The Treatment of Lumbar Disc Herniation through Percutaneous Hydrodiscectomy

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Abstract: Objective: To evaluate the clinical feasibility of percutaneous hydrodiscectomy in the treatment of lumbar disc herniation. Method: Between February and June 2009, 69 lumbar disc herniation patients who met inclusion criteria for the present study were selected from the Cooperative Medicine Center and underwent percutaneous hydrodiscectomy using SpineJet, manufactured by HydroCision Inc. of the United States, guided by C-arm X-ray, CT, or DSA. Therapeutic efficacy was observed and recorded on day 15, 30, 90, 150, 210, and 270 postoperatively. Results: Evaluated using the modified MacNab method, the rate of excellent or good response was 56.5%, 82.6%, 88.4%, 98.6%, 98.6%, and 98.6% on day 15, 30, 90, 150, 210, and 270, respectively. Therapeutic efficacy was directly correlated with time elapsed since the operation ($P < 0.01$). Conclusions: Percutaneous hydrodiscectomy is characterized by being simple to perform, easy to master, minimally invasive, does not affect the biomechanical stability of the spine, and does not entail serious complications.

Key words: SpineJet; lumbar disc herniation

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Lumbar disc herniation is a common condition that is frequently encountered in clinical contexts. The primary cause underlying this condition is degeneration of a vertebral disc in which the fibrous ring degenerates at a faster rate than the nucleus pulposus which it surrounds, resulting in a bulging or herniated disc. In recent years, the various advantages of minimally invasive treatment—its small degree of trauma, genuine therapeutic efficacy, few complications, preservation of spinal column stability, and the small degree of pain suffered by the patient and quick recovery—have stimulated a rapid development in the minimally invasive treatment of lumbar disc herniation, which has been thoroughly welcomed by physicians. At present, minimally invasive treatment represents the current trend in the treatment of uncomplicated lumbar disc herniation [(1)]. In the past, a multitude of methods, including chemical and physical approaches, were used clinically. While these approaches were fairly effective, they entailed a number of undesirable aspects [(2 – 11)]. Hence, clinical physicians continued searching for safer, more effective, less invasive approaches.

In 2003, the U.S. FDA approved the use of HydroCision Inc.'s SpineJet in performing percutaneous hydrodiscectomy, as a non-thermogenic liquid-jet-based discectomy approach. As yet, there have been no reports from China regarding the use of the SpineJet in the treatment of lumbar disc herniation. Since February 2009, the authors have been the first physicians in China to perform percutaneous hydrodiscectomy, achieving very optimal response rates in our treatment of lumbar disc herniation. Treatment results for 69 patients for whom complete data is available, out of 93 patients with lumbar disc herniation treated at the Cooperative Medicine Center between February and June 2009, are reported below.

Data and Methods

1. General data: 69 patients with a confirmed diagnosis of uncomplicated lumbar disc herniation presented, in accordance with criteria established by McCulloch [(12)] in 1980, with: (1) leg pain exceeding lumbar pain; (2) paresthesia and the like specific, radiculopathy symptoms; (3) a score of 50% below normal on straight-leg leg-lift test; (4) abnormal tendon reflex; and (5) a positive score on an intensified test. 49 patients were male and 20 were female. Their ages were 18 – 65 years, with an average age of 40.9 years. Duration of illness ranged from 3 – 13 years, with an average of 3.5 years. Of these 69 patients, there were 47 cases of single-level herniation, 20 cases of two-level herniation, and 2 cases of three-level herniation. Involved were L3/4: 18 discs; L4/5: 46 discs; and L5/S1: 29 discs. 44 discs were herniated to the left, 37 discs were herniated to the right, and 12 discs had medial herniations. Herniations extended from 3 to 6 mm past the posterior border of the vertebra, with an average distance of 4.8 mm.

Inclusion criteria: Patients who met the following 4 criteria were enrolled as subjects of observation: (1) patient meets the criterion established by McCulloch in 1980 of no improvement in patient's clinical symptoms after conservative treatment for ≥ 3 months; (2) pathological changes shown by MRI or CT are consistent with patient's clinical symptoms; (3) patient's intervertebral distance ≥ 50%; (4) patient's herniation extends ≤ 6 mm past posterior border of vertebra.

