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The use of targeted percutaneous laser disc decompression under the guidance of puncture-radiating pain leads to better short-term responses in lumbar disc herniation

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Abstract. – OBJECTIVE: Traditional percutaneous laser disc decompression (PLDD) eliminates nucleus pulposus in the center of lumbar discs. Targeted PLDD is an alternative technique that involves elimination and decompression of the target area located 5-8 mm in the front of the herniated disc. We aimed to compare the efficacy of targeted PLDD with traditional PLDD in the treatment of lumbar disc herniation and evaluate the usefulness of guidance by puncture-radiating pain on clinical outcomes of PLDD.

PATIENTS AND METHODS: We treated 61 patients with lumbar disc herniation. Patients were stratified into control group, which included patients who underwent traditional PLDD, and study group in patients underwent targeted PLDD. Clinical outcomes and efficacies were evaluated at different time points using the visual analog scale (VAS) and modified MacNab criteria.

RESULTS: Patients in the study group demonstrated significantly greater decreases in the VAS scores compared with those in control group. These differences were observed on Day 3, and 1 and 3 months after the treatment. Further, VAS scores were markedly lower in the patients whose treatment was guided by the puncture-radiating pain. Thus, at 1 month after the operation, 64.1% of those patients showed excellent or good outcomes based on MacNab criteria, which was almost twice the percentage seen in patients who did not experience the puncture-radiating pain (36.4%).

CONCLUSIONS: Targeted PLDD is an effective, minimally invasive, and safe technique for lumbar disc herniation, and this technique achieves better short-term postsurgical outcomes than traditional PLDD. Puncture-radiating pain is an important prognostic indicator for better short-term responses to the treatment.

Key Words:

Lumbar disc herniation, Laser treatment, Percutaneous laser disc decompression, Puncture-radiating pain.

Introduction

Lumbar disc herniation is a displacement of nucleus pulposus or annulus fibrosis beyond the intervertebral disc space. It is not clear why disc herniation causes back and/or radicular pain, because pressure on a peripheral nerve root should produce paresthesia, but no pain. It is possible that biochemical factors play a role in pain associated with disc herniation. Supporting this, high levels of pro-inflammatory mediators are found inside degenerative discs and around the nerve root[1,2].

Disc decompression is used to treat patients after failure of conservative therapies. Percutaneous laser disc decompression (PLDD) is an effective minimally invasive treatment for lumbar disc herniation[3-5] and is thought to work through two potential mechanisms. First, PLDD reduces intradisc pressure, leading to reduction of nerve root compression[6]. Second, PLDD achieves thermal destruction of intradisc nociceptors, which may affect the pathophysiology of disc pain[7].

To ensure optimal safety and efficacy, it was suggested that the needle should be parallel to the disc axis, midway between the two endplates[8,9]. The needle tip should be placed beyond one-third of intervertebral space, when viewed laterally, and at the midline on anteroposterior view[8,9]. Indeed, most studies use the needle tip location similar to original description[10,11]. However, there are also opinions questioning the suggested optimal location of the needle tip. Thus, some authors, using T1-weighted MRI images, divide the herniated disc into 4 quadrants and 3 zones in a concentric circle (central, middle, and peripheral zones)[12], and suggest to target the middle zone of the quadrant that includes the herniated portion of the disc to provide better clinical

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outcomes (Figure 1)[12]. Our study confirmed that location of needle tip and area of laser-evaporated nucleus pulposus should be close to disc herniation to be able to achieve optimal efficacy.

Further, the original publication[13] argues against the nerve anesthesia, such that the patients report sciatic pain when the therapeutic needle contacts the root. The surgeon is supposed to subsequently withdraw the needle and aim for the 'safe triangle' during reinsertion[13]. However, we believe that this description may easily misinterpreted such that the pressure point is erroneously considered dangerous when this radiating pain occurs. As a result, another point may be chosen. According to our case load, this pain is very often not caused by the contact of the needle tip with the nerve root. We call this pain as "puncture-radiating pain". We found that this type of pain is an important marker to predict therapeutic outcomes. To the best of our knowledge, there were no reports on importance of this pain as a prognostic marker. The lack of awareness about importance of this pain may lead a surgeon to miss the best puncture point on the annulus fibrosis for the needle tip.

