中国临床研究 Chin J Clin Res, May 2024, Vol.37, No.5
Cite as: Xu C, Yang JC, Ji SF, et al. Trans-segmental shunt surgery for the treatment of syringomeylia resulting from trauma and infection [J]. Chin J Clin Res, 2024, 37(5):703-708.
DOI: 10.13429/j.cnki.cjcr.2024.05.011

Trans-segmental shunt surgery for the treatment of syringomeylia resulting from trauma and infection

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Abstract: Objective To investigate the clinical effect of trans-segmental shunt of syringomyelia due to trauma and infection combined with cerebrospinal fluid dynamics. **Methods** A total of 17 syringomyelia patients admitted to the inpatient Syringomyelia Department in Zhengzhou Central Hospital from July 2019 to June 2021 were collected, all patients underwent cross-segmental shunt surgery for syringomyelia. The clinical features, electromyography and imaging features of patients before and after operation were analyzed. The Chicago Chiari Outcome Scale (CCOS) and Japanese Orthopaedic Association (JOA) score were used to evaluate the clinical prognosis of patients. Pearson method was used to analyze the correlation between the improvement index of JOA score and CCOS score and the difference of peak velocity of cerebrospinal fluid. **Results** After trans-segmental shunt, the clinical symptoms of 14 cases were significantly improved, and 3 cases did not improve. The JOA score was significantly higher after surgery than before surgery (17.65±1.80 *vs* 8.94±2.36, t=11.609, P=0.001). Limb numbness, dissociative sensory disorder, gait disorder, dizziness, lower limb weakness, ataxia, sensory nerve conduction, motor nerve conduction, maximum diameter of cavity and peak cerebrospinal fluid flow in the foramen magnum and the midbrain aquaquet during systolic and diastolic periods were significantly improved after surgery (P<0.05). JOA score improvement index and CCOS score were significantly correlated with the difference of CSF peak velocity (P<0.05). **Conclusion** For patients with syringomyelia caused by trauma or infection, trans-segmental shunt of syringomyelia can improve the cerebrospinal fluid dynamics of patients with syringomyelia to a certain extent, promote the reduction of syringomyelia and improve the clinical symptoms of patients.

Keywords: Trans-segmental Shunt Surgery; Syringomyelia; Arachnoiditi; Spinal cord injury; Cerebrospinal fluid dynamics
Fund program: Science and Technology Research Project of Henan Province (222102310652)

Syringomyelia is caused by the filling of potential cavities in the spinal cord parenchyma or central canal with fluid due to various reasons [1]. It is mostly associated with congenital diseases such as Chiari malformation, and can also be caused by acquired tumors, trauma, infection, spinal cord tethering, or arachnoiditis. Adhesion in the subarachnoid space can lead to distortion of cerebrospinal fluid flow in the subarachnoid space, resulting in syringomyelia several years after a traumatic event [2]. The clinical symptoms of syringomyelia are mainly a series of motor and sensory disorders caused by compression of the spinal cord at the level of the cavity, and it is a chronic progressive neurological injury. In this study, patients were treated with cross-segmental shunt surgery. We compared the clinical symptoms, electromyographic changes, and cerebrospinal fluid dynamics before and after surgery to explore the clinical efficacy of cross-segmental shunt surgery in the treatment of syringomyelia caused by trauma and infection, providing a more scientific basis for surgical treatment of patients with syringomyelia.

1. Materials and Methods

1.1 General Information

Clinical data from 17 patients with syringomyelia who were admitted to the Spinal Cord Cavernous Malformation Specialist inpatient department of Zhengzhou Central Hospital from July 2019 to June 2021 were collected. There were 10 male patients and 7 female patients, with ages ranging from 28 to 76 years, and an average age of 47.29 years. The disease duration ranged from 1 to 12 years, with an average duration of 5.70 years.

Inclusion Criteria: (1) Patients had preoperative magnetic resonance imaging examination suggesting syringomyelia [3]; (2) they had obvious clinical symptoms and signs including but not limited to intracranial hypertension, progressive neurological damage, ataxia, muscle strength sensory disorder, etc.; (3) patients and their families volunteered to seek cross-segmental shunt surgery after understanding the purpose, risks, and effects of the surgery; (4) they did not have hydrocephalus or congenital developmental deformities.

