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Needle-Guided Suture Technique for Lumbar Annular Fiber Closure in Microendoscopic Discectomy: A Technical Note and Case Series

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Background: Annular fiber closure techniques have been proven effective in reducing short-term recurrence after discectomy. However, annular fiber closure devices are expensive and still fail at a low rate. We present a novel suture method, needle-guided annular closure suture (NGACS) that does not require a special device and can be performed for annular fiber closure following microendoscopic discectomy.


Material/Methods: Twenty-five patients who underwent treatment with NGACS were reviewed by analysis of the medical records. The clinical outcomes were assessed and compared preoperatively and immediately, 1, 6, and 12 months post-operatively. The parameters included the Visual Analog Scale (VAS)-back and VAS-leg scores and the Oswestry Disability Index (ODI). Midsagittal T2WI images were obtained to evaluate lumbar disc degeneration using the Pfirrmann grade. Additional adverse events were also recorded and tracked.

Results: The VAS-back and VAS-leg scores and the ODI were significantly different at each follow-up time point ($P < 0.001$), and improvements in pain and disability were maintained well during the follow-up period. Lumbar disc reherniation or other serious adverse events were not observed in this series. There was no significant difference between the initial and final Pfirrmann grades ($Z = -1.414$, $P = 0.157$). The preoperative average disc height was 9.94 ± 1.97 mm, and the disc height at 12 months after surgery was 9.14 ± 1.88 mm. The average decrease in disc height was $8.11 \pm 3.36\%$.

Conclusions: This study demonstrates the feasibility and superior clinical outcomes of the NGACS technique. This method can be a good substitution when annular fiber closure devices are not available. Moreover, this technique can be easily popularized due to its low cost and few restrictions.

MeSH Keywords: **Discectomy • Endoscopes • Suture Techniques • Wound Closure Techniques**

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Background

The microendoscopic discectomy (MED) technique for the treatment of lumbar disc herniation was first reported by Foley and Smith [1]. An increasing number of studies have shown that it can achieve satisfactory clinical outcomes [2–4]. However, the recurrence rate after MED is occasionally reported to be higher than that after conventional discectomy, at 1.6% to 10.8% for the former [3–6] and 1% to 15% for the latter [7–10]. A number of studies have indicated that annular fiber (AF) defects might be an important risk factor for potential reherniation [11–13]. Therefore, the AF closure technique has been widely accepted and emphasized by most orthopedists. This procedure can restore the mechanical integrity of the AF and significantly increase the failure strength of the disc [14,15]. Moreover, it can significantly delay the process of disc degeneration after surgery [14,16].

To achieve AF closure in a narrow incision space, special instrumentation is usually needed. Currently, there are various annular fiber closure devices (ACDs) for intraoperative AF repair, such as the Barricaid® (Intrinsic Therapeutics, Inc., Woburn, MA, USA) [16–19] and Xclose® Tissue Repair System (Anulex Technologies, Minnetonka, MN, USA) [20]. All of these devices have shown superior clinical outcomes in reducing the short-term reherniation rate. However, the ADCs aforementioned are implantable devices that require preparation of the implantation environment. In some cases, when the environment does not meet the requirements, these ADCs are not suitable. Furthermore, ADCs still have a small probability of failure, such as invalid implantation [19], bone resorption/loosening [21,22], infection [16,21], and instrumentation fracture. Thus, revision surgery is necessary for these conditions. The high price of ADCs can also be an additional financial burden for patients without insurance coverage. Therefore, it is urgent to find an alternative to ADCs for AF closure when ADCs fail or are unavailable.

Here, we present a novel technique called needle-guided annular closure suture (NGACS), which can be performed in a narrow incision space using common surgical instruments in the operating room. We also established a case series to show the clinical outcomes.

Material and Methods

This study received approval from the Institutional Review Board of The Affiliated Hospital of Medical School of Ningbo University.

Patient enrollment

This was a retrospective study of medical records between January 2016 and January 2017. The inclusion criteria included the following: 1) patients with progressive neurological deficit symptoms confirmed by imaging; 2) patients with intractable lower back pain (meaning that the symptoms could not be relieved by 12 weeks of conservative treatment); 3) patients who underwent MED surgery with AF repair; and 4) a follow-up period of at least 1 year. The exclusion criteria included the following: 1) patients with severe AF ossification; 2) use of any other ACDs; 3) patients with pedicle screw fixation or spinal fusion.