This report describes our case series with this modified PLDD that we call "targeted PLDD" and highlights the significance of puncture-radiating pain as a prognostic marker.

Patients and Methods

Patients

This study enrolled all patients examined in our Division from April 1, 2008 to December 1, 2012 due to lower back pain radiating to the leg. In all patients, a 3-months conservative therapy had failed. The CT and MRI scans indicated posterolateral nonsequestered lumbar intervertebral disc herniation. The clinical symptoms were attributed to herniated discs. We excluded patients with unstable neurological deficits, cauda equina syndrome, bony spinal canal stenosis, uncorrectable bleeding diathesis, metastatic disease of the spine, severe scoliosis, severe spondylolisthesis, psychosis, drug dependency, severe neurosis, or pregnancy.

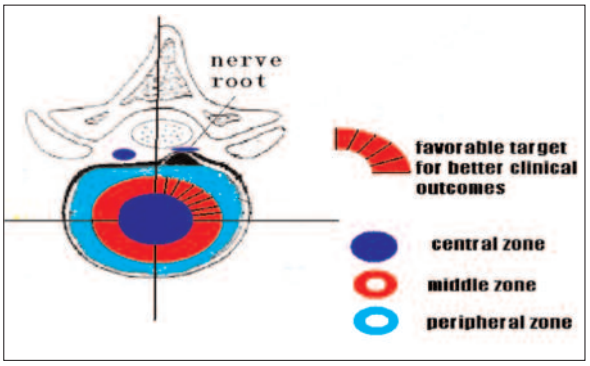

Figure 1. The herniated disc divided on a T1-weighted MRI scans into 4 quadrants and 3 zones in a concentric circle (central, middle, and peripheral zones). The middle zone in the quadrant, including the herniated portion of the disc, appears to be a favorable target for better clinical outcomes.

Study Design

Sixty-one patients (34 men and 27 women) with nonsequestered lumbar intervertebral disc herniation were enrolled in the study. The average age of the patients was (mean ± SD) 42.5 ± 15.1 (range: 16-73) years. There were 42 L4/5 discs, 10 L5/S1 discs, 2 combined L3/4 and L4/5 discs, and 7 combined L4/5 and L5/S1 discs treated by PLDD. Fifty-one patients showed a positive Lasegue's sign, determined as sciatic pain appearing after straight leg was raised below 60°. All patients signed a statement of informed consent to participation in this study.

Targeted PLDD

There are recommendations by some clinicians[14] to insert the needle into the extruded part of the nucleus pulposus, as this decreases the volume of this portion of tissue. This leads to superior clinical results compared with procedures that decrease the volume of the intradisc nucleus pulposus. However, the former path requires C-arm fluoroscopy to localize the entry point of the needle on the skin to the medial border of the facet joint, about 0.5-1.0 cm from the midline, suggesting the use of a posterior approach different from previously described (Figure 2).

Our approach was similar to those previous reports[12,14] in that better results can be obtained when the needle tip is closer to the herniated part of the disc. We defined an area 5-8 mm in the front of the herniated disc as the target area for needle insertion (Figure 3) and decompressed the nucleus pulposus in this area. This access we called as "targeted PLDD". In most cases, the target area was located within the quarter of the intervertebral space on the lateral view and at a connecting line of the medial border of the vertebral pedicle on the anteroposterior view (Figure 4).

