ORIGINAL PAPER Neurosurgery

Outcomes of microscopy-assisted anterior cervical discectomy and fusion in a selected cohort with soft giant cervical disc herniation-induced cervical spondylotic myelopathy

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KEY WORDS

anterior cervical discectomy and fusion, cervical spondylotic myelopathy, giant cervical disc herniation, microscopy

ABSTRACT

INTRODUCTION Giant cervical disc herniation (GCDH), defined as CDH occupying more than 50% of the spinal canal, presents a significant challenge in spinal surgery. This study specifically investigated a distinct subgroup of patients with soft GCDH, characterized by an absence of ossification of the posterior longitudinal ligament (OPLL) or significant calcification.

AIM We aimed to assess the feasibility and efficacy of microscopy-assisted anterior cervical discectomy and fusion (MS-ACDF) for treating soft GCDH-induced cervical spondylotic myelopathy (GCDH-CSM).

MATERIALS AND METHODS This retrospective study analyzed 22 consecutive patients with soft GCDH-CSM who underwent MS-ACDF. The inclusion criteria explicitly required confirmation of soft DH without OPLL or signs of significant calcification on preoperative imaging. The analysis included clinical and imaging data, encompassing demographic characteristics, pre- and postoperative visual analog scale (VAS), Neck Disability Index (NDI), and Japanese Orthopedic Association (JOA) scores, X-ray, magnetic resonance imaging (MRI), and computed tomography results to assess efficacy of the technique.

RESULTS All surgical procedures were successfully completed without complications, demonstrating the safety and reliability of the MS-ACDF technique. Postoperative assessment showed marked clinical improvement, with MRI confirming thorough removal of the herniated disc and adequate decompression of the spinal cord. During a median (interquartile range [IQR]) follow-up of 14 (13–17) months, mean (SD) VAS and NDI scores, respectively, decreased from preoperative 4.82 (1.11) and 15.95 (2.26) to 2.22 (1.08) and 10.22 (2.02) at day 3 postoperatively, and further to 0.77 (0.79) and 7.04 (1.06) at the final follow-up. Mean (SD) JOA score improved from 9.27 (1.81) preoperatively to 12.77 (1.51) on postoperative day 3, and further increased to 15.22 (0.95) at the final follow-up. No severe complications were noted.

CONCLUSIONS MS-ACDF represents a viable option for soft, noncalcified GCDH, providing satisfactory clinical and functional improvement at mid-term follow-up.

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INTRODUCTION In 1999, Dantas et al[1] were the first to propose a new classification of cervical disc herniation (CDH) according to the degree of spinal cord compression: small (up to 12%), medium (13%–25%), big (26%–50%), and giant CDH (GCDH), defined as CDH occupying more than 50% of the spinal canal. Although anterior cervical discectomy and fusion (ACDF) represents the gold standard treatment for CDH, it is rarely reported in GCDH.[2] The management of GCDH, especially GCDH-induced cervical spondylotic myelopathy (GCDH-CSM), through AC approaches, including AC corpectomy decompression and fusion (ACCF) and ACDF, presents significant risks and potential complications, such as ischemia--reperfusion injury, dural tear, and spinal cord injury.[3] Several researchers advocate posterior surgery for GCDH-CSM.[2,4,5] Ghogawala et al[5] demonstrated that AC surgery exhibited higher complication rates than posterior surgery, leading to a preference for posterior cervical procedures in GCDH treatment.[6] However, the efficacy of posterior cervical surgery remains inadequately documented. Research indicates that combined anterior and posterior surgery for CSM increases the risk of intraoperative cerebrospinal fluid leakage, extends operative time, and elevates hospitalization costs.[7-9]

Microscopy-assisted spinal surgery has gained prominence recently. Microscopic lumbar discectomy has emerged as the preferred standard. The microscopic approach separates the surgeon's hands and visual field, adhering to ergonomic principles and minimizing damage to sensitive tissues, including blood vessels and nerves. Furthermore, research suggests viability of single-stage ACDF for GCDH.[2,10,11] Microscopy-assisted ACDF (MS-ACDF) has been implemented in GCDH management, demonstrating promising results.[2,8] Nevertheless, the safety and efficacy of MS-ACDF for GCDH-CSM require comprehensive validation.

This retrospective analysis evaluated the effectiveness of MS-ACDF in treating GCDH-CSM. The study included 22 patients who underwent MS-ACDF. The primary aim was to introduce this novel technique, which adopts a stable retractor system and leverages advanced microscopy to provide a minimally-invasive alternative, thereby improving clinical efficacy and encouraging a wider use of this technology.

MATERIALS AND METHODS

Patients This retrospective study consecutively enrolled patients who underwent MS-ACDF between February 2019 and July 2024. The final sample size of 22 participants was determined by including all eligible cases meeting the predefined inclusion and exclusion criteria during this period, without a priori sample size calculation. Clinical and imaging data were obtained from an electronic medical record system, with written informed consent secured from all participants. The inclusion criteria involved: 1) significant CSM signs and symptoms; 2) preoperative magnetic resonance imaging (MRI) evidence of large herniated disc occupying over 50% of the spinal canal; 3) MS-ACDF procedure completion; and 4) explicit confirmation of soft DH without ossification of the posterior longitudinal ligament (OPLL) or sign of significant calcification on preoperative computed tomography (CT). Exclusion criteria encompassed: 1) vertebral metastases or primary tumors; 2) neck skin and soft tissue infections; 3) previous cervical spine surgery; 4) cervical radiculopathy; and 5) presence of OPLL or significant disc calcification.