Surgical technique and NGACS management

All operations were performed by the same surgical team. Patients were placed in a prone position under general anesthesia. After a 20 mm paramedian incision was made and correct placement of the 22 G location needle was confirmed, the guide wire was inserted. The initial dilator was inserted through the guide wire, and then the wire was removed. Sequential dilators were inserted until the tubular retractor could be placed. Fluoroscopy was used to reconfirm the trajectory of the tubular retractor, and it was docked. To separate the soft tissue and expose the lamina, laminotomy, and flavectomy were performed routinely using a high-speed drill and laminectomy rongeur. The nerve root and dural sac were identified and separated carefully, then, the nerve root was retracted gently using a retractor to expose the herniated disc. Annulotomy was performed in a linear or cruciate manner (easy for suturing), and the nucleus pulposus was removed using grasping forceps.

After discectomy, we started the procedures for NGACS, as follows: 1) we prepared 2 long 22 G needles (0.7×180 mm) for suture line guiding and 2 long 4-0 suture lines (Coated, Braided Silk, Jiangsu, China) for each suture process. 2) Each suture line was passed through a long needle to ensure that both ends of the line were exposed. This process could be easily accomplished with the help of vacuum suction. The key point was that the suture line needed to be kept wet; otherwise, the excessive friction between the suture line and needle inhibited the suture line from passing through the needle. 3) We inserted the line needle into one edge of the AF incision to embed one end of the suture line into the disc. Then, we clamped this end outside of the incision using grasping forceps. Although this procedure might be time consuming, it is much easier to find the line by following the tip of the needle. 4) This procedure was repeated at the other edge of the AF incision. 5) Now, 2 ends of each line are available through the AF incision. The inner ends of both lines are knotted together; then, the outer ends of both lines are pulled outward to embed the inner knot

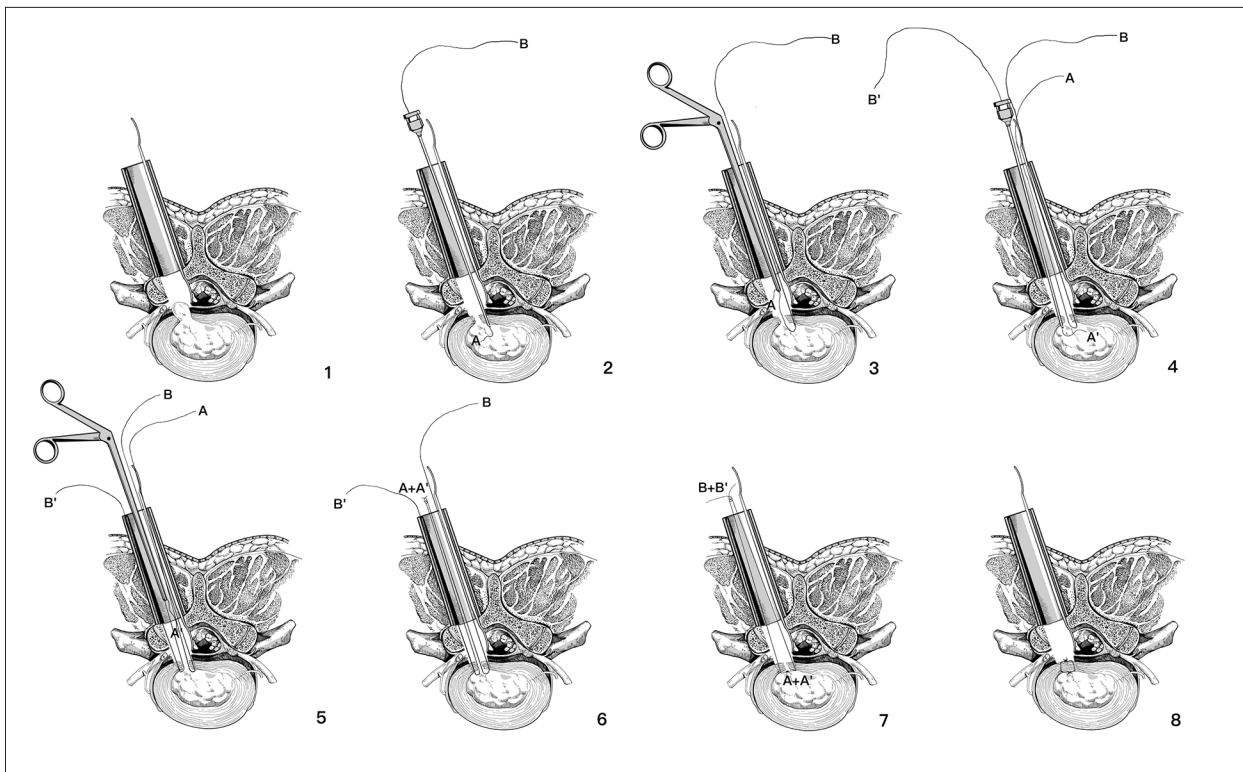


Figure 1. The needle-guided annular closure suture (NGACS) procedure: Stab the line-needle into one edge of the AF incision and clamp inner end out. Repeat this procedure at another edge of AF incision. Knot 2 inner ends together, pull the outer ends outward to embed inner knot into the disc. Then knot the outer end using knot pusher.

