extra space is required for surgical access. This requirement is lessened by the ultrasonic osteotome as calcified disc can be removed *via* a narrower access channel.

One patient developed recurrence of non- calcified herniation at 1 week after surgery. We aver that in this patient a wide resection of calcified tissue left an annular defect with consequent nuclear prolapse. The patient recovered after another PTED.

Despite the advantages of the ultrasonic osteotome, some recent studies have reported complications including epidural, spinal cord, and nerve injuries. Hu *et al.*[24] used it for spinal surgery in 128 patients; of these, 1 had a dural injury attributed to a thermal effect. Ito *et al.*[6,25] performed laminectomy or semi-laminectomy in 12 patients; of these, 1 experienced dural injury during resection of tumor by ultrasonic osteotome due to tumor-related dural ossification. In our experience, an adverse event of tip fracture occurred. The calcification was hard and we applied excessive lateral pressure to the tip which caused it to break.

Based on reports and our experience, the following key issues should be considered when using ultrasonic osteotome: (1) The high-frequency vibration of ultrasonic osteotome causes heating. This can be partly cooled with irrigation,[26] but prolonged operation at the same location should be avoided. (2) Due care should be exercised to avoid contusion of the spinal cord caused by squeezing when operating near the dural mater or in cases with severe stenosis. (3) Excessive lateral pressure to the tip will not improve the efficiency of bone cutting but may affect the normal vibration which could cause local overheating or compression damage to the nerves and even break the tip. (4) Direct contact with ossified dural tissue should be avoided in cases of suspected dural ossification to prevent local dural damage. (5) Semi-calcified tissues with texture between bone and soft tissue are not so well distinguished by the ultrasonic osteotome. Therefore, various other instruments may also be required.

It is reported that persistent annular defect post discectomy is associated with increased risk of reherniation and may accelerate intervertebral degeneration.[27,28] As resection of the lesion may lead to annulus fibrosus defect. Whether the range of calcification removal is related to the probability of postoperative recurrence and disc degeneration is still unclear. In our study, according to the immediate effect and the convenience as well as safety of the operation, we removed the whole calcification of symptomatic while about 54% on average of the contralateral. No additional complications or adverse reactions were found so far which means that our treatment strategy is feasible.

Conclusion

The ultrasonic osteotome for PTED for treatment of CLDH is a safe and effective method that affords symptom relief without an increase in the incidence of complications. It avoids the need for traditional open surgery for CLDH and expands the indications for endoscopic surgery. In addition, the operation is relatively simple even for beginners and may help make up for the lack of experience and operation skills of surgeons.

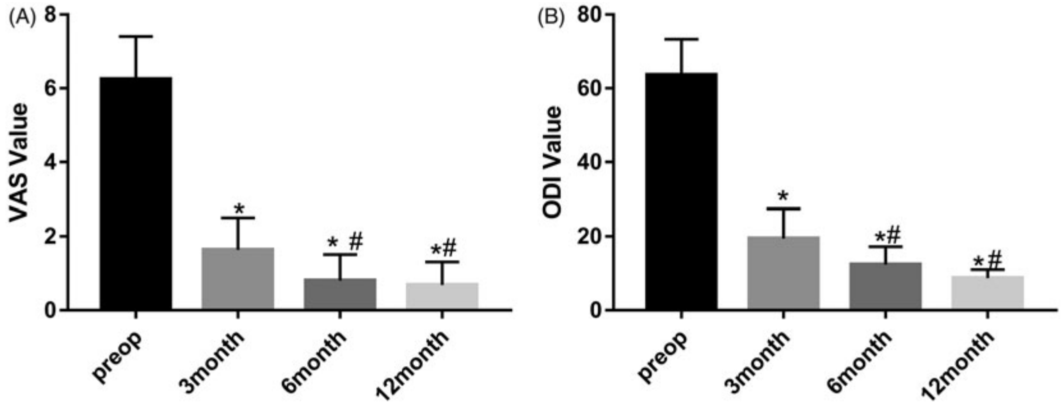

Figure 4. VAS and ODI in pre-and post-operative (*means statistically significant difference compared with preoperative; #statistically significant difference compared with 3 month postoperative).

Ethics approval

Research involving human participants and/or animals: This study was approved by the ethics committee of Changzheng Hospital, Second Military Medical University. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent

Written informed consent was obtained from all patients.

Disclosure statement

The authors declare that they have no conflict of interest.

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