Exclusion Criteria: (1) syringomyelia caused by other etiologies such as Chiari malformation, tumor, spinal cord tethering, surgery, etc.; (2) patients with concomitant atlantoaxial dislocation or subluxation, hydrocephalus, flat skull base, scoliosis, etc.; (3) patients with concomitant cardiopulmonary dysfunction and severe impairment of important organ function who were unable to cooperate with surgery.

1.2 Data Collection

Both preoperative and postoperative electromyography and PC-MRI were performed on the patients. All enrolled patients were evaluated with Japanese Orthopaedic Association (JOA) score [4] both before and after surgery, and the improvement of JOA scores was calculated (JOA score improvement index = post-treatment score - pre-treatment score, post-treatment score improvement rate = [improvement index / 29 - pre-treatment score] × 100%). Postoperative Chicago Chiari Outcome Scale (CCOS) [5] was used to assess the prognosis of patients, with a score of 10 as the cutoff point, defining >10 as a good prognosis and ≤10 as a poor prognosis.

1.2.1 Electromyography

The Danish-Dantec KEY POINT electromyography device was used to perform nerve conduction studies, motor nerve conduction, F-wave, and H-reflex testing on the bilateral median nerves, tibial nerves, and peroneal nerves of the patients in a supine position. Surface electrodes were used for stimulation and recording.

1.2.2 PC-MRI Scan

In this study, a Siemens Skyra 3.0T superconducting nuclear magnetic resonance scanner was used. Under retrospective ECG gating, PC-MRI scanning of the head and neck was performed at the central segment of the mesencephalic aqueduct and the foramen magnum **[Figure 1]**.

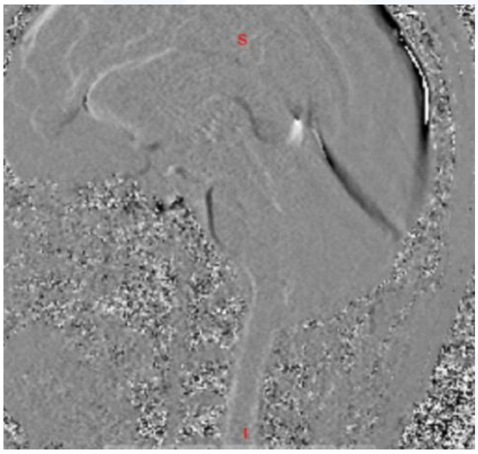

Fig.1 PC-MRI image

1.3 Trans-segmental shunt for syringomyelia

All patients underwent trans-segmental shunt for syringomyelia. After intubation and general anesthesia, the patient was placed in the left lateral position, and the head was fixed with a three-pin head holder. Routine disinfection and draping were performed. Based on preoperative MRI localization, a semi-laminectomy was performed at the appropriate spinal segment with the largest diameter of the syringomyelia and the thinnest spinal cord (without affecting spinal stability). The corresponding subcutaneous fascia was dissected, and a vertical incision of approximately 8 cm was made to expose the correct thoracic vertebra. Bone biting was performed with a rongeur to decompress the vertebrae. Muscle tissue was hemostatic **[Figure 2A]**. Intraoperative ultrasound was used to locate the adherent sites (the probe was placed on the surface of the dural sac). The patient was placed in a head-down, foot-up position (to avoid a large loss of cerebrospinal fluid leading to postoperative hypotensive headache). The dural sac and arachnoid were longitudinally incised, with an incision of 1-3 cm. The dural sac was suspended on both sides, and the underlying spinal cord was found to be adherent to surrounding tissues. The adherent nerves were fully released **[Figure 2B].** The same method was used to gradually incision and release adherent tissues downstream of the adherent sites. Intraoperative ultrasound again demonstrated a clear gap on the dorsal side of the spinal cord. A standard straight cerebrospinal fluid shunt tube (France, B019-10) was used. One end was placed in the subarachnoid space on the left side of the inferior border of the upstream vertebral plate, and the other end was placed in the subarachnoid space on the right side of the inferior border of the downstream vertebral plate. The suture was first passed through the sturdy side of the shunt tube, and then the shunt tube was sutured and fixed to the dural sac and muscle tissue **[Figure 2C]**. The arachnoid and dural sac were sutured in layers (note that excessive tension during suturing may lead to suture breakage and cerebrospinal fluid leakage). A biological dural patch (Heal-ALL®, Yantai Zhi-Bio, model: 4 cm×6 cm) was used to repair and suture the dura mater **[Figure 2D]**. The surgical field was suctioned clean with an aspirator, and normal saline was used to irrigate until it was clear. Note that the aspirator should not be perpendicular to the dural sac to avoid negative pressure causing damage to the dural sac, which may increase the difficulty of suturing. Hemostasis was performed within the surgical field, and the surgical incision was watertight sutured with Prolene 6.0 sutures. The subcutaneous tissues were sutured in layers, and the surgery was completed. All surgeries were performed by qualified senior surgeons. Intraoperative neurophysiological monitoring (motor and somatosensory evoked potentials, i.e., MEP and SSEP) was used to observe changes in nerve function and adjust the spinal cord incision site in a timely manner.