All procedures were performed in a sterile operating room with patients placed in prone posi-

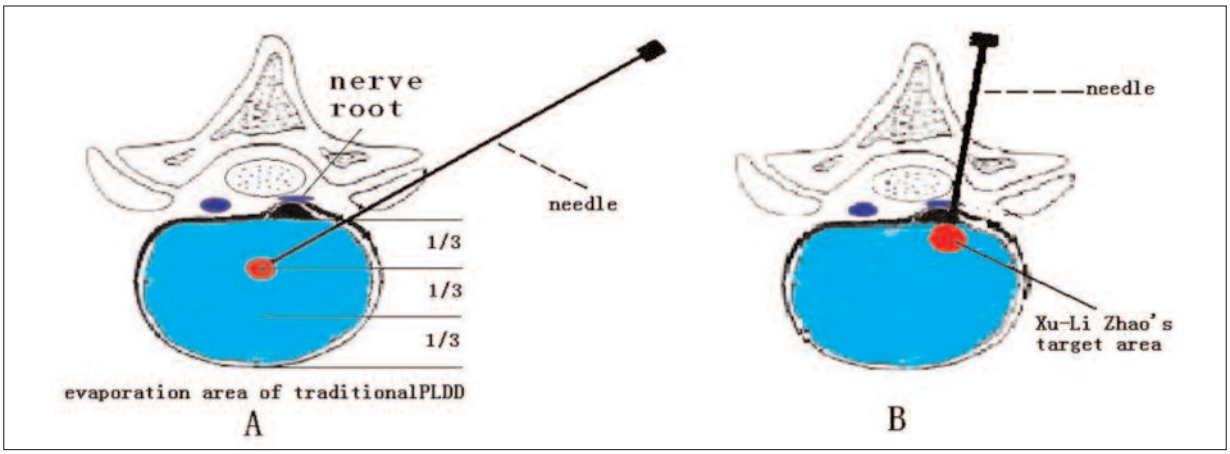

Figure 2. Traditional and targeted PLDD. ***A,*** Central evaporation area and posterior-lateral approach of traditional PLDD. ***B,*** The target evaporation area in targeted PLDD and posterior approach of the needle are different from those reported before.

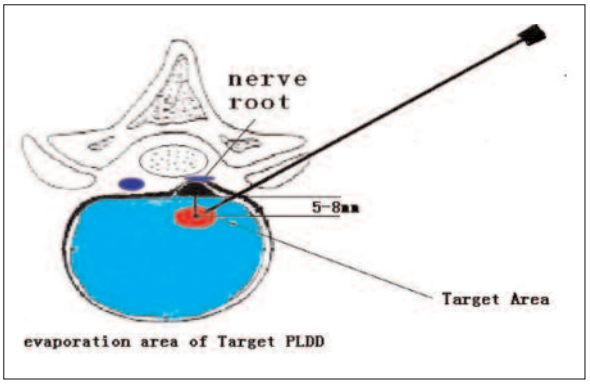

Figure 3. Targeted area. We defined the area 5-8 mm in the front of the herniated disc as target area for needle insertion in the targeted PLDD procedure.

tion on a surgical bed. The treatment level and entry point were localized by C-arm fluoroscopy. The posterolateral needle entry point was generally 10-12 cm from the midline above the iliac crest for the L4/5 disc and 7-9 cm for the L5/S1 disc. The point of entry was prepared with antiseptic solution, and skin, deep fascia, and muscle layers were locally anesthetized. We used caution to avoid injecting the anesthetic into the flavum ligament and epidural space in order to keep the spinal nerve unanesthetized. An 18-gauge needle was slowly inserted into the target area under fluoroscopic guidance.