Radiographic assessment The degree of canal compromise was defined as the ratio of the herniated area to the original spinal canal area (area method) or the corresponding sagittal diameters (linear method), measured on an axial T2-weighted MRI slice showing the most severe compression.[2] All measurements were performed independently by 2 blinded spinal surgeons.

Fusion assessment Radiological fusion for the zero-profile (ZP) and cage-plate (CP) constructs was assessed using a set of 3 criteria. Successful interbody fusion was defined by the fulfillment of any 2 of the following: 1) absence of significant angular motion at the index segment on dynamic lateral radiography; 2) absence of a radiolucent line at the cage-endplate interfaces, indicating stable bone-implant contact; and 3) presence of bone bridging with trabeculation across the intervertebral space on either radiography or CT.[12,13]

Surgical procedure A single surgeon conducted all surgical procedures. Following anesthesia administration, the patient's head was positioned supine, secured in slight hyperextension, and laterally tilted. After standard disinfection, sterile draping, and C-arm fluoroscopic positioning of the lesion, an AC incision was made parallel to the transverse cervical stripe along the medial sternocleidomastoid muscle, followed by layer--by-layer exposure. The procedure incorporated innovative techniques. These innovations, including Kirschner wire utilization for intervertebral space protection and establishment of a stable exposure system, improved procedural safety and stability. Initially, the intervertebral space was distracted using a propping needle, and 1.5-mm Kirschner wires, premarked at a depth of 8 mm, were positioned at each vertebral body's lateral margin. Intraoperative fluoroscopy with a C-arm machine showed a relatively safe position and depth of the Kirschner wire (**FIGURE 1A** and **1B**). Second, a stable retractor system was formed using a hemostat, scarf forceps, and 250 ml of saline secured to the bent Kirschner wire via a silk thread. This saved human resources, better exposed the surgical field, made the operation more delicate and gentler, and avoided intraoperative spinal cord injury (**FIGURE 1C**). These innovations, along with meticulous attention to detail, ensured a high level of safety and efficacy of the procedure. Subsequently, the CD and cartilage endplates were fully scraped under a microscope using a micro nerve hook and reverse angle curette. The posterior osteophytes or the posterior margin of the vertebral body were polished with a grinder, and the posterior longitudinal ligament was opened for exploration to