1.4 Postoperative Evaluation

All enrolled patients were followed up 6 months after surgery. During the follow-up, physical examination, EMG, routine MRI, and PC-MRI were performed on the patients. The surgical outcomes were evaluated using the CCOS score [6-7]. The changes in motor function, sensation, and bladder function were reflected by changes in the JOA score. Routine MRI was used to assess the size of the cavity in the T2-weighted sagittal plane. A decrease in cavity size of ≥50% was considered a significant improvement, a decrease of ≥10% was considered an improvement, and a decrease of <10% was considered no improvement (Figure 3). PC-MRI was used to evaluate changes in cerebrospinal fluid dynamics after surgery. The improvement index was calculated as the difference between the post-treatment score and the pre-treatment score. The improvement rate of the post-treatment score was calculated as [(improvement index / 29 - pre-treatment score) × 100%].

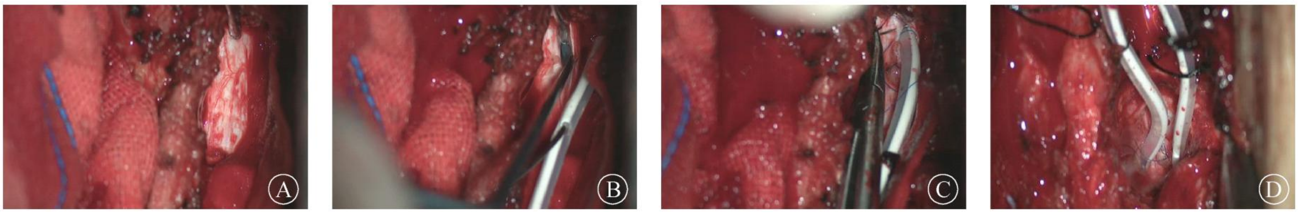

Fig. 2 Intraoperative image of trans-segmental shunt surgery for syringomyelia patients

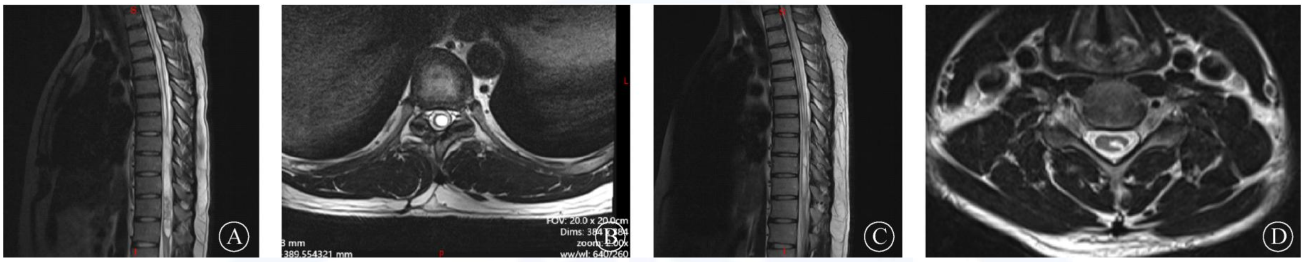

Fig.3 Preoperative and postoperative MRI images of syringomyelia patient

1.5 Statistical Methods

SPSS 27.0 statistical analysis software was used. Measurement data that conformed to a normal distribution were expressed as $\bar{x} \pm s$, and comparisons between groups were performed using paired *t*-tests. Measurement data that did not conform to a normal distribution were expressed as M (P_{25}, P_{75}), and comparisons between groups were performed using the Wilcoxon signed-rank test. Categorical data were expressed as number of cases (%). Comparisons between groups were performed using McNemar's test. Pearson correlation analysis was used to analyze the correlation between the difference in peak cerebrospinal fluid flow rate after surgery and the improvement index of the JOA score and CCOS score. $P < 0.05$ was considered statistically significant.