Puncture-radiating pain was defined as patient-reported pain that radiated to the leg when the in-

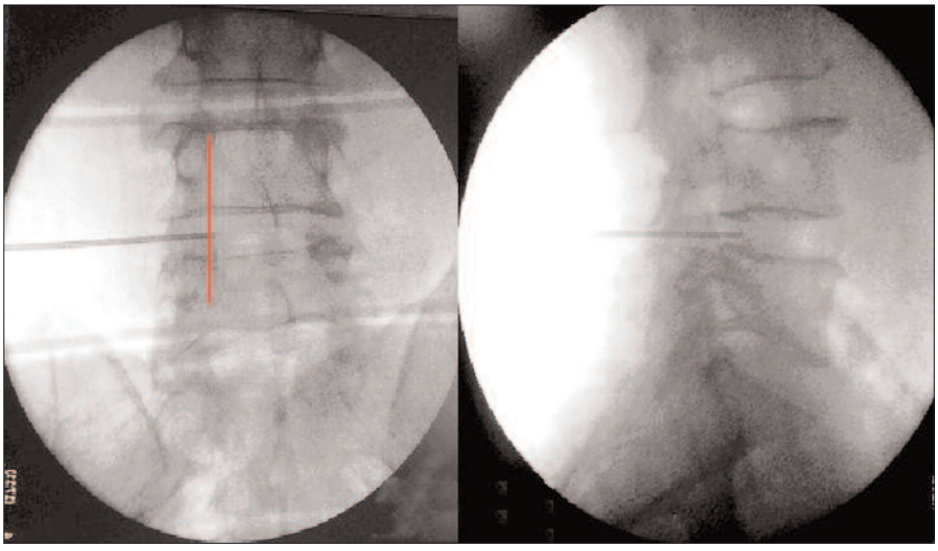

Figure 4. Position of the needle tip in targeted PLDD under X-ray monitoring. The target are of the needle tip located at one-fourth of the distance into the intervertebral space on the lateral view and at the connecting line of the medial border of the vertebral pedicle (*red line*) on the anteroposterior view.

serted needle pressed against the annulus fibrosis. After radiographically validating the needle position in the target area, an optical fiber was inserted through the needle. The fiber was then connected to the diode laser device (wavelength of 808 nm; Quanta Series A, Italy). The laser power was set to 10-12 W, with 1-sec pulses and 1-sec pauses. The total laser energy was determined by the patient response and usually ranged from 600 to 1500 J. During vaporization phase, the surgeon monitored patient' response, specifically asking the patient about the low back or radiating pain. After the operation, we removed both the fiber and needle, and covered the puncture point with sterile dressing. We then allowed the patient to turn over and monitored for changes in symptoms, as well as rechecked for Lasegue's sign.

Traditional PLDD Technique

As per published protocols[6], the needle tip was at one-third into the intervertebral space on the lateral view and on the middle line on the anteroposterior view. The rest of the procedure was similar to that described above.

Pre- and Post-Operational Care

In both groups, patients were treated with antibiotics 30 min before the operation and were instructed to rest in bed for 24 hours after the operation. All patients were followed up for 12 months.

Efficacy Criteria

Clinical outcomes were evaluated in 3 days, and 1, 3, and 12 months after either PLDD. The 3-day efficacy was evaluated only by the visual analog scale (VAS: 0-10), while the 1-, 3-, and 12-months efficacies were evaluated using both VAS and modified MacNab criteria (Table I)[12].

The VAS score decrease rate for each patient was calculated using the following formula: (pre-operation VAS – postoperation VAS at a specified time point) / pre-operation VAS × 100%. The MacNab excellent and good rates were calculated using the following formula: (excellent number + good number) / total number × 100%.

Statistical Analysis

Statistical analysis of the data was performed using SPSS statistical software (version 16.0, IBM SPSS, Chicago, IL, USA). The VAS scores and decreases in VAS score rates are reported as mean ± SD. Evaluation results of MacNab criteria are reported as excellent and good rates. The VAS score reduction rates were compared using Student's *t*-tests. Excellent and good rates were compared using chi-square test. Differences with the p value of < 0.05 were considered statistically significant.