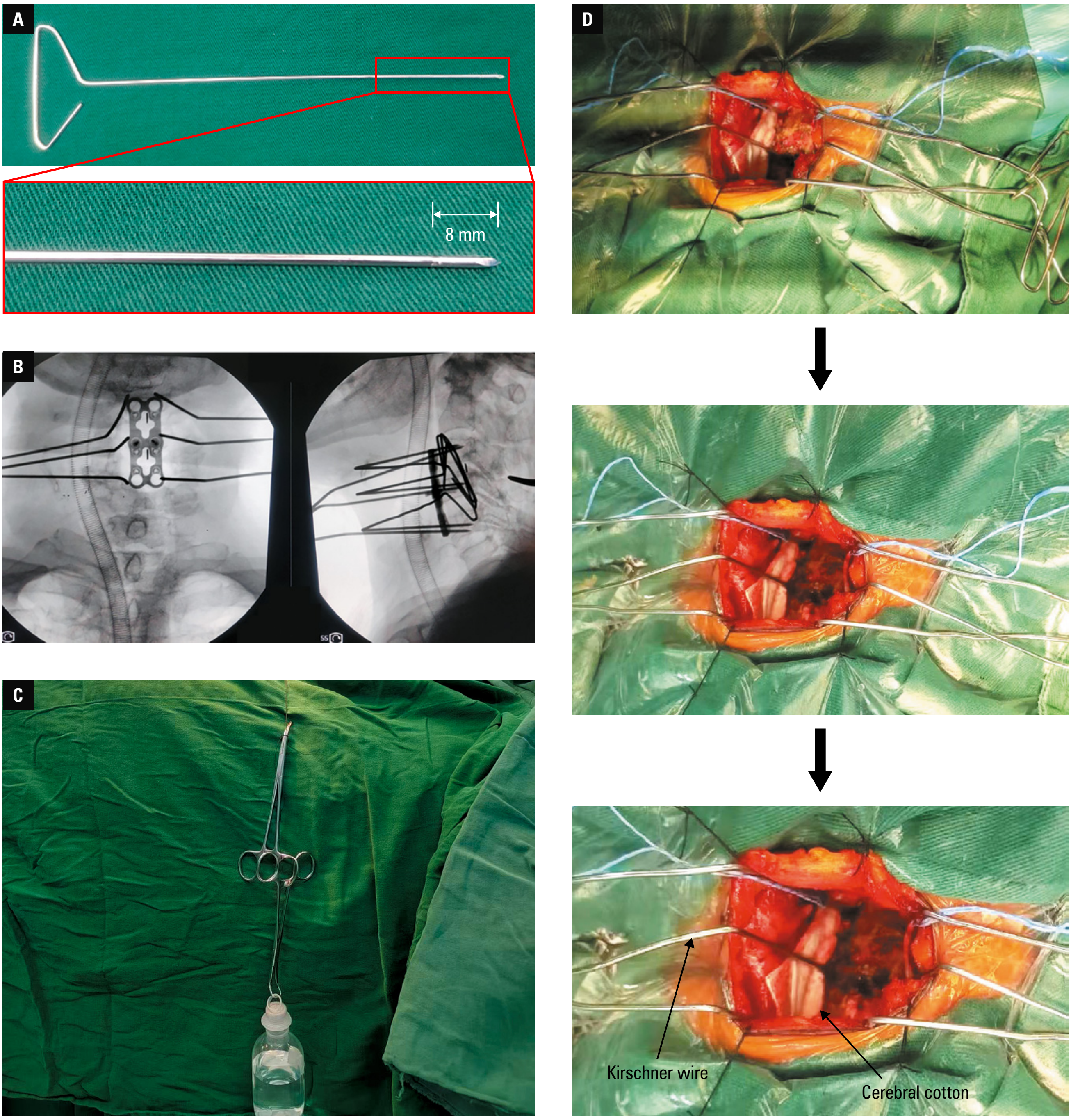

FIGURE 1 The exposure system; **A** – general view of the prebent Kirschner wire (diameter, 1.5 mm) and a magnification of the 8-mm front-end; **B** – anteroposterior and lateral images derived from a C-arm machine, showing the position and depth of the Kirschner wire; **C** – stable pull-hook system formed using a hemostat, scarf forceps, and 250 ml of saline; **D** – demonstration of the exposure system in anterior cervical discectomy and fusion surgery

observe the spinal cord and nerve roots for full decompression (FIGURE 1D). After thorough hemostasis was achieved with the combined application of an absorbable gelatin sponge and a flowable hemostatic agent, an appropriate cervical fusion device was implanted into the intervertebral space, titanium plates and screws were fixed, and C-arm fluoroscopy was used to confirm that the position was satisfactory. Large quantities of saline and light iodine povidone were repeatedly used to rinse the operative area and check for active bleeding. A negative pressure drain was placed, and the incision was closed layer by layer.

Evaluation of efficacy and safety The visual analog scale (VAS), Neck Disability Index (NDI), Japanese Orthopedic Association (JOA), radiography, CT, and MRI data were collected preoperatively and postoperatively on day 3 and month 3, and at the last follow-up.

Statistical analysis Data are expressed as mean (SD) and median (interquartile rage [IQR]). Paired *t* tests were used to evaluate changes in the preoperative and postoperative VAS, NDI, and JOA scores. Significance was set at a P value below 0.05. Data processing was performed