Exclusion criteria: Any patient having any of the following was excluded: (1) mixed-type spinal canal stenosis; (2) lumbar spondylolisthesis; (3) migrated nucleus pulposus; (4) major organ dysfunction; (5) psychiatric abnormality; (6) a history of physical or chemical intervertebral disc treatment; (7) other complicating symptoms (such as cauda equina syndrome).

2. Treatment method: The following surgical equipment was used: (1) SpineJet, manufactured by HydroCision Inc. of the United States; (2) C-arm X-ray/CT/DSA; (3) multiparameter electrocardiographic monitor.

Patients were placed on operating table in the prone position with a 15-cm-high support beneath the lower abdomen. Life signs were continuously monitored and recorded. Positioning was accomplished with C-arm X-ray/CT/DSA. Puncture sites were selected on an individual basis. Routine disinfection was performed, the patient was covered with a sterile surgical towel, and local anesthetic was applied to the selected puncture site. Needle insertion was generally performed at a point 8 – 10 cm to the side of the spinous process at an angle of approximately 45° to the sagittal plane. The procedure can be divided into three parts: Step one: The percutaneous needle travels directly to the triangular safe zone, passes through the fibrous ring, and enters the nucleus pulposus. Frontal imaging is used to ensure that the point of the needle does not cross the midline of the spinous process; lateral imaging ensures that the point of the needle is positioned at the posteromedial one third of the disc. Step two: Before a number two trocar, guided by percutaneous needle, is inserted through the skin, an incision of approximately 1 cm in length has to be made in the skin in order to ensure that the number two trocar can be twisted smoothly layer by layer through the triangular safe zone. At this point, if the patient is not experiencing discomfort in his or her lower extremities, the number two trocar can be forcefully twisted through the fibrous ring and into the nucleus pulposus, which should be accompanied by a noticeable sensation of popping through a barrier. Step three: The nut on the upper end of the number two trocar is twisted off, and a number three trocar is inserted over the number two trocar and slowly twisted while being pushed forward towards the triangular safe zone, gradually making contact with the fibrous ring. When contact is made, if the patient is not experiencing abnormal sensation in his or her lower extremities, the number three trocar can be forcefully twisted into the nucleus pulposus. The point of the number three trocar, located in the posteromedial one third of the disc, will be visible by means of C-arm lateral imaging (see figure 1). Frontal imaging or CT scan establishes that the point of the number three trocar is located within the nucleus pulposus (see figure 2). The smaller the angle of the incision, the closer the head of the SpineJet can be brought to the herniated part of the disc, and the larger the angle, the farther the head of the SpineJet will be from the herniated part of the disc. After a circular saw is inserted into the trocar, the fibrous ring is cut open, and the head of the SpineJet is inserted into the trocar, being gradually advanced by means of pushing, pulling, and twisting, while cutting and vacuuming up nucleus pulposus tissue. When the SpineJet offers a noticeable sensation of looseness and emptiness while the head of the SpineJet is within the disc, this indicates: nucleus pulposus volume, quantity, and pressure have been reduced and the objective of the procedure has been achieved. Discectomy time is generally 3 minutes. It is also possible to check the nucleus pulposus tissue in the collection bottle, ascertaining that it has turned the water from clear to turbid, resembling rice soup, and containing a fairly large number of nucleus pulposus particles. At this point, the patient's primary complaint—pain symptoms in the lumbar region and lower extremities prior to the operation—will have significantly abated. After the completion of discectomy, the patient's wound was stitched, dressed, and bandaged, and the procedure was concluded.

Postoperatively, we routinely prescribed a dehydrating agent for 3 days, antibiotics for 3 days, and in-bed recumbency 3 ≥ hours. After 24 hours, patients were permitted to perform straight-leg leg-lift exercises. For the first 3 months, patients were required to wear a back brace during activity.