Results

The VAS Score Rates

Twenty-one patients underwent traditional PLDD, while 40 patients were subjected to targeted PLDD. Results of the VAS scores in patients of both study groups are presented in the Tables II and III. Patients in the targeted group experienced significantly greater decreases in VAS scores compared with those who under the traditional technique: (day 3, respectively: 54.4% ± 19.0% vs. 35.9% ± 18.8%, $p < 0.01$; month 1: 65.1% ± 12.6% vs. 55.7% ± 14.2%, $p < 0.01$; month 3: 71.1% ± 12.7% vs. 62.2% ± 18.4%, $p < 0.05$). At 12 months after the operation, the rates were not significantly different between both groups (respectively, 79.6% ± 14.5% vs. 74.6% ± 16.3%).

One month after the operation, the excellent and good outcomes were observed in 57.5% patients of study group vs. 47.6% of patients of control group who were treated with traditional PLDD. At month 3 and 12, these parameters respectively became 67.5% vs. 57.1%, and 82.5% vs. 76.2%. These differences did not reach statistical significance.

Table I. Modified MacNab criteria for assessing clinical outcomes after treatment.

Outcome	Description
Excellent	Disappearance of symptoms; complete recovery to work and sports
Good	Occasional episodes of low back pain or sciatica; no limitations to occupational activities
Fair	Insufficient improvement of symptoms; periodic administration of drugs
Poor	No improvement of clinical situation; limitation of physical activities

Table II. VAS score decrease rates in control and study groups.

		Control group (traditional PLDD) (n = 21)	Study group (targeted PLDD) (n = 40)
Pre-operation	VAS	6.51 ± 0.93	6.64 ± 1.12
3-day	VAS	4.10 ± 1.15	2.94 ± 1.10
	Rate (%)	35.9% ± 18.8%	54.4% ± 19.0%**
1-month	VAS	2.86 ± 0.9	2.24 ± 0.66
	Rate (%)	55.7% ± 14.2%	65.1% ± 12.6%**
3-month	VAS	2.43 ± 1.14	1.86 ± 0.78
	Rate (%)	62.2% ± 18.4%	71.1% ± 12.7%*
12-month	VAS	1.62 ± 1.05	1.31 ± 0.85
	Rate (%)	74.6% ± 16.3%	79.6% ± 14.5%

Footnote: Data are presented as mean ± SD. *$p < 0.05$, **$p < 0.01$ vs. control group.

The short-term VAS Scores and MacNab Criteria

The results for patients who experienced puncture-radiating pain and those who did not are presented in the Tables IV and V. Thirty-nine patients who reported puncture-radiating pain were classified into the "pain" group, while the remaining 22 patients were assigned to the "no pain" group.

Interestingly, patients in the "pain" group demonstrated greater VAS score decrease rates than those who did not experience pain. This was true both 3 days and 1 month after the operation (respectively, 52.9% ± 19.6% vs. 40.2% ± 21.1% on day 3, $p < 0.05$; 65.0% ± 14.0% vs. 56.4% ± 12.4% at month 1, $p < 0.05$). By contrast, no significant differences in the VAS score decrease rates were observed at months 3 and 12 after the operation.

Further, at 1 month after the operation, 64.1% of patients who experienced puncture-radiating pain reported excellent or good MacNab criteria. This was significantly higher than in patients in the "no pain" group (36.4%, $p < 0.05$). Further, 67.5% and 82.1% of patients in the pain group, and 57.1% and 77.3% of patients in the "no pain" group showed excellent and good outcomes at the 3- and 12-months time points. However, these differences did not achieve statistical significance.

No serious complications, such as infection, nerve root injury, hematomas of the psoas major muscle, or serious low back pain, were observed in study patients.

Discussion

The first PLDD was performed in February 1986[15]. To this date, PLDD has been successfully used in many countries[16-18]. In most studies, 75%-85% of patients demonstrated excellent and good rates, judged by the MacNab criteria for long-term responses[13,17]. However, short-term outcomes (i.e., 3 days and 1 month) have not been well studied. The short-term efficacy is very important to quickly diminish low back and leg pain. Based on the results reported in our study, we believe that targeted PLDD, guided by the puncture-radiating pain, is very helpful to improve short-term clinical outcomes following PLDD.