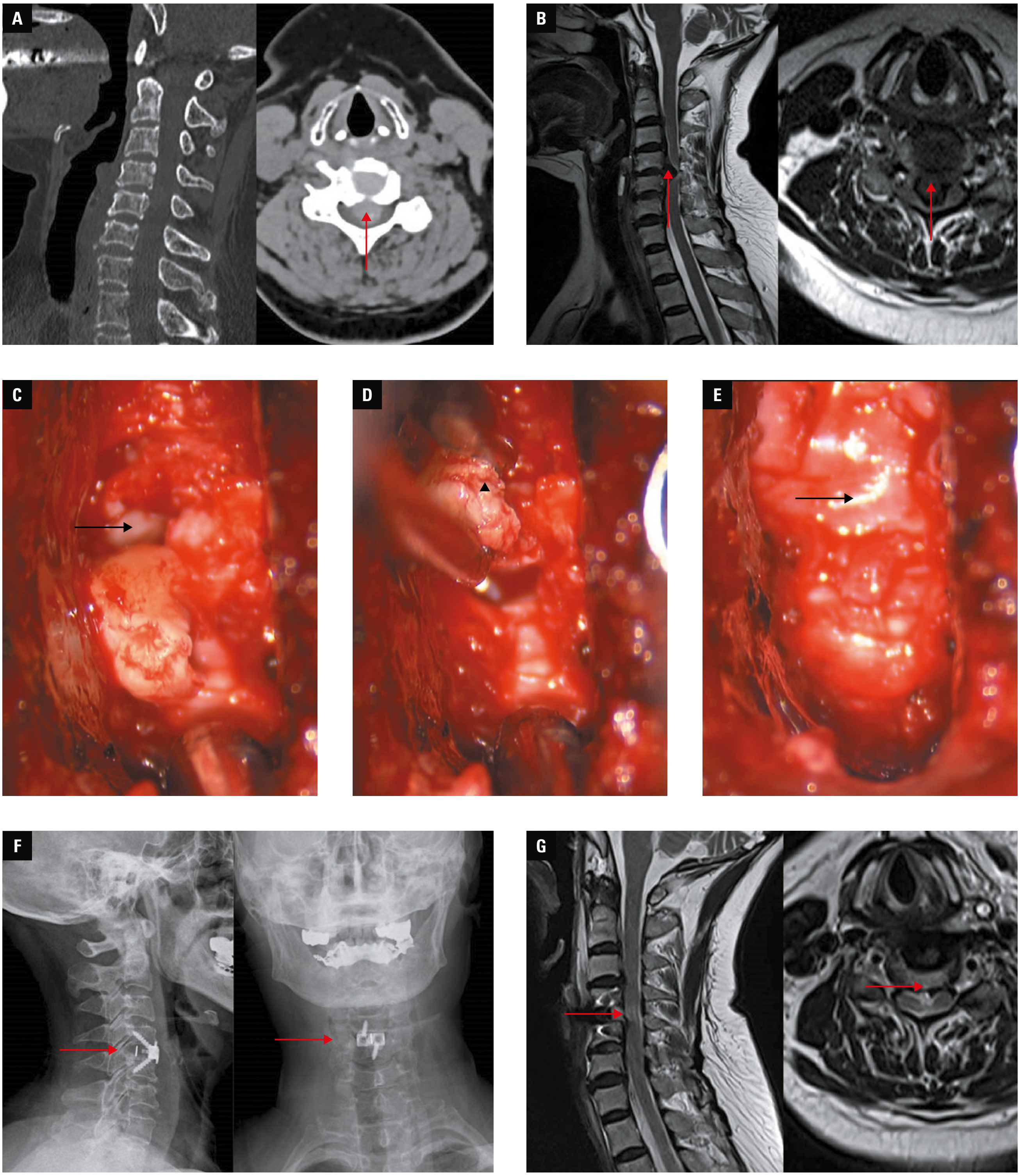

FIGURE 2 Case 1. A 37-year-old woman with weakness and numbness in the lower extremities lasting for 6 months; **A** – preoperative sagittal computed tomography showing no ossification of the posterior longitudinal ligament, and a coronal view showing giant disc herniation in the C4/C5 intervertebral space (arrow); **B** – preoperative magnetic resonance imaging (MRI) showing giant disc herniation in the C4/C5 intervertebral space, compressing the spinal cord (arrows); **C** – herniated giant cervical disc compressing the spinal cord and forming a depression (arrow); **D** – removal of the herniated cervical disc (arrow); postoperative MRI showing the herniated giant disc completely removed, and the spinal cord adequately decompressed (arrow); **E** – spinal cord swelling and filling up after the herniated cervical disc removal to relieve the compression; **F** – postoperative frontal and lateral radiographs showing the implanted zero-profile system (arrows); **G** – postoperative MRI showing the herniated giant disc completely removed and the spinal cord adequately decompressed (arrows)

TABLE 1 Baseline characteristics of the patients (n = 22)

Case no.	Sex	Age, y	Duration of symptoms, mo	JOA score, points	Diseased segment	Fixation type	Follow-up, mo
1	Woman	37	1	7	C4/C5	ZP	13
2	Man	61	48	7	C4/5, C5/C6	CP	12
3	Man	72	12	9	C3/C4, C4/C5, C5/C6	CP	14
4	Man	72	2	11	C4/C5, C5/C6	CP	13
5	Man	58	6	12	C4/C5, C5/C6	CP	50
6	Man	66	1	10	C5/C6	ZP	12
7	Man	48	3	6	C5/C6	CP	16
8	Man	41	6	8	C3/C4	ZP	37
9	Man	39	8	9	C5/C6	CP	64
10	Man	60	1	13	C5/C6, C6/C7	CP	14
11	Man	57	6	11	C5/C6	CP	16
12	Man	59	12	9	C4/C5	CP	13
13	Man	38	2	9	C5/C6	CP	16
14	Man	49	12	10	C4/C5	CP	13
15	Woman	50	12	8	C3/C4, C4/C5	CP	14
16	Woman	58	12	9	C4/C5, C5/C6	CP	14
17	Woman	57	10	11	C4/C5	CP	53
18	Woman	49	1	12	C3/C4, C4/C5, C5/C6	CP	13
19	Woman	61	2	8	C5/C6	ZP	12
20	Woman	57	12	7	C4/C5	CP	15
21	Woman	46	10	8	C6/C7	CP	17
22	Woman	44	7	10	C5/C6	CP	66

Abbreviations: CP, cage-plate; JOA, Japanese Orthopedic Association; ZP, zero-profile

TABLE 2 Pre- and postoperative visual analog scale, Neck Disability Index, and Japanese Orthopedic Association scores (n = 22)

Variable	Preoperatively	3 Days postoperatively	3 Months postoperatively	Final follow-up
VAS	4.82 (1.11)	2.22 (1.08)[a]	1.18 (0.78)[a]	0.77 (0.79)[a]
NDI	15.95 (2.26)	10.22 (2.02)[a]	8.09 (1.53)[a]	7.04 (1.06)[a]
JOA	9.27 (1.81)	12.77 (1.51)[a]	14.55 (1.27)[a]	15.22 (0.95)[a]

Data are presented as mean (SD).

a $P < 0.05$ as compared with the preoperative value

Abbreviations: NDI, Neck Disability Index; VAS, visual analog scale; others, see TABLE 1

using the GraphPad Prism software, version 8.0 (GraphPad Software, San Diego, California, United States). Two doctors (HJ and HQ) performed all efficacy assessments.