3. Response evaluation: Follow-up tracking was performed by telephone, in accordance with the modified MacNab method [(13)], on day 15, 30, 90, 120, 150, and 270, respectively. Evaluation criteria: (1) Excellent: no pain, unrestricted movement, patient extremely satisfied; (2) good: occasional pain in the lumbar region or lower extremities but not affecting work or daily life; a significant improvement over preoperative condition; patient satisfied; (3) fair: significant functional improvement; however, from time to time, the patient experiences intermittent pain of a degree that can be "tolerated," having a slight impact on work and life; patient fairly satisfied; (4) poor: no improvement with regard to pain or functionality; patient unsatisfied.

4. Statistical analysis: SPSS 11.5 statistical software was used. The χ^2 test was employed for count data. The relationship between efficacy and postoperative time was analyzed by means of linear regression. A difference was statistically significant when $P < 0.05$ and extremely statistically significant when $P < 0.01$.

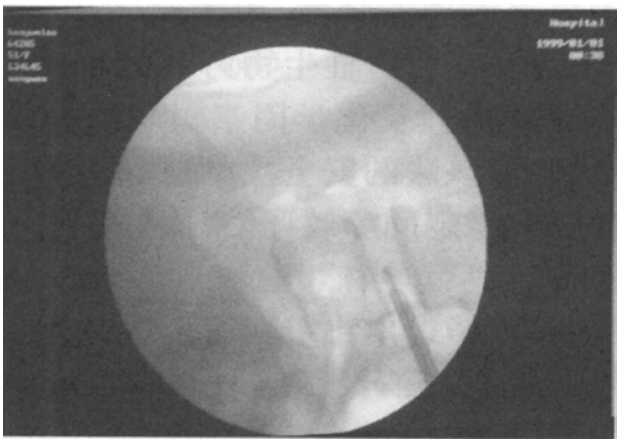

Figure 1 Position determined by C-arm X-ray

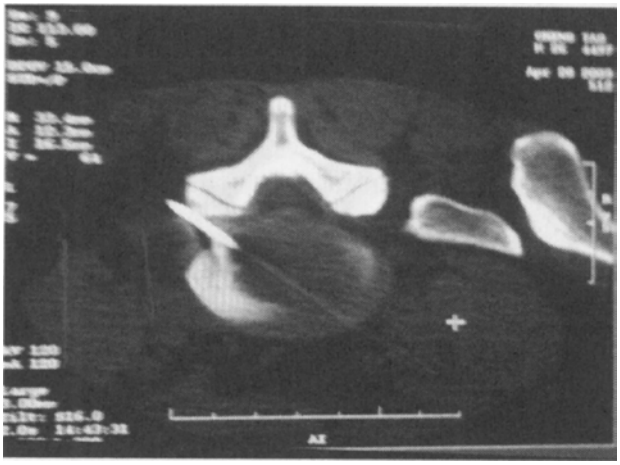

Figure 2 Positioning under the guidance of CT

Conclusion

Operating time per level: 20 min – 42 min. On average, each level took 28 min. Duration of inpatient hospitalization was 2 – 42 days, with an average hospital stay of 7.5 days. Shortest period of in-bed recumbency: patient dismounted bed immediately after procedure. Longest period of in-bed recumbency: 7 hours. Average period of in-bed recumbency: 3.8 hours. Evaluated using the modified MacNab method, the rate of excellent or good response was 56.5%, 82.6%, 88.4%, 98.6%, 98.6%, and 98.6% on postoperative day 15, 30, 90, 150, 210, and 270, respectively (see table). It was determined by χ^2 test that response on postoperative day 30 was greater by an extremely significant degree than on postoperative day 15 ($\chi^2 = 12.03$, $P = 0.007 < 0.01$), response on postoperative day 90 was not significantly greater than on postoperative day 30 ($\chi^2 = 4.275$, $P = 0.233$), response on postoperative day 150 was significantly greater than on postoperative day 90 ($\chi^2 = 8.026$, $P = 0.045 < 0.05$), response on postoperative day 210 was not significantly greater than on postoperative day 150 ($\chi^2 = 7.303$, $P = 0.063$), and that response on postoperative day 270 showed no further improvement of a significant degree over that on postoperative day 210 ($\chi^2 = 2.126$, $P = 0.345$). The relationship between efficacy and postoperative time was subjected to linear regression analysis. Using the F significance test, it was found that $F = 128.949$, $P = 0.000 < 0.01$, the regression equation was significant, and efficacy was directly correlated with postoperative time. There were two cases in which outcomes were fairly poor: In one case, intervertebral distance was 50% of normal and the degenerated portion of the disc was calcified. In another case, postoperative complicating disc space infection occurred. In the former case, the patient's outcome was evaluated as "fair" at postoperative day 90 and as "good" on day 150 during the follow-up period. In the latter case, after the patient had been under observation for 270 days, improvement began to be shown, and outcome was assessed as "fair."

