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Original Article

Treatment results in different surgical approaches for intraspinal tumor in 51 patients

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Abstract: To investigate the treatment results for the different surgical approaches for intraspinal tumor in lumbar spine. We retrospectively reviewed data for 51 patients with intraspinal tumors who were treated with surgery. We used the navigation system (group A) or traditional method (group B) to guide the surgery. Through the comparison of group A (22 patients) and group B (29 patients), we found some differences between the two groups, such as their total resection rate, the placement of pedicle screws, the mean operating time, intraoperative operation loss, JOA scores. In group A, the total resection rate was 95.45%. One hundred and ten pedicle screws were implanted, and no screw injured the nerve tissues or blood vessel; the placement of 94.55% of the pedicle screws was excellent. In group B, the total resection rate was 86.28%. A total of 134 pedicle screws were implanted, including five screws that injured nerve tissues or blood vessels; the placement of 87.31% of the pedicle screws was excellent. The postoperative symptoms were significantly improved in the two groups, and there were no deaths. The operation times were significantly lower in group A than in group B ($P < 0.05$), and the intraoperative operation loss was significantly lower in group A than in group B ($P < 0.01$). Additionally, the postoperative improvement in percent evaluated by Japan Orthopaedic Association (JOA) back pain evaluation questionnaire was significantly higher in group A than in group B ($P < 0.05$). The navigation system can provide crucial help in the treatment of spinal operation as an assisted method, which has great potential to improve the accuracy and safety.

Keywords: Navigation system, intraspinal tumor, surgical treatment, lumbar spine, pedicle screw, total resection rate

Introduction

Intraspinal tumors are one of the most common diseases requiring surgical treatment, and common types of intraspinal tumors include neurilemmoma, neurofibroma and meningioma [1, 2]. Tumor oppression can cause severe neurological symptoms, and severe cases can lead to paralysis. It is well established that surgical treatment is the only effective method for treating intraspinal tumors. It is usually difficult to excise the complete tumor using traditional surgery methods. Intraspinal tumors were adjacent to the spinal cord, nerve roots and other important organizations, which may easily lead to nerve injury during operations. This surgery is extremely difficult and often leads to different degrees of nerve dysfunction after surgery. Presently, developments in surgical treatment are aimed at improving the accuracy of tumor resection and rate of total resection and reducing intraoperative nerve injury; however, it is difficult to achieve these requirements with traditional surgery.

With the development of science and technology, navigation systems have gradually developed and were first used in the spine surgery in the early 1990s of the 20th century [3]. Surgeons are proficient in their use to treat spinal fracture, but they still lack clinical experience in operations for intraspinal tumors. Additionally, there is insufficient clinical data demonstrating that the navigation system is

Table 1. Summary of the baseline characteristics of two groups

Group	N	Age year	Male/ Female	Course of disease (mouth)
A	22	41.71 ± 17.57	10/12	9.74 ± 6.07
B	29	50.39 ± 12.91	15/14	13.30 ± 13.51

This table shows the baseline characteristics of the two groups. The data are expressed as the mean ± standard deviation. There was no significant difference between the group A and group B (P > 0.05).

superior in the excision of intraspinal tumors [4, 5]. Therefore, we collected information about 51 patients who suffered from intraspinal tumors, and we performed a retrospective analysis of the curative effects of the navigation system used in the treatment of intraspinal tumors.

Materials and methods

Ethical statement

All study procedures were reviewed and approved by the Institutional Ethics Review Board at the First Affiliated Hospital of Guangxi Medical University and conducted according to the principles expressed in the Declaration of Helsinki. Informed consent was exempted by the board due to the retrospective nature of this research. Patient records/information was anonymized and de-identified prior to analysis.

Clinical data

We collected data for 51 patients with intraspinal tumors for the surgical treatment in the first affiliated hospital of Guangxi Medical University from January 2010 to April 2013. The ages of the patients ranged from 5 to 73 years (mean age of 44.98 ± 16.42 years). The course of disease ranged from 1 to 60 months (mean time of 11.34 months) (**Table 1**).