Ethics This study was carried out with the approval of the ethics committee of the Affiliated Hospital of Zunyi Medical University (KLL-2023-627).

RESULTS The study included 22 consecutive patients; their baseline data are presented in TABLE 1. Mean (SD) age of the patients was 53.24 (3.21) years, and 59% of them were men. Most lesion segments were located at the C4/C5 and C5/C6 levels, of which 81% were fixed with a CP, and the remaining 19% with ZP. Median (interquartile range [IQR]) follow-up was 14 (13–17) months. All patients successfully underwent the MS-ACDF procedure without incurring any intraoperative complications, including vertebral artery injury, nerve injury, dural laceration, or esophageal injury. No postoperative complications, such as neurological deficits, cerebrospinal fluid leakage, wound infection, or pseudarthrosis, were observed during follow-up, and no degeneration of adjacent segments was found at the final follow-up. Mean (SD) VAS, NDI, and JOA scores, respectively, decreased from 4.82 (1.11), 15.95 (2.26), and 9.27 (1.81) preoperatively to 2.22 (1.08), 10.22 (2.02), and 12.77 (1.51) at postoperative day 3, and further to 0.77 (0.79), 7.04 (1.06), and 15.22 (0.95) at the final follow-up (TABLE 2). All follow-up results were significant, as compared with the preoperative results (TABLE 2). No cases of disc residue were observed on postoperative CT and MRI (FIGURES 2 and 3), and the spinal cord compression caused by the protruding nucleus pulposus disappeared, achieving complete decompression of the spinal cord in all patients.

Case illustration **Case 1** A 37-year-old woman presented with weakness and numbness in the lower extremities lasting for 6 months. Preoperative sagittal CT suggested no OPLL, and the coronal view showed a giant DH at the C4/C5 level (FIGURE 2A). Preoperative MRI also suggested GCDH at the C4/C5 level, which compressed the spinal cord (FIGURE 2B). During the procedure, massive CDH was clearly exposed. The spinal cord was compressed to form a significant depression (FIGURE 2C). MS-ACDF was performed with a diagnosis of GCDH-CSM at the C4/C5 level. After the removal of the herniated CD, the spinal cord was considerably distended and pulsed (FIGURE 2D and 2E). Postoperative radiography indicated that the plate and cage were well fixed (FIGURE 2F). MRI showed that the GCDH had been completely removed, and the spinal cord was sufficiently decompressed (FIGURE 2F and 2G). The patient's preoperative symptoms improved notably, and no limb weakness or numbness was observed at a 13-month postoperative follow-up.

Case 2 A 61-year-old man presented with weakness and numbness in the upper and lower extremities that had persisted for 48 months. Preoperative CT and MRI consistently indicated a diagnosis of GCDH-CSM at the C4/C5 level (FIGURE 3A and 3B). During the MS-ACDF procedure, the herniated disc was carefully removed, and the spinal cord was distended (FIGURE 3C–3E). Postoperative radiography and MRI confirmed that the disc had been completely removed, and the spinal cord was substantially decompressed and re-expanded (FIGURE 3F and 3G).

DISCUSSION GCDH-CSM poses a significant challenge for spinal surgeons, and the optimal