Table III. Comparison of MacNab scores in control and study groups.

		N	Excellent	Good	Fair	Poor	Excellent and good rate
1-month	Control group	21	2	8	8	3	47.6%
	Study group	40	3	20	12	5	57.5%
3-month	Control group	21	4	8	7	2	57.1%
	Study group	40	5	22	10	3	67.5%
12-month	Control group	21	6	10	3	2	76.2%
	Study group	40	15	18	5	2	82.5%

Footnote: Patients in control group were treated by traditional PLDD, while patients in study group by targeted PLDD.

Table IV. Comparison of VAS score decrease rates between "pain" and "no-pain" groups.

		No pain group (n = 22)	Pain group (n = 39)
Pre-operation	VAS	6.16 ± 0 .90	6.81 ± 1.06
3-day	VAS	3.66 ± 1.28	3.11 ± 1.17
	Rate (%)	40.2% ± 21.1%	52.9% ± 19.6%*
1-month	VAS	2.64 ± 0.66	2.33 ± 0.86
	Rate (%)	56.4% ± 12.4%	65.0% ± 14.0%*
3-month	VAS	2.02 ± 0.87	2.04 ± 0.92
	Rate (%)	66.7% ± 15.5%	69.3% ± 14.3%
12-month	VAS	1.52 ± 0.97	1.34 ± 0.92
	Rate (%)	74.8% ± 17.0%	79.7% ± 14.2%

Footnote: Data are presented as mean ± SD. *$p < 0.05$, **$p < 0.01$ vs. no-pain group.

Our observations of the efficacy of targeted PLDD were primarily based on patients' feedback during the operation. Laser evaporation of the target area close to the herniated disc often led to relief of sciatic pain, alleviation of numbness, and increased flexibility and strength of lower limbs following the surgical procedure. Additionally, we found that more patients in the targeted group experienced reductions in VAS scores at 3 days, 1 month, and 3 months after the operation, confirming that targeted PLDD leads to better short-term clinical outcomes.

Compared with open surgery, PLDD achieves better long-term functional outcomes, and is much safer and less invasive[17]. The drawback of this technique is that it is not as reliable as open surgery for short-term sciatic pain relief. An excellent minimally invasive surgical method should be more effective to relieve pain immediately, as is often achieved in microdiscectomy. Targeted PLDD appears to sufficiently improve short-term clinical outcomes to make up for these deficiencies and the relatively poor efficacy of traditional PLDD.

Most cases of lumbar disc herniation involve regression and dehydration of the nucleus pulposus, and possible rupture of the annulus fibrosis, which markedly decrease the elasticity of the disc[19-21]. Evaporation of the center of such discs may not completely alleviate the pressure of herniated disc on the nerve root. However, evaporation close to the area of disc herniation results in a softer herniated disc compared with results of pre-operation, thereby decreasing the pressure of the herniated disc on the nerve root. Furthermore, in targeted PLDD, thermal energy is easily transferred to the peripheral area of the nerve root. Thereby, the effects of targeted PLDD are better than evaporation of the center of the disc.

In general, our experiences with targeted PLDD are comparable with published reports[12,14]. There are, however, some differences. The target area in our study was more accurately defined and was much closer to the herniated disc than in previous reports[14]. Further, X-ray positioning was utilized in our study in order to operate more easily. As some authors[12] used C-arm fluoroscopy to localize the entry point of the needle on the skin to the medial border of the facet joint, about 0.5-1.0 cm from the midline, this suggests that their posterior approach was different from our approach and those described elsewhere[12,14].

Table V. Comparison of MacNab scores in control and study groups.

		N	Excellent	Good	Fair	Poor	Excellent and good rate
1-month	No pain group	22	2	6	10	4	36.4%
	Pain group	39	3	22	10	4	64.1%*
3-month	No pain group	22	4	7	9	2	50.0%
	Pain group	39	5	23	8	3	71.8%
12-month	No pain group	22	8	9	3	2	77.3%
	Pain group	39	13	19	5	2	82.1%

Footnote: *$p < 0.05$ vs. "no-pain" group.