2 Results

2.1 General Information

All 17 patients underwent cross-segment shunt surgery, and there were no cases of postoperative infection, new neurological dysfunction, shunt tube blockage, postoperative paralysis, respiratory failure, or death. The symptoms of 14 patients were significantly relieved, with an overall symptom improvement rate of 82.39% (14/17). The symptoms of 3 patients did not improve significantly. According to the CCOS score, the prognosis was good for 14 patients and poor for 3 patients.

2.2 Preoperative Clinical Data Characteristics

The incidence of clinical symptoms in the preoperative group was as follows: lower limb weakness and sensory abnormalities (numbness and dissociated sensory disturbances) in the corresponding areas were the most common (90%-100%), followed by low back pain, upper limb weakness, and sensory abnormalities (numbness and dissociated sensory disturbances) in the corresponding areas (53%-65%).

The incidence of neck pain, hoarseness, drinking cough, nystagmus, and dizziness was the lowest (0-35%) **[Table 1]**.

2.3 Postoperative Clinical Symptoms and Improvement of Electromyography

Compared with preoperative conditions, there was no improvement in postoperative neck pain, low back pain, convulsions, upper limb weakness, nystagmus, dysphagia, hoarseness, and drinking cough symptoms, and the difference was not statistically significant ($P > 0.05$). Postoperatively, the patient's limb numbness, dissociated sensory disturbances, gait disturbance, dizziness symptoms, lower limb weakness, and ataxia improved compared with preoperative conditions ($P < 0.05$). Compared with preoperative conditions, the electromyography (sensory nerve conduction, motor nerve conduction, F wave, and H reflex) of postoperative patients improved ($P < 0.05$) **[Table 1]**.

2.4 Postoperative MRI examination and improvement of JOA score

Compared with preoperative conditions, the maximum horizontal diameter of the cavity in the patients decreased after surgery. The peak systolic velocity (PSV) and end diastolic velocity (EDV) in the region of foramen magnum of occipital bone (Figure 4A) and the PSV and EDV in the central segment of the midbrain aqueduct (Figure 4B) were slower than those before surgery. The JOA score was higher than that before surgery (P<0.05) **[Table 2]**.

2.5 Correlation between JOA score improvement index, CCOS score, and cerebrospinal fluid peak flow velocity difference

The JOA score improvement index and CCOS score in patients with syringomyelia were positively correlated with the difference in peak flow velocity in the foramen magnum of occipital bone and the central segment of the midbrain aqueduct (P<0.05) **[Table 3]**.

Tab.1 Preoperative and postoperative clinical symptoms and electromyography [n=17, case (%)]

Item	Preoperation	Postoperation	χ^2	P
Clinical Symptoms				
Neck pain	5(29.41)	2(11.76)	1.126	0.254
Low back pain	9(52.94)	5(29.41)	1.542	0.169
Convulsion	3(17.64)	0	1.874	0.094
Numbness of limbs	15(88.23)	6(35.29)	3.329	0.003
Upper limb weakness	11(64.71)	7(41.18)	1.064	0.198
Lower limb weakness	16(91.12)	6(35.29)	3.632	0.001
Nystagmus	4(23.53)	1(5.88)	1.561	0.202
Segmental sensory disturbance	17(100.00)	10(58.82)	2.998	0.004
Gait disturbance	14(82.35)	7(41.18)	2.523	0.012
Dysphagia	3(17.64)	0	1.796	0.084
Hoarseness	4(23.52)	2(11.76)	0.896	0.385
Choking when drinking water	4(23.52)	3(17.64)	0.925	0.741
Ataxia	13(76.47)	3(17.64)	3.942	0.001
Dizziness	6(35.29)	1(5.88)	2.295	0.026
Abnormal Electromyography				
Sensory nerve conduction	14(82.35)	8(47.06)	2.012	0.036
Motor nerve conduction	8(47.06)	1(5.88)	2.732	0.005
F wave	11(64.71)	3(17.64)	2.985	0.004
H reflex	13(76.47)	4(23.53)	2.652	0.003