Inclusion criteria

All of the patients we selected were treated by total laminectomy, so the surgical options of tumors resection all needed internal fixation of pedicle screws; we had complete clinical data for all of them as well as at least 12 months of follow-up data. We collected the patients suffered from intraspinal tumor in lumbar spine and the diameter of the tumor < 3 cm according to the postoperative pathological analysis.

Surgical methods

Surgery was assisted by using the navigation system: 1. Preoperative processes: CT scan was performed and we imported CT data to a computer workstation to perform CT reconstruction, including three-dimensional reconstruction of the spine, spinal cord and tumors. The procedures were planned on the basis of reconstructed images. 2. Intraoperative processes: After a series of operations, the acanthi was exposed, the reference Arc on acanthi was fixed, and the infrared camera's position was adjusted. Then we began to register and locate the tumor position. Operations were begun to implant pedicle screws and resect the tumors and assisted by the navigation system's real-time monitoring after determining the location of the tumors.

Surgery was assisted by using traditional method: 1. Preoperative processes: We planned the procedures on the basis of MRI data. 2. Intraoperative processes: We only used the C-arm tracker to aid the operation, and the pedicle screws were implanted by hand. The positions of implanted pedicle screws were observed by X-ray fluoroscopy after inserted the screws.

Clinical evaluation methods

We recorded the data including the operation time, intraoperative blood loss, and rate of total resection. We evaluated the improvement in the clinical symptoms using symptoms and signs changing during the period of postoperative one week to one month. The criteria of short-term clinical efficacy were mainly referenced to the changes in the motor and sensory dysfunction, nerve root pain, and urine disorder between pre-and post-operation. Each category was divided into three grades, namely cured, improved, unchanged, and deteriorative. In the evaluation of recent clinical efficacy, cure and improvement were regarded as effectivity, no change and deterioration was regarded as nullity.

The Japan Orthopaedic Association (JOA) back pain evaluation questionnaire was used to evaluate the long-term curative effect [7, 8]. Richter perforation classification was used to evaluate the effect of pedicle screw implantation. The American Spinal Injury Association (ASIA) Impairment Scale was used for neuro-

Table 2. Classification of pedicle screw implantation

Group	Grade I	Grade II	Grade III	Excellent pedicle screws' placement rate (%)
A	0	6	104	94.55★
B	5	12	117	87.31

This table shows the effect of pedicle screw implantation. Grade I means the placement of the pedicle screw implantation is bad, grade II means the placement is good, and grade III means the placement is excellent. ★P < 0.05 vs. Group B.

Table 3. Summary of the results for the operation time, intraoperative blood loss and total resection rate

Group	Operation time (h)	Intraoperative blood loss (ml)	Total resection rate (%)
A	2.29 ± 0.51★	556.36 ± 265.29★	95.45▲
B	2.73 ± 0.91	840.35 ± 326.12	86.28

This table shows the results for the operation time, intraoperative blood loss and total resection rate. The data are expressed as the mean ± standard deviation. ★P < 0.05 vs. Group B. ▲P > 0.05 vs. Group B.

logical classifications of spinal cord injury and long-term evaluations of the neural functions.

The ASIA Impairment Scale was used to evaluate the neural functions (from 1 to 3 years): A: Complete. No sensory or motor function is preserved in the sacral segments S4-5; B: Sensory Incomplete. Sensory, but not motor function, is preserved below the neurological level and includes the sacral segments S4-5 (light touch or pin prick at S4-5 or deep anal pressure), and no motor function is preserved more than three levels below the motor level on either side of the body; C: Motor Incomplete. Motor function is preserved below the neurological level, and more than half of the key muscle functions below the neurological level of injury (NLI) have a muscle grade less than 3 (Grades 0-2); D: Motor Incomplete. Motor function is preserved below the neurological level, and at least half (half or more) of the key muscle functions below the NLI have a muscle grade > 3; and E: Normal [9, 10]. If the sensation and motor function, as tested with the ISNCSCI, are graded as normal in all segments, and the patient had prior deficits, then the ASIA grade is E. Richter perforation classification was as follows: 1). grade I bad: pedicle perforation > 1 mm with the need for screw revision due to irritation or injury of the roots or the myelon or due to the reduced biomechanical stability; 2). grade II good: pedicle perforation > 1 mm without the need for screw revision; and 3). grade III excellent: correct screw placement without pedicle perforation or with pedicle perforation < 1 mm [11, 12].