Table Efficacy at various points in time following procedure (number of patients, %)

Number of days after procedure	Excellent		Good		Fair		Poor		Excellent or good rate
	Patients	Rate	Patients (n)	Rate (%)	Patients (n)	Rate (%)	Patients (n)	Rate (%)	
15 days	17	24.6	22	31.9	28	40.6	2	2.9	56.5
30 days	27	39.1	30	43.5	10	14.5	2	2.9	82.6*
90 days	39	56.5	22	31.9	7	10.1	1	1.4	88.4
150 days	48	69.6	20	29.0	—		1	1.4	98.6**
210 days	59	85.5	9	13.0	1	1.4	—		98.6
270 days	64	92.8	4	5.8	1	1.4	—		98.6

* : Postoperative day 30 compared with postoperative day 15 using χ^2 test, $P = < 0.01$.
** : Postoperative day 150 compared with postoperative day 90, $P < 0.05$.

Discussion

With the uninterrupted development of medical science and technology, an increasing number of minimally invasive and interventional techniques have displayed their skills in the field of minimally invasive spinal surgery; all offer different degrees of efficacy. Percutaneous discectomy was first reported by Hijikata in 1975. In 1985, Onik improved discectomy, creating an automated percutaneous discectomy system with a success rate of 66% - 80% [(14)]. In 2003, the SpineJet, manufactured by HydroCision Inc., was used clinically. Subsequently, this technology has been used in 19 countries in succession, and an accumulated total of over 20,000 clinical patients have been cured using this treatment. In February 2009, this technology was clinically used in China for the first time

by the authors. As of the end of June 2009, we had performed procedures on an accumulated total of 93 clinical patients. In the present paper, we report our evaluation of treatment and efficacy in those 69 patients for whom complete data is available. Clinical observation shows that percutaneous hydrodiscectomy is significantly effective. The excellent or good rate gradually reached 98.6% by the 150th day after surgery, treatment response was directly correlated with time elapsed since the procedure, and results show that the efficacy of this technique is superior to that of any other currently available minimally invasive treatment.

Hydrodiscectomy is a mechanical cutting technique without causing concerns about the damage resulting from physical and chemical factors to the intervertebral disc, and, in particular, the cartilaginous end plate. The greatest advantage of hydrodiscectomy is that it can achieve optimal reduction in pressure in patients with severe symptoms and comparatively large herniations. In particular, with a surgeon employing CT guidance to control the direction of the SpineJet, disc material at the posterior and inferior corners on either side can be cut and vacuumed away completely, something that is very hard to achieve with other minimally invasive techniques. The present data shows: hydrodiscectomy not only delivers very optimal results in terms of reducing pressure while preserving the intervertebral disc, it also preserves the biomechanical stability of the spine and entails matchlessly few complications. This is the objective, and the concept, that has been jointly pursued by both clinical physicians and patients.

The core technique involved in hydrodiscectomy is the targeted cutting and vacuuming of the nucleus pulposus. Hence, in addition to a correct understanding of when the procedure is indicated, the physician must do a sound job of preoperative planning. Penetration, cutting and vacuuming should be performed under CT guidance with the entry at specific layer and location (see figure 2). If conditions do not permit the use of CT guidance, the procedure may also be performed using DSA or C-arm X-ray (see figure 1). Three-dimensional reconstruction of spiral CT imaging helps physicians to more accurately determine puncture locations, makes operations safer, and further helps improve treatment efficacy.