Tab.2 Changes in preoperative and postoperative parameters in 17 patients（n=17，$\bar{x}\pm s$）

Parameter	Preoperation	Postoperation	t	P
Maximum diameter of cavity (mm)	8.16±3.00	5.26±3.12	4.085	0.002
PSV of occipital bone (cm/s)	7.84±0.86	5.68±0.72	8.097	0.001
EDV of occipital foramen (cm/s)	7.83±0.84	5.78±0.72	7.716	0.001
PSV of middle segment of mesencephalic duct (cm/s)	6.80±1.50	4.72±0.91	5.801	0.001
EDV of central segment of mesencephalic duct (cm/s)	6.53±1.51	4.71±0.91	5.388	0.001
JOA Score	8.94±2.36	17.65±1.80	11.609	0.001

Tab.3 Correlation between JOA score improvement index, CCOS score and difference in cerebrospinal fluid peak flow velocity

Variable	PSV difference of foramen magnum of occipital bone		EDV difference of foramen magnum of occipital bone		PSV difference in the central segment of the midbrain aqueduct		EDV difference in the central segment of the midbrain aqueduct	
	r Value	P Value	r Value	P Value	r Value	P Value	r Value	P Value
JOA score improvement index	0.476	0.008	0.602	0.001	0.466	0.009	0.415	0.023
CCOS rating	0.634	0.001	0.741	0.001	0.534	0.002	0.473	0.008

2.6 Postoperative complications

Among the 17 patients with syringomyelia, 6 patients experienced complications after surgery: 1 patient developed incision fat liquefaction, which was treated with local anesthesia, thorough drainage of subcutaneous fluid, repeated flushing with iodine-containing disinfectant, re-suturing of the incision, application of epidermal growth factor, and enhanced dressing change. The incision healed well without infection; 2 patients developed headaches, which improved after lumbar puncture and cephalosporin antibiotic treatment for 1 day; 3 patients developed postoperative fever with a temperature of less than 38.5°C. This may be due to a small amount of blood flowing into the subarachnoid space during dissection of the outer layer of the dura mater, resulting in stimulatory fever and headache. Lumbar puncture revealed yellow or brownish cerebrospinal fluid. After cerebrospinal fluid drainage of 10 ml and conservative treatment, the symptoms disappeared. None of the patients developed intracranial infection, incision infection, shunt tube blockage, or cerebrospinal fluid leakage after surgery.

3 Discussion

The purpose of routine shunt surgery for syringomyelia patients is to reduce the fluid in the cavity, decrease the cavity, decrease spinal cord tension, and avoid further damage to the spinal cord and worsening of clinical symptoms caused by the progression of the cavity [8-11]. Different shunt surgeries have their own advantages and disadvantages, and there is a lack of unified standards for relevant research and evaluation. The shunt surgery diverts cerebrospinal fluid from the subarachnoid space to the pleural cavity, abdominal cavity, and subarachnoid space, as well as the newly emerging fourth ventricular subarachnoid shunt surgery in recent years [12]. Diverting cerebrospinal fluid to the pleural cavity and abdominal cavity can lead to chest complications such as pleural infection, chest pain, and trunk numbness, as well as common abdominal complications such as omental obstruction of the shunt. Both diverting cerebrospinal fluid to the pleural cavity and abdominal cavity change the original cerebrospinal fluid circulation pathway. The subarachnoid shunt does not change the original cerebrospinal fluid circulation pathway, and the cerebrospinal fluid still flows in the subarachnoid space and is absorbed by the subarachnoid granular tissue. The subarachnoid space is a more suitable shunt site [13]. The cross-segmental shunt surgery for syringomyelia changes the cerebrospinal fluid circulation pathway through a shunt tube, allowing cerebrospinal fluid to cross the adherent areas caused by trauma or infection, rebuild the cerebrospinal fluid circulation pathway below the adhesion, increase the cerebrospinal fluid flow in the area below the adhesion, thereby improving nerve tissue damage caused by poor cerebrospinal fluid circulation [14-15].