into the disc. Attention should be paid to avoid high temperature and cutting effects caused by drawing the suture line too fast. 6) The outer ends of both lines are knotted together using a knot pusher, ensuring that there is some strain in the knot to obtain a better closure effect. 7) Steps 1–6 are all the procedures of a single suture operation, which can be repeated if necessary (Figure 1).

Data collection

We collected the demographic data, clinical data, and radiological data preoperatively and immediately, 1, 6, and 12 months postoperatively. The clinical outcome parameters included the Visual Analog Scale (VAS) score [23] of the low back (VAS-back), the VAS score of the lower limbs (VAS-leg), and the Oswestry Disability Index (ODI) [24]. Magnetic resonance imaging (MRI) data for each patient were collected preoperatively and 12 months postoperatively and evaluated independently by a radiologist. Radiological data were acquired from midsagittal T2WI images, including the degree of disc degeneration (using the Pfirrmann grading system [25]) and the average disc height (ADH). The ADH was defined as the mean value of the anterior disc height, posterior disc height and central disc height (Figure 2). All adverse events, such as reherniation, infection, and neural lesions, were also documented.



Figure 2. The measurement of average disc height: average disc height (ADH) was defined as the mean value of anterior disc height (a), central disc height (b) and posterior disc height (c).

Statistical analysis

SPSS version 22.0 (IBM Co., Armonk, NY, USA) was used for statistical analysis. Repeated measures ANOVA and the least significant difference (LSD)-t test were used for comparing measurement data with a normal distribution. The Wilcoxon

Table 1. Patient characteristics.

No.	Sex	Age	BMI	LDH level	Pfirschmann grading	LDH type	AF incision shape
1	Female	52	24.7	L4–L5	IV	Extrusion	Linear
2	Male	37	22.2	L4–L5	III	Protrusion	Cruciate
3	Female	40	22.8	L5–S1	III	Protrusion	Cruciate
4	Female	63	25	L4–L5	IV	Extrusion	Linear
5	Male	46	24.2	L5–S1	III	Protrusion	Cruciate
6	Male	28	24.6	L5–S1	III	Protrusion	Cruciate
7	Male	51	20.1	L5–S1	III	Protrusion	Box defect
8	Female	55	22.4	L4–L5	IV	Extrusion	Linear
9	Female	52	25.6	L5–S1	III	Protrusion	Linear
10	Female	46	22.2	L5–S1	III	Extrusion	Cruciate
11	Male	42	25.7	L4–L5	IV	Extrusion	Linear
12	Male	49	19.9	L4–L5	IV	Protrusion	Box defect
13	Female	36	21.5	L4–L5	III	Protrusion	Linear
14	Male	36	20.4	L4–L5	III	Protrusion	Linear
15	Male	45	27.2	L5–S1	III	Extrusion	Linear
16	Male	38	26.7	L5–S1	III	Protrusion	Cruciate
17	Female	56	25.1	L3–L4	III	Protrusion	Linear
18	Male	63	20.7	L5–S1	V	Extrusion	Box defect
19	Female	60	19.3	L4–L5	IV	Protrusion	Cruciate
20	Female	44	21.1	L5–S1	III	Extrusion	Cruciate
21	Male	31	20	L4–L5	III	Protrusion	Cruciate
22	Female	58	26.5	L4–L5	IV	Extrusion	Linear
23	Male	26	19.4	L4–L5	III	Protrusion	Cruciate
24	Male	55	23.4	L5–S1	IV	Extrusion	Linear
25	Male	45	26.3	L4–L5	III	Protrusion	Linear

BMI – body mass index; LDH – lumbar disc herniation; AF – annular fiber.

matched-pairs signed-rank test was used for comparing ranked data. Significance was defined as a *P*-value <0.05.

Results

Patient characteristics

There were 11 female patients and 14 male patients enrolled in this study. All patients were diagnosed with single-level lumbar disc herniation and treated by MED with the NGACS technique. The follow-up period was at least 1 year. The mean age was 45.6 ± 10.9 years, and the mean body mass index (BMI) was 23.1 ± 2.6 kg/m². The discs involved in this study were L3–L4 (1 case), L4–L5 (13 cases), and L5–S1 (11 cases). The disc degeneration degree, lumbar disc herniation type and AF incision shape are described in Table 1.