Statistical analysis

All statistical analyses were performed using SPSS17.0; numerical data were presented as $\overline{x}$ ± s. $P < 0.05$ was considered statistically significant. The measurement data such as the pre-operation and post-operation JOA scores, the operation time and intraoperative blood loss were compared using the t-test, short-term clinical efficacy were compared with the Chi-square test or the rank-sum test.

Results

Postoperative general condition and complications

There were 12 cases of spinal meningioma (23.53%), 25 cases of neurilemmoma (49.02%), three cases of epidermoid cyst (5.88%), two cases of cavernous hemangioma (3.92%), four cases of lipoma (7.85%), four cases of metastatic tumor (5.88%), one cases of teratoma (1.96%), and one case of angioreticuloma (1.96%). Of the 22 patients with successful resection in group A, 21 patients had total resection, whereas one patient had subtotal resection (the rate of total resection was 95.45%). Additionally, 110 pedicle screws were implanted without screw-related injury from a pedicle screw perforating the vertebral pedicle and injuring the nerve tissues or blood vessels. Pedicle screw placement was excellent in 94.55% of the cases, and placement was good for 5.45%. Of the 29 patients with successful resection in group B, 25 patients underwent total resection, whereas four patients underwent subtotal resection (the rate of total resection was 86.28%). Additionally, 134 pedicle screws were implanted and five patients experienced screw-related injuries. The placement was excellent in 87.31% of the cases, good in 8.96% of the cases, and bad in 3.73% of the cases. The precisions of the implanted pedicle screws were significantly higher in group A than

Table 4. Analysis of short-term clinical efficacy

Group	Nerve root pain				Urine disorder			
	N	Efficacy	Nullity	Rate of efficacy (%)	N	Efficacy	Nullity	Rate of efficacy (%)
A	14	14	0	100▲	5	4	1	80.00▲
B	19	18	1	94.74	4	3	1	75.00

This table shows the results for short-term clinical efficacy in the group A and group B. ▲*P* > 0.05 vs. group B.

Table 5. Analysis of short-term clinical efficacy

Group	Motor dysfunction				Sensory dysfunction			
	N	Efficacy	Nullity	Rate of efficacy (%)	N	Efficacy	Nullity	Rate of efficacy (%)
A	9	7	2	77.78▲	11	11	0	100▲
B	10	8	2	80.00	10	9	1	90

This table shows the results for short-term clinical efficacy in the group A and group B. ▲*P* > 0.05 vs. group B.

in group B (P = 0.049) (**Table 2**). Operation time: The mean operation time for group A was 2.29 ± 0.51 hours (range 1.5-4.0 hours), and the mean operation time for group B was 2.73 ± 0.90 hours (range 1.0~5.0 hours). The operation time was significantly lower in group A than in group B (P = 0.034) (**Table 3**). Intraoperative blood loss: The mean intraoperative blood loss in group A was 556.36 ± 265.29 ml; the mean intraoperative blood loss in group B was 840.35 ± 326.12 ml. The intraoperative blood loss was significantly lower in group A than in group B (P = 0.005) (**Table 3**). The number of postoperative complications was as follows: In group A, there was one case of infection, one case of cerebrospinal fluid (CSF) leaks, one case of local pain, and one case of abnormal incision healing. In group B, there were one case of infection, three cases of cerebrospinal fluid (CSF) leakage, two cases of local pain, and without abnormal incision healing.

Short-term clinical effects

The main clinical symptoms of the patients are motor and sensory dysfunction, nerve root pain, and urine disorder [6]. In group A, 12 patients experienced preoperative nerve root pain and then recovered to normal, and two patients improved to various degrees, without patients remained unchanged or deteriorated; 10 patients experienced sensory dysfunction and recovered to normal, while one patient improved to various degrees, without patients remained unchanged or deteriorated; six patients with motor dysfunction recovered to normal, one patient improved, one patient remained unchanged, and one patient experienced reduced myodynamia. Four patients experienced urine or fecal disorder that improved to various degrees, and one patient remained was unchanged. In group B, 16 cases of preoperative nerve root pain returned to normal, two cases improved to various degrees, one case was unchanged, and no cases deteriorated; three cases of urine disorder improved to various degrees, and one case was unchanged; five cases of motor dysfunction returned to normal, three cases improved to various degrees, one cases remained unchanged, and one case had reduced myodynamia; six cases of sensory dysfunction returned to normal, three cases improved to various degrees, one case remained unchanged, and none of the cases deteriorated. Based on the results above, the short-term clinical efficacy in the group A have no significant difference to that in the group B (P > 0.05; **Tables 4**, **5**)