The occurrence of SM can lead to various nerve injuries. This study analyzed the clinical symptoms of 17 syringomyelia patients before and after surgery, and the results showed significant improvement in limb numbness, dissociated sensory disturbance, gait disturbance, dizziness, lower limb weakness, and ataxia symptoms compared to before surgery. Cross-segmental shunt surgery can effectively improve SM symptoms. Cross-segmental shunt surgery diverts abnormal fluid in the cavity to the subarachnoid space, relieves the compression of spinal cord tissue caused by central canal dilation, reduces the size of the spinal cord cavity, improves cerebrospinal fluid circulation below the adherent area, protects the nerve tissue below the adherent area, thereby alleviating clinical symptoms [16-17]. Bertram[18] believes that when the subarachnoid space is narrow, cerebrospinal fluid below the narrowing can enter the spinal cord cavity, leading to an increase in the volume of the spinal cord cavity. The study found that the peak flow velocity curve of cerebrospinal fluid in the midbrain aqueduct and occipital condyle region of syringomyelia patients after posterior fossa decompression surgery was less different from that of normal people, and the peak flow velocity of cerebrospinal fluid was higher than that of normal people. In this study, it was found that the peak flow velocity of cerebrospinal fluid in the occipital condyle region during contraction and diastole in syringomyelia patients underwent cross-segmental shunt surgery decreased to some extent compared to before surgery. In addition, compared with the preoperative group, the clinical symptoms of the postoperative group were significantly improved, the maximum transverse diameter of the cavity was significantly reduced, and the JOA score was significantly increased compared to before.

PC-MRI has certain clinical value in the diagnosis, surgical indications, and postoperative outcome assessment of patients with syringomyelia caused by trauma or infection [19]. This study found that through PC-MRI examination of 17 patients before and after surgery, the peak flow velocity of cerebrospinal fluid in the patients after surgery was significantly lower than that before surgery, and the level of cerebrospinal fluid peak velocity difference was closely related to the improvement rate of JOA score and CCOS score. Before surgery, the cerebrospinal fluid flow of the patients was abnormal, which was a pathological state. After performing spinal cord syringomyelia cross-segment shunt surgery, the adhesion was removed to affect the cerebrospinal fluid pathway, the cerebrospinal fluid circulation obstruction state was alleviated, and the pressure gradient in the subarachnoid space of the spinal cord was reduced, creating an anatomical space where the cerebrospinal fluid dynamics returned to a normal physiological state. The clinical symptoms of the patients improved, and the cerebrospinal fluid dynamics tended to be normal. Studies have shown that there is no direct correlation between the diameter of spinal cord syringomyelia and symptoms [20]. In this study, there was a significant difference in the maximum anteroposterior diameter of the spinal cord syringomyelia before and after cross-segment shunt surgery. It was considered that the shunt tube reconstructed the cerebrospinal fluid pathway at the upper and lower ends of the cavity, which reduced the cerebrospinal fluid flow velocity around the cavity. Due to the Venturi principle, the cerebrospinal fluid pressure around the cavity increased compared with before surgery, and the fluid in the cavity decreased compared with before surgery, and the cavity decreased accordingly. Three months later, we followed up 17 patients and found that the shunt tubes of the patients did not fall off. When our team performed spinal cord syringomyelia cross-segment shunt surgery, we accurately placed the drainage tube position based on preoperative PC-MRI examination and intraoperative observation of the adhesion position between the spinal cord and surrounding tissues, and sutured and fixed the shunt tube to the dura mater and muscle tissue, so the shunt tube was not easy to fall off. During the follow-up period, PC-MRI examination showed that the spinal cord syringomyelia maintained the same level, and the spinal cord syringomyelia did not progress compared with before, and the patient's symptoms did not gradually worsen, which could exclude the occurrence of shunt tube blockage.