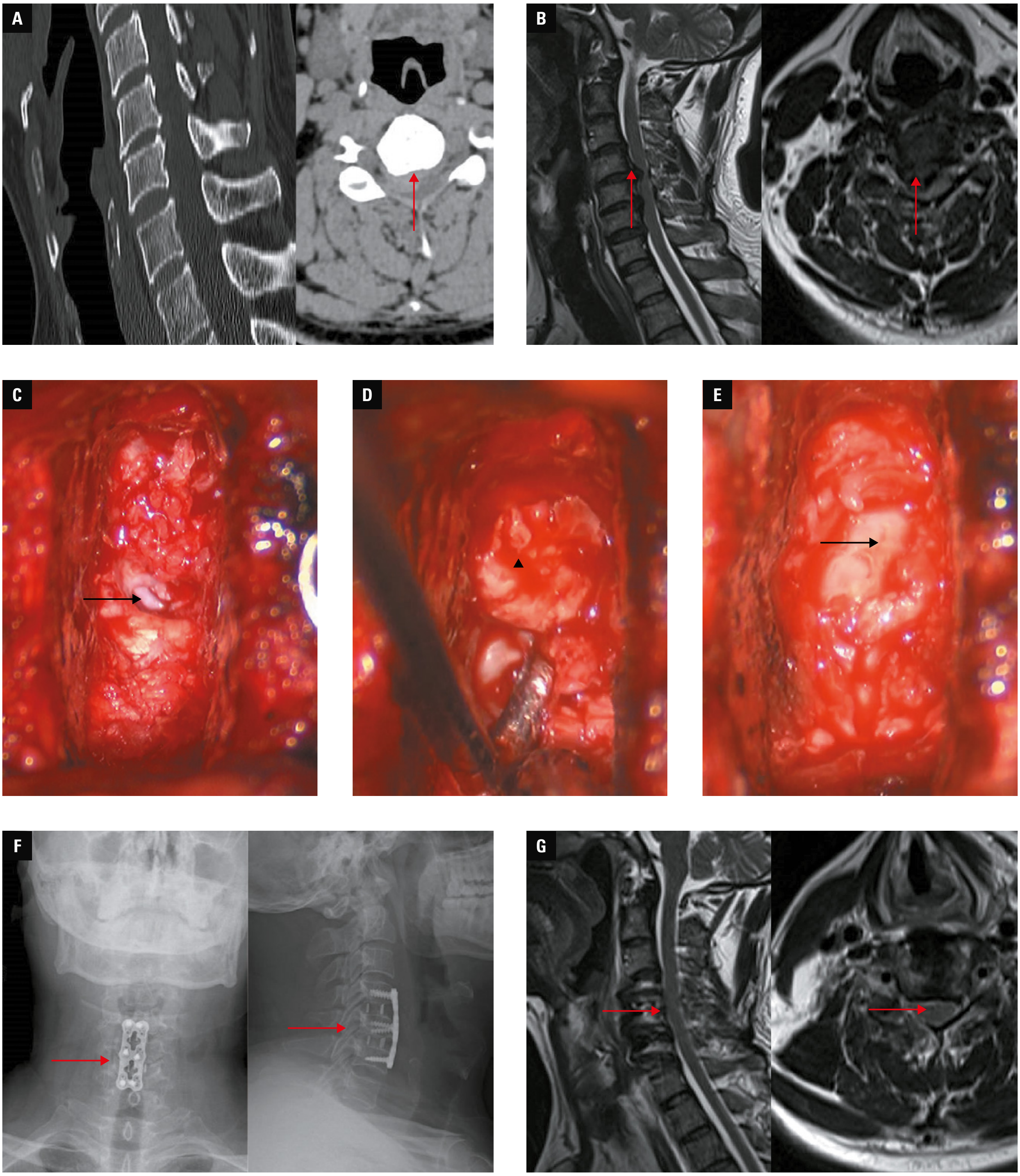

FIGURE 3 Case 2. A 61-year-old man with weakness and numbness in upper and lower extremities that had persisted for 48 months; **A** – preoperative sagittal computed tomography showing no ossification of the posterior longitudinal ligament, and a coronal view showing the herniated disc at the C4/C5 level (arrow); **B** – preoperative magnetic resonance imaging showing giant disc herniation in the C4/C5 intervertebral space (arrows); **C** – natural rupture formed by the herniated nucleus pulposus tissue in the intervertebral space (arrow); **D** – protruding free nucleus pulposus tissue (arrowhead); **E** – spinal cord distension and filling after removing the herniated cervical disc to relieve compression (arrow); **F** – postoperative frontal and lateral radiographs showing the implanted cage-plate system (arrows); **G** – postoperative MRI with spinal cord re-expansion after decompressive discectomy (arrows)