In the present group of patients, one of the cases in which outcome was fairly poor resulted from the fact that (1) it took place at the beginning of the surgeries, when the authors were inexperienced at performing this procedure; and (2) the patient insisted that this method be used. It was determined through follow-up that the patient's response had improved to "fair" by day 90 and to "good" by day 150. However, in fact, this case represents an instance where the indications for performing the procedure were not understood correctly, and should be taken as a cautionary lesson! Thus, correctly understanding when surgery is indicated is a precondition for ensuring the effectiveness of the procedure. In another case, the patient had complicating disc space infection, which caused the outcome of the procedure to be unsatisfactory. In this case, after 270 days of observation, the patient showed improvement and the patient's response was upgraded to "fair."

Analysis of the relationship between efficacy and postoperative time in this group of patients has yielded the following: the rate of excellent or good response was 56.5% on postoperative day 15; response on postoperative day 30 was greater by an extremely significant degree than on postoperative day 15, with the rate of excellent or good response reaching 82.6% ($P < 0.01$); and response was temporarily stable at a rate of 82.6% - 88.4% from postoperative day 30 to postoperative day 90. From postoperative day 90 to day 150 during the follow-up period, response again undertook a striking improvement ($P < 0.05$), with the rate of excellent or good response reaching 98.6%. Follow-up was continued until day 270, during which period it was found that the rate of excellent or good response remained basically stable at 98.6%. The authors speculate that this may be due to the fact that although nerve root pressure is relieved after discectomy (see figures 3 and 4), inflammatory substances and Substance P are still present and require a definite amount of time to break down and be eliminated, and hence the patient's symptoms are not relieved noticeably. However, after the compression symptoms have been relieved, and after neuronal nutrition and blood supply have gradually been restored to normal, inflammatory substances and Substance P are absorbed and metabolized, and nerves which had been compressed repair themselves after a period of time. Thus, with the passage of time, the patient's clinical symptoms gradually improve and lift to a significant degree. Furthermore, the fact that this procedure is only mildly invasive, takes a short time, interferes to an extremely small degree with a patient's overall internal environment, basically does not affect the biomechanical stability of the spine, and does not involve interfering factors such as physical or chemical factors which are damaging to cartilaginous end plates, all serve to make this approach one that is safe, reliable, and practical. The evaluation that hydrodiscectomy offers truly stable efficacy should, based on the present data, apply to the period of time starting at postoperative day 90 and thereafter. Of course, the results of this observation also suggest to the clinical physician that after cutting and vacuuming have been completed and the number two trocar is being withdrawn, an anti-inflammatory steroid/analgesic liquid compound can be injected when the trocar is near the nerve root, in order to reduce radiculopathic inflammation and edema. The possibility of further improving short-term therapeutic efficacy awaits further clinical observation.

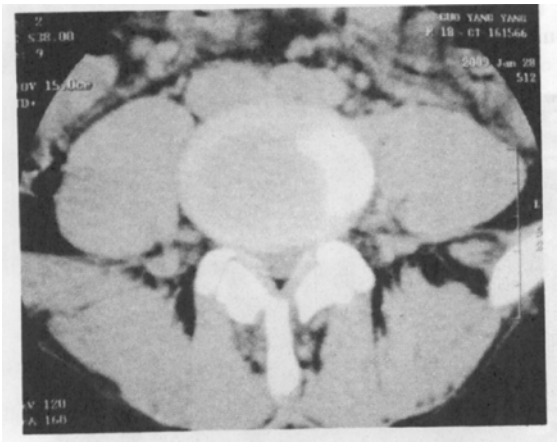

Figure 3 Preoperative image

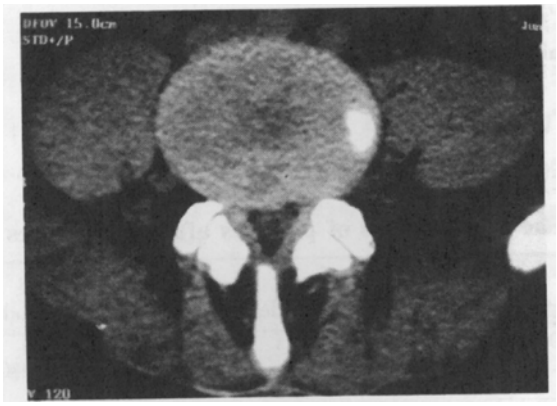

Figure 4 Image on postoperative day 5

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