Clinical outcomes

The average VAS-back and VAS-leg scores preoperatively and immediately, 1 month, 6 months, and 12 months postoperatively were 4.56 ± 1.26 , 3.04 ± 0.94 , 1.88 ± 0.73 , 1.72 ± 0.94 , and 1.32 ± 1.07 and 6.48 ± 0.87 , 2.40 ± 0.50 , 2.04 ± 0.46 , 1.44 ± 0.51 , and 1.32 ± 0.56 , respectively. The difference in the VAS-back score over the entire period was statistically significant ($F=51.778$, $P<0.001$), corresponding to the difference in the VAS-leg score ($F=427.027$, $P<0.001$). The ODI preoperatively and 1 month, 6 months, and 12 months postoperatively was $61.33 \pm 6.32\%$, $22.49 \pm 5.22\%$, $17.96 \pm 3.26\%$, and $15.20 \pm 3.83\%$, respectively. The overall difference was significant ($F=617.584$, $P<0.001$), and significant differences were also found between each follow-up time point ($P<0.05$) (Figure 3). Improvements in pain and disability were maintained well during the follow-up period.

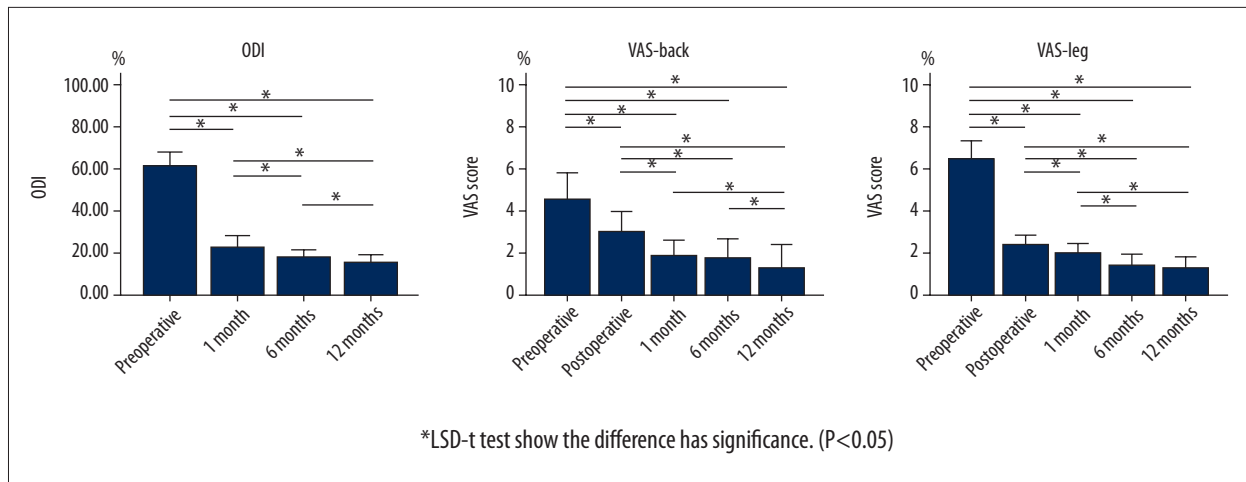


Figure 3. The Visual Analog Scale (VAS)-back, VAS-leg score and Oswestry Disability Index (ODI) in each period.

Table 2. Radiological Outcomes(Pfirschmann Grading and ADH).

No.	Pfirschmann grading		Average disc height		
	Preoperative	12 months	Preoperative (mm)	12 months (mm)	Height decrease (%)
1	IV	IV	8.41	7.92	5.83
2	III	III	11.47	10.44	9.01
3	III	III	11.25	10.66	5.21
4	IV	IV	8.17	7.46	8.69
5	III	III	10.10	9.38	7.10
6	III	III	11.73	10.76	8.24
7	III	IV	11.12	9.25	16.76
8	IV	IV	8.37	7.68	8.28
9	III	III	10.15	9.70	4.46
10	III	III	9.70	9.09	6.26
11	IV	IV	8.67	8.22	5.15
12	IV	IV	6.38	5.95	6.79
13	III	III	9.81	9.07	7.57
14	III	III	11.13	9.97	10.04
15	III	IV	11.74	10.43	11.16
16	III	III	12.60	11.72	7.04
17	III	III	10.37	9.50	8.36
18	V	V	4.62	3.82	17.30
19	IV	IV	8.13	7.53	7.42
20	III	III	10.79	9.78	9.36
21	III	III	12.46	12.06	3.21
22	IV	IV	8.14	7.32	10.07
23	III	III	11.25	10.69	4.98
24	IV	IV	9.55	8.77	8.17
25	III	III	12.47	11.40	8.58

Radiological outcomes

The Pfirrmann grade and the ADH at each time point are presented in Table 2. The signed-rank test showed no significant difference between the initial and final grade ($Z=-1.414$, $P=0.157$). The preoperative ADH was 9.94 ± 1.97 mm, and the ADH at 12 months postoperatively was 9.14 ± 1.88 mm, resulting in a decrease in ADH of $8.11\pm 3.36\%$.