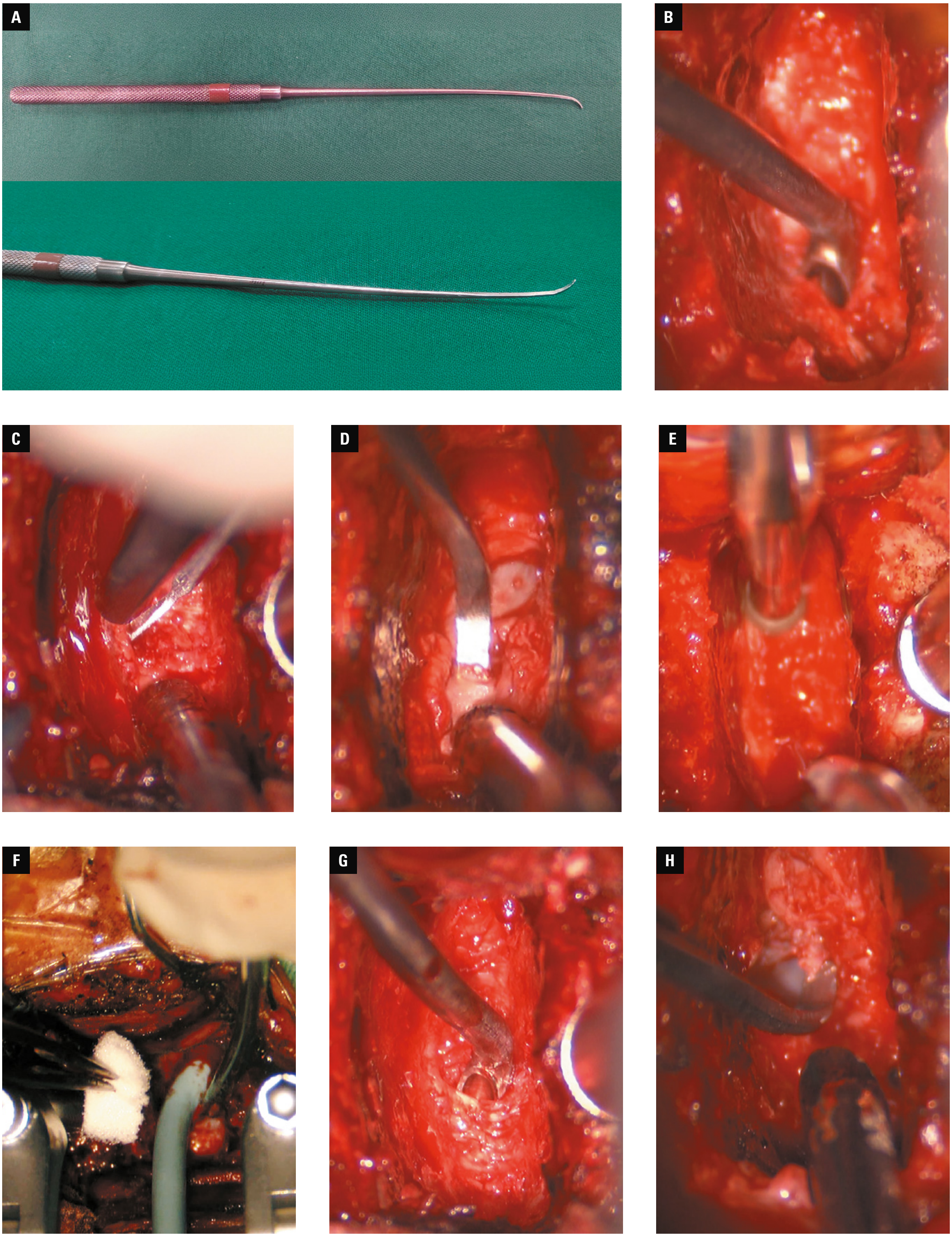

FIGURE 4 Procedure instruments and course; **A** – micro nerve hook; **B** – detachment of the soft tissue from the posterior vertebral margin using a reverse angle curette; **C** – removal of posterior osteophytes with a pituitary rongeur; **D** – separation of the soft tissue at the posterior aspect of the disc space from the dura mater with a reverse angle curette; **E** – separation of the posterior longitudinal ligament from the dura mater with a micro nerve hook; **F** – polishing of the ossified posterior vertebral margin with a grinder; **G** – extraction of a disc fragment with a micro nerve hook; **H** – combined use of fluid gelatin and gelatin sponge for hemostasis

surgical approach remains controversial. While the efficacy of anterior approaches in providing direct decompression for GCDH-CSM has been confirmed, concerns regarding safety persist, as these procedures are associated with a risk of complications, such as postoperative neurologic impairment and dysphagia.[5,14,15] In contrast, posterior approaches (eg, laminoplasty) are relatively safe, but may not achieve complete decompression for ventral lesions, potentially resulting in suboptimal functional recovery.[16,17] Although combined anterior and posterior approaches may offer certain advantages in reducing complications and promoting specific functional outcomes, their more invasive nature, longer operative time, and increased blood loss contribute to higher overall medical expenses.[18-20] This study specifically demonstrated the feasibility and effectiveness of MS-ACDF in the treatment of soft GCDH-CSM. Notably, all patients reported satisfaction with their outcomes, and no instances of recurrence or adjacent segment degeneration were observed during follow-up.

MS-ACDF provides superior visualization and is less invasive than conventional open procedures. It enables surgeons to clearly distinguish fine anatomical structures during surgery, thereby helping prevent iatrogenic spinal nerve injury. A key technical factor contributing to the success of MS-ACDF in this series was the use of a self--designed stable retractor system. This system was easily assembled using readily available instruments: a hemostat, scarf forceps, a 250-ml saline bag, prebent Kirschner wires, and a silk thread. Its notable stability liberated the assistant from the physically demanding task of prolonged manual retraction, and the system remained securely in place without requiring repositioning despite intraoperative adjustments in patient position. The straightforward setup of this stable retractor system provided a consistently clear operative field, which facilitated surgical maneuvers, reduced surgeon arm fatigue, and contributed to procedural precision and safety. It should be noted, however, that these perceived benefits are based on a subjective operative experience of the surgeons and assistants involved. Future studies could incorporate objective measures—such as recording the first assistant's postoperative VAS scores for bilateral arm discomfort or quantifying the number of intraoperative readjustments per hour via video review—to formally validate these advantages.

Comparative analysis with mainstream retractors, such as the Caspar pin-based system and traditional blade retractors (eg, S-shaped retractors), showed that our stable retractor system mitigated various issues, including screw malposition, screw loosening, and edema in adjacent tissues or organs resulting from aggressive retraction—complications often associated with conventional systems that can lead to dysphagia, dyspnea, or pharyngeal discomfort.[21,22] Our system was designed to integrate the advantages of stable distraction achieved via Kirschner wires with a simple, self--retaining mechanism. Its core value lies in offering a practical, low-cost, and efficient alternative that facilitates meticulous microsurgical dissection, particularly in settings with limited access to robotic surgical systems. We acknowledge that its fixed design necessitates vigilance against sustained pressure on adjacent soft tissues, such as the esophagus. However, no such complications were observed in the present case series, which may be attributed to vigilant intraoperative monitoring and the system's ability to provide sustained, stable retraction without repeated adjustments. These features collectively address the anterior approach safety concerns previously raised by Kuo et al[14] and Zhai et al.[17]