Long-term clinical effects

We used the ASIA Impairment Scale to evaluate the final neural function. Of the 22 patients in group A, there were 0 grade A and grade B patients, one grade C patient, one grade D patient, 20 grade E patients, and no recurrent patients. Of the 29 patients in group B, there were 0 grade A and grade B patients, two grade C patients, one grade D patient, 26 grade E patients, and no recurrent patients. We used JOA back pain evaluation questionnaire to calculate postoperative improvement in percent = ((postoperative score) - (preoperative score))/(29-(preoperative score)) * 100%. In group A, preoperative score is 15.91 ± 4.82, postoperative score is 26.77 ± 3.10, and postoperative improvement in percent is (85.97 ± 17.29)%. In group B, preoperative score is 17.14 ± 4.48, postoperative score is 24.93 ± 4.34, and post-

Table 6. The change in the pre- operation and post-operation JOA scores

Group	Preoperative	Postoperatively	Postoperative improvement (%)
A	15.91 ± 4.82★	26.77 ± 3.10	85.97 ± 17.29▲
B	17.14 ± 4.48	24.93 ± 4.34	71.92 ± 25.50

This table shows the results for the change in the pre-operation and post-operation JOA scores. The data are expressed as the mean ± standard deviation. ★P > 0.05 vs. Group B, ▲P < 0.05 vs. Group B.

operative improvement in percent is (71.92 ± 25.50)%. There was no significant difference in the preoperative score between the group A and group B (P = 0.35). There was a significant difference in the postoperative improvement in percent between the group A and group B (P = 0.024) (**Table 6**).

Typical case

A 39-year-old female patient had pain in the left lower limb for more than 2 years; she was diagnosed with L2~3 intraspinal tumors. She was treated by resection of the intraspinal tumor and internal fixation of the pedicle screw guided by the navigation system. The pathological diagnosis was spinal meningioma. Intraoperative blood loss was 400 mL and operation time was 2.5 hours; four pedicle screws were implanted, and all pedicle screws were completely within the pedicle. The clinical effects were excellent. The JOA scores promoted from 18 to 29.

Discussion

Intraspinal tumors influence a person's quality of life and endanger a patient's life. The traditional method for determining the location of the tumor is preoperative images and intraoperative X-ray fluoroscopy. The traditional method has many drawbacks. Currently, the main use of navigation system includes the treatment of intraspinal tumors, installation of pedicle screws and other aspects [13, 14]. This technique can real-time guiding the surgical instruments far away from the important anatomical structures and ensuring the safety of the surgery. Additionally, it can help doctors perform the surgery more objectively. The location of the surgical instrument can be updated in real-time on intraoperative imaging, and the images have the advantage of being high definition.

Neurological dysfunction after the resection of intraspinal tumors has relevance in intraoperative spinal cord injury. Therefore, it requires highly advanced technology and experience in tumor resection and screw installation. In addition, the operative difficulty increases because of the complicated physical position of the tumors. It is difficult to satisfy the requirements for the accurate positioning of intraspinal tumors with the traditional method of X-ray fluoroscopy. If nerve tissues were intraoperatively injured, there would be serious consequences. Repeated fluoroscopy not only extends the operation time, it poses hazards for the health of the patient and operators. The navigation system can compare the preoperative or intraoperative imaging data with the anatomical structure. The navigation system can trace surgical instruments during the operation, and the position of surgical instruments is displayed on the computer in real-time, which makes the surgery faster and more accurate and safe. In this study, the significant difference in the rates of total resection and the pedicle screw success rate between groups A and B illustrates the advantages of the navigation system for its accuracy and security.