Adverse events

During the entire follow-up period, we confirmed that no cases of reherniation occurred at the surgical segment based on the judgment of symptoms and MRI findings. In addition, no cases of surgical infection were observed. The only adverse event was one case of hyperesthesia of the lower limb on the affected side, while myodynamia remained normal. This may have been caused by traction of the nerve root during the operation. This patient's symptoms were relieved during the 6th week after neurotrophic treatment and rest.

Discussion

Adequate evidence indicates that AF closure after discectomy can improve clinical outcomes. The major advantages of AF closure are improved postoperative symptoms, early postoperative rehabilitation and a reduced short-term recurrence rate [16–20].

Currently, several kinds of AF closure methods that do not require ACDs have been reported, each of which has its own indications and limitations. Suh et al. [26] reported a method for AF closure using 2 sewn threads and an anchor fixed to cortical bone. This technique requires an AF incision close to the vertebral body and produces high longitudinal tension in the suture area. Li et al. [27] reported the application of a kind of pistol-shaped, disposable fibrous ring stitching instrument. This device allows automatic puncture and easy knotting, but it also has high requirements for incision shape; incisions over 3 mm in width cannot be processed by this device. Compared with the limitations of existing methods, the NGACS method we suggest in this study allows the suturing of AF incisions unrestricted by shape. The contraindications to NGACS are severe AF ossification and a complete defect in the incisal edge.

In our study, MED combined with the NGACS technique showed good maintenance of symptomatic improvement, and no short-term reherniation cases were observed. For the majority of cases in our study, in which a linear or cruciate AF incision was used, the NGACS technique achieved sealed closure of the AFs and prevented the nucleus pulposus from extruding through the breach. For those cases with an AF defect, NGACS

may not be able to completely close the AFs, but it can reduce the cross-sectional area of the AF defect. More importantly, repeated suturing can form a net barrier for the nucleus pulposus. Examination of the case data revealed that in the 2 box-defect cases in our study, the patients had severe ADH loss. This type of patient is prone to having wide basal AF folds at the posterior aspect of the disc; thus, thorough decompression tends to remove more AFs. We suggest that AFs should be resected to a limited extent on the premise of ensuring the decompression effect in such patients. Although there was no recurrence in either of the 2 box-defect cases, we suggest that this kind of AF incision should be avoided as much as possible. Studies have shown that the box-defect incision is associated with a higher recurrence rate [28], and even after repair, the strength will be only 40–50% of that resulting from a linear or cruciate incision during the early healing process [29].

For the prevention of disc degeneration, NGACS also showed good maintenance of the disc signal on imaging and the ADH. The preoperative and 12-month Pfirrmann grades were similar, and maintenance of the disc height was superior to the results of previous studies, in which discectomy was performed without AF repair [28,30,31]. Regarding surgical complications, the only case of hyperesthesia may have been associated with severe nerve root compression and traction. There was no evidence that NGACS increases the likelihood of other complications in our limited case study. Suturing under endoscopy can be visualized and controlled well to ensure the lowest risk of nerve injury.

There are still some limitations to this study. This was a retrospective non-controlled study, and the conclusions might be biased. The sample size of this study was small, and the follow-up period was short. To verify the reliability of the NGACS technique, further biomechanical studies and large sample-size case-control studies are needed.

NGACS also has some shortcomings. Compared with the use of the automatic disposable suture device, the NGACS procedure is more cumbersome. A well-trained surgeon usually needs to spend an extra 10 to 15 minutes for suturing. Moreover, there are 2 knots in each NGACS suture, which makes it theoretically more probabilistic for the knots to loosen. As a complement, when NGACS is contraindicated or fails, other AF suture technique or an ACD can still be considered. Therefore, we believe that the NGACS technique is an ideal and widely adaptable suture method that can complement the existing AF closure technology as a low-cost alternative when ACDs or disposable suture devices are not available or have failed.

Conclusions

This present study demonstrates the feasibility and superior outcomes of a method for AF closure that does not require a special device. We suggest that the NGACS technique can serve as a back-up or low-cost alternative technique for AF closure.

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