One-stage anterior surgery demonstrates significant advantages for managing soft GCDH-CSM, including reduced operative time, shorter hospital stays, and lower overall costs, as compared with posterior or combined approaches. It should be emphasized, however, that this study exclusively involved patients with soft DHs without significant OPLL.[23,24] In the cases with extensive OPLL, a posterior or combined strategy is generally favored over a standalone anterior procedure. This recommendation stems from the substantially elevated risks associated with anterior resection of calcified lesions, where adherence between the ossified ligament and the dura elevates the potential for dural tear and spinal cord injury.[25] A posterior approach circumvents these risks by achieving indirect decompression via canal expansion. According to Yang et al,[26] patients with OPLL involving more than 3 vertebral levels or a canal occupancy ratio exceeding 50% should be considered for posterior or combined surgery to minimize risks and ensure sufficient decompression. In this study, none of the 22 patients with soft GCDH-CSM sustained spinal cord, vertebral artery, or nerve injuries. During surgery, a micro nerve hook and a reverse angle curette were used to separate the lesions, and the narrow surgical field was magnified under microscopic visualization. Intraoperative bleeding is a common concern for every surgeon and influences the patient's postoperative recovery. Although tiny capillaries and nerves are clearly visualized under a microscope, bleeding from the surface of the herniated nucleus pulposus and minor vascular tears on the spinal cord surface are sometimes inevitable. In such situations, the surgeon must maintain composure, accurately identify the bleeding source, and administer a flowable hemostatic agent precisely onto the site. The surgeon then inserts an absorbable gelatin sponge and applies firm pressure for approximately 1 minute to achieve complete hemostasis. Although we were also concerned about ischemia-reperfusion injury, no such complications occurred. Therefore, performing gentle intraoperative maneuvers is essential.

We have to acknowledge that this study has several limitations. First, it was designed retrospectively to compare pre- and postoperative data, and therefore comparisons with the posterior or combined anterior and posterior surgical approaches were not possible. Second, the number of patients included in this study was relatively small, and no long-term results were obtained. Furthermore, the stable surgical field provided by the self-designed retractor system may have contributed to the precision of the microsurgical dissection, enhancing the surgeon's capability to perform delicate maneuvers within the confined surgical space, and thereby improving procedural safety. These technical advantages may have served as supplementary factors in achieving the positive results reported. Further multicenter, large-sample, randomized controlled studies are necessary to confirm these findings.

Technical note In our study, we used a self-designed stable retractor system. It not only saves human resources but also prevents loosening during intraoperative position adjustment. In fact, the spinal cord is capable of accepting slow compression to some extent but is flimsy during sudden violent operations. After breaking layer-by-layer, the bony structures were cleared first, followed by the soft tissues deeper in the compression. A reverse angle curette was used to separate the posterior edge of the vertebral body from the soft tissue, and a gap was created to bite off the posterior vertebral body bone (**FIGURE 4A** and **4B**; *Videos 1* and *2*). A micro nerve hook (**FIGURE 4C–4E**; *Videos 3* and *4*) was used to explore the breakthrough between the soft tissues and the dura mater, and the reverse angle curette was then used to extend the gap. Free nucleus pulposus tissue slid out automatically after the compressed tissue was cleared. A micro nerve hook was used to excise the tissue hidden behind the vertebrae (**FIGURE 4F**; *Video 5*). Unlike in common CDH, the key to managing GCDH-CSM is to remove the nucleus pulposus tissue from the back of the intervertebral space. It is not necessary to clear the thin, soft tissues on the surface of the spinal cord because they do not cause compression and are usually accompanied by complex venous plexuses. When bleeding occurred on the surface of disc tissue, bipolar electrocoagulation was used for hemostasis (*Video 6*). When the blood vessels on the surface of the spinal cord tore and caused bleeding, the first step was to find the bleeding point, spray fluid gelatin against it, and cotton to compress for 1 minute or place a 1 mm × 5 mm × 1 mm compressed gelatin sponge into the bleeding point (**FIGURE G**; *Video 7*). For patients with calcification of the posterior longitudinal ligament, a high-speed grinding drill was used to polish the calcified tissue, after which the lesion was removed (**FIGURE H**; *Video 8*). For 1-sided herniation, the less severely affected side of the lesion was usually treated first.

CONCLUSIONS The application of a stable retractor system in MS-ACDF proves to be a technically feasible and clinically effective strategy for managing carefully selected cases of soft GCDH-CSM. This approach demonstrates a favorable safety profile and achieves sustained functional recovery throughout mid-term follow-up.

ARTICLE INFORMATION

VIDEO The video files are available online at https://dx.doi.org/10.20452/wiitm.2025.17995.

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CONTRIBUTION STATEMENT HJ: writing the original draft, reviewing and editing the paper, methodology, and formal analysis. LL, SL, CY, ZZ, GW, XW, and XY: follow-up analysis, methodology, and formal analysis. LH: resources, methodology, formal analysis, and data curation. HQ: resources, data curation, and supervision. JA: conceptualization, reviewing and editing the manuscript, formal analysis and supervision. JQ and HQ: surgery performance. All authors read and approved the final version of the manuscript.

AI STATEMENT Artificial intelligence was not used in the preparation of this manuscript.

CONFLICT OF INTEREST None declared.

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JOURNAL INFORMATION

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