At the early stages of operating the navigation system, the operation time and blood loss increased because the operators were initially unskilled. After the operators become proficient with the navigation system, the accuracy in localization during the surgery increased, while the unnecessary procedures and repetition, operating time, fluoroscopy times and intraoperative blood loss were reduced. In this study, the significant difference in the operating time and blood loss between groups A and B illustrates the advantages of the navigation system. Other studies have demonstrated that the navigation system could decrease the fluoroscopy times (Kim CW. 2004) [15, 16]. All of these results show that skillful operation of navigation system can not only reduce the operating time but also it significantly reduces the X-ray exposure for the patients and the operators. According to our research, there isn't much difference in the improvement of short-term clinical efficacy between group A and group B, but there was a significant difference in the improvement of long-term clinical efficacy between the group A and group B.

Based on the results of this study, we can summarize the advantages of the navigation system in the resection of intraspinal tumors as follows: (1). The accurate positioning enhanced the resection rate of tumors and decreased the intraoperative injuries, particularly reducing the incidence of spinal cord injury. The accuracy of using the navigation system to position the lesion was higher than that of the traditional method, which is particularly beneficial for positioning smaller lesions. Because of this advantage, we can reduce the postoperative complications and quickly resume nerve and muscle's function. (2). The operating time and intraoperative blood loss were reduced. At the early stages of using the navigation system for operation, the operation time and blood loss increased as part of the training period. With increased proficiency in using the navigation system, the operation time and blood loss were reduced. (3). The occurrence of screw-related injuries was decreased. Screw-related injury was not rare when the traditional method of free-hand pedicle screw implantation was used, which some scholars have already confirmed [17-19]. In this study, the precision of implanted pedicle screws was significantly higher in group A than in group B. (4). Improving the surgeon's recognition of spinal tissues improves the surgeon's skill level. With developments in spinal surgery, operators also need to be aware of the unexposed parts; in this case, the navigation system can satisfy this requirement. (5). The risk of recurrence is reduced. The application of the navigation system can increase the total resection rate, which would reduce the recurrence rate. (6). The fluoroscopy times and postoperative complications were reduced, especially for the cases with unclear boundaries that were difficult to separate. (7). Navigation system is more effective to improve the long-term clinical efficacy, it's better to improve patients' postoperative quality of life.

In this study, we found that the application of the navigation system in the surgical treatment of intraspinal tumors could significantly improve the surgical accuracy and safety, thus increasing the rate of total resection, promoting the accuracy of pedicle screw placement, reducing the rate of spinal cord injury and the risk of tumor recurrence, shortening the operation time, and reducing the postoperative complications and fluoroscopy times. The navigation system has already become a relatively mature technology for spinal surgery and has been gradually recognized by spinal surgeons [20]. The navigation system will become the main assisted method for spine surgery because of its advantages. Although this system still has limitations and shortcomings, it will improve with further innovations in the technology. Meanwhile, there will be more hospitals using this system in the future.

Disclosure of conflict of interest

None.

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References

[1] Engelhard HH, Villano JL, Porter KR, Stewart AK, Barua M, Barker FG and Newton HB. Clinical presentation, histology, and treatment in 430 patients with primary tumors of the spinal cord, spinal meninges, or cauda equina. J Neurosurg Spine 2010; 13: 67-77.

[2] Yang S, Yang X and Hong G. Surgical treatment of one hundred seventy-four intramedullary spinal cord tumors. Spine (Phila Pa 1976) 2009; 34: 2705-10.

[3] Nolte LP, Zamorano LJ, Jiang Z, Wang Q, Langlotz F and Berlemann U. Image-guided insertion of transpedicular screws. A laboratory set-up. Spine (Phila Pa 1976) 1995; 20: 497-500.

[4] Kalfas IH. Image-guide spinal navigation. Clin Neurosurg 2000; 46: 70-88.

[5] Kamimura M, Ebara S, Itoh H, Tateiwa Y, Kinoshita T, Takaoka K. Accurate pedicle screw insertion under the control of a computer-assisted image guiding system: Laboratory test and clinical study. J Orthop Sci 1999; 4: 197-206.