As our results demonstrate, patients reporting puncture-radiating pain showed better short-term VAS score decrease rates and MacNab criteria, confirming that puncture-radiating pain is an important prognostic indicator of short-term outcomes. Therefore, the puncture point of the needle tip on the annulus fibrosis, which causes puncture-radiating pain, should be carefully controlled in order to achieve better clinical outcomes. Some surgeons erroneously believe that this region is too dangerous to be punctured and, therefore, refrain from such punctures. However, this jeopardizes their ability to find the best puncture point. Understanding the importance of the puncture-radiating pain will help to improve the efficacy of PLDD, and this is another goal of our report.

The puncture-radiating pain may be important because of three reasons. First, it confirms that the diagnosis was done correctly. Second, it indicates that the point of the needle tip on the annulus fibrosis is very close to the herniated disc. Third, it shows that the herniated disc is elastic, suggesting that the pressure on the nerve root will decrease after evaporation. In most cases, the radiating pain was not caused by the contact of the needle tip with the nerve root, as the needle was in the "safe triangle". However, it is possible that puncture-radiating pain may be caused by the contact of the needle tip with the nerve root, as previously discussed[13]. Therefore, surgeons need to observe the pain level and motor function response of patients in order to avoid nerve root injury. If patients could endure the pain, we inserted the needle into the disc slowly and gently. If patients were unable to endure the pain, we moved the needle forward from the point A to point B (Figure 5), farther from the herniated disc. The puncture-radiating pain then failed to appear or presented mildly. We inserted the needle into the disc, eliminated the nucleus pulposus, and decompressed the disc. We then moved the needle back to the point A. Once the disc pressure was reduced, puncture-radiating pain failed to manifest or presented only mildly. We were then able to enter the disc and evaporate the target area successfully.

No serious complications were observed in this study. The surgeon performing targeted PLDD should eliminate the nucleus pulposus of the disc, and observe the pain response in the lumbar and leg regions. Any injury to the endplate or nerve root must be avoided. Use of excessive energy may injure the endplate or nerve root.

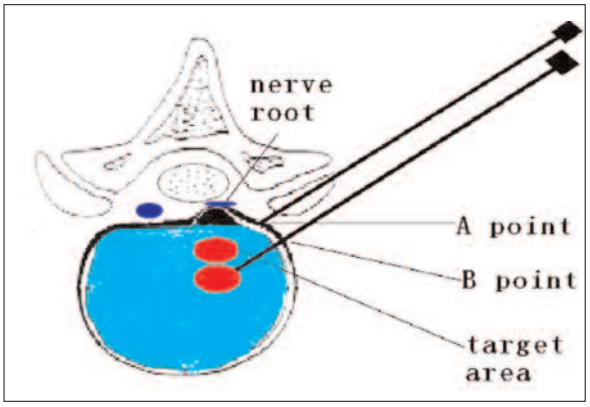

Figure 5. Puncture method if a patient cannot endure puncture-radiating pain. If a patient cannot endure puncture-radiating pain, we move the needle forward from the **point A**, to the **point B**, After elimination of the nucleus pulposus and decompression of the disc, we then moved the needle back to the point A.

Although targeted and pain groups tended to have better VAS score reduction and MacNab rates at 12 months after operation, these were not statistically different from those in patients treated traditionally. This may be attributed to a limited number of patients in this study. Thus, this was just a preliminary study. Further investigations with bigger patient numbers are needed to verify these results.

Conclusions

These results suggested that targeted PLDD is an effective, minimally invasive, safe technique to treat lumbar disc herniation. Further, puncture-radiating pain is an important prognostic indicator of short-term (≤ 3 months) therapeutic outcomes after the operation.

Conflict of Interest

The Authors declare that there are no conflicts of interest.

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