[6] Jinnai T, Koyama T. Clinical characteristics of spinal nerves heath tumors: analysis of 149 cases. Neurosurgery 2005; 56: 510-515.

[7] Izumida S, Inoue S, Kataoka H, Tajima N, Nakano N, Hasue M and Ubukata S. Assessment of treatment for low back pain. J Jpn Orthop Assoc 1986; 60: 391-394.
[8] Ohtori S, Ito T, Yamashita M, Murata Y, Morinaga T, Hirayama J, Kinoshita T, Ataka H, Koshi T, Sekikawa T, Miyagi M, Tanno T, Suzuki M, Aoki Y, Aihara T, Nakamura S, Yamaguchi K, Tauchi T, Hatakeyama K, Takata K, Sameda H, Ozawa T, Hanaoka E,Suzuki H, Akazawa T, Suseki K, Arai H, Kurokawa M, Eguchi Y, Suzuki M, Okamoto Y, Miyagi J, Yamagata M, Toyone T and Takahashi K; Chiba Low Back Pain Research Group. Evaluation of low back pain using the Japanese Orthopaedic Association Back Pain Evaluation Questionnaire for lumbar spinal disease in a multicenter study: differences in scores based on age, sex, and type of disease. J Orthopaedic Science 2010; 15: 86-91.
[9] American Spinal Injury Association. Internat-ional Standards for Neurological Classification of Spinal Cord Injury. revised 2000. Atlanta, GA: Reprinted, 2008.
[10] Waring WP 3rd, Biering-Sorenson F, Burns S, Donovan W, Graves D, Jha A, Jones L, Kirshblum S, Marino R, Mulcahey MJ, Reeves R, Scelza WM, Schmidt-Read M and Stein A. 2009 reviews and revisions of the International Standards for The Neurological Classification of Spinal Cord Injury. J Spinal Cord Med 2010; 33: 346-352.
[11] Li SG, Sheng L, Zhao H, Zhang JG, Zhai JL and Zhu Y. Clinical applications of computer-assisted navigation technique in spinal pedicle screw internal fixation. Zhonghua Yi Xue Za Zhi 2009; 89: 736-739.
[12] Gelalis ID, Paschos NK, Pakos EE, Politis AN, Arnaoutoglou CM, Karageorgos AC, Ploumis A and Xenakis TA. Accuracy of pedicle screw placement: a systematic review of prospective in vivo studies comparing free hand, fluoroscopy guidance and navigation techniques. Eur Spine J 2012; 21: 247-255.
[13] Amiot LP, Labelle H, DeGuise JA, Sati M, Brodeur P and Rivard CH. Computer-assisted pedicle screw fixation. A feasibility study. Spine (Phila Pa 1976) 1995; 20: 1208-12.
[14] Schlenzka D, Laine T and Lund T. Computer-assisted spine surgery. Eur Spine J 2000; 9: 57-64.
[15] Kim CW, Lee YP, Taylor W, Oygar A, Kim WK. Use of navigation-assisted fluoroscopy to decrease radiation exposure during minimally invasive spine surgery. Spine J 2008; 8: 584-590.
[16] Wang D, Yang J, Zhao J and Zhao Y. Application of computer-assistant neuronavigation in spinal operation. Zhonghua Yi Xue Za Zhi 2004; 84: 18.
[17] Laine T, Mäkitalo K, Schlenzka D, Tallroth K, Poussa M and Alho A. Accuracy of pedicle screw inspection: a prospective CT study in 30 low back patients. Eur Spine J 1997; 6: 402-405.
[18] Steinmann JC, Herkowitz HN, Kommos H and Wesolowski DP. Spinal pedicle fixation. Confirmation of an image-based technique for screw placement. Spine (Phila Pa 1976) 1993; 18: 1856-1861.
[19] Amiot LP, Labelle H, DeGuise JA, Bellefleur C and Rivard CH. Computer assisted pedicle screw installation. Our first 3 cases. Ann Chir 1996; 50: 626-630.
[20] Nowitzke A, Wood M, Cooney K. Improving accuracy and reducing errors in spinal surgery-a new technique for thoracolumbar-level localization using computer-assisted image guidance. Spine J 2008; 8: 597-604.