However, there are certain limitations in spinal cord syringomyelia cross-segment shunt surgery: spinal cord syringomyelia cross-segment shunt surgery belongs to active drainage, and there needs to be a pressure difference. As the disease progresses, the pressure on both sides of the shunt tube tends to be equal, and the drainage effect almost disappears. However, it can still maintain the balance of internal and external pressure, so the spinal cord syringomyelia can be maintained at a smaller level for a long time. If the shunt tube is removed, it will lead to the rapid expansion of the cavity again in a short time. To solve this problem, multiple drainage tubes can be tried at the same time to achieve long-term stable and effective drainage. However, multiple drainage tubes will lead to insufficient space, increased surgical difficulty, and increased risk of shunt tube falloff and blockage. The best surgical method still needs to be further explored.

Overall, spinal cord syringomyelia cross-segment shunt surgery can improve the cerebrospinal fluid circulation abnormalities caused by adhesions and trauma, reconstruct the cerebrospinal fluid circulation pathway, and significantly improve the clinical symptoms of patients. It is an ideal surgical method. However, the sample size of this study is relatively small, and further large-sample prospective studies are needed in the future to provide more scientific and powerful evidence-based medical evidence for surgical decision-making in patients with SM.

Conflict of Interest None

References

[1] Xu GH, Yang JC, Ji SF, et al. Effect of shunt surgery with four ventricles-subarachnoid shunt on patients with recurrent and idiopathic syringomyelia[J]. J Xinxiang Med Univ, 2023, 40(8): 744-748.**[In Chinese]**

[2] Gruber MD, Weber M, Toop N, et al. Treatment of post-traumatic syringomyelia with placement of syringopleural shunt and resection of intrasyringeal hematoma: 2-dimensional operative video[J]. Oper Neurosurg, 2023, 25(6): e376-e377.

[3] Cho PG, Noh SH, Kim SH. A new surgical method for treating syringomyelia secondary to arachnoiditis following cervical spine surgery: the syringo-cisterna Magna shunt[J]. Eur Spine J, 2022, 31(12): 3724-3730.

[4] Zhang JH, Liu BG, Sang DC, et al. Risk factors of C5 nerve root palsy after anterior cervical discectomy and fusion[J]. Chin J Spine Spinal Cord, 2023, 33(1): 1-8. **[In Chinese]**

[5] Zhang MC, Hu Y, Song DP, et al. Exploring the prognostic differences in patients of Chiari malformation type I with syringomyelia undergoing different surgical methods[J]. Front Neurol, 2023, 13: 1062239.

[6] Yang M, Niu HT, Jiang HS, et al. Posterior fossa decompression and duraplasty with and without tonsillar resection for the treatment of adult Chiari malformation type I and syringomyelia[J]. Medicine, 2022, 101(50): e31394.

[7] Wang B, Wang C, Zhang YW, et al. Long-term outcomes of foramen magnum decompression with duraplasty for Chiari malformation type I in adults: a series of 297 patients[J]. Neurosurg Focus, 2023, 54(3): E5.

[8] Lou YL, Yang JC, Wang LX, et al. The clinical efficacy study of treatment to Chiari malformation type I with syringomyelia under the minimally invasive surgery of resection of Submeningeal cerebellar Tonsillar Herniation and reconstruction of Cisterna Magna[J]. Saudi J Biol Sci, 2019, 26(8): 1927-1931.

[9] Liu BL, Wang Y, Liu SJ, et al. Tonsillectomy with modified reconstruction of the cisterna Magna with and without craniectomy for the treatment of adult Chiari malformation type I with syringomyelia[J]. Acta Neurochir, 2020, 162(7): 1585-1595.

[10] Meng C, Chang PP, Li ZL. Comparison of the clinical effectiveness of different ranges of bony decompression for the treatment of Chiari malformation type I[J]. J Xuzhou Med Univ, 2023, 43(7): 480-484. **[In Chinese]**

[11] Holste KG, Muraszko KM, Maher CO. Epidemiology of chiari I malformation and syringomyelia[J]. Neurosurg Clin N Am, 2023, 34(1): 9-15.

[12] Emerson SN, Scott RM, Al-Mefty O. Resolution of primary or recalcitrant chiari-associated syringomyelia requires adequate cerebrospinal fluid egress from the fourth ventricle[J]. World Neurosurg, 2022, 163: 24.

[13] Naseri Kouzehgarani G, Feldsien T, Engelhard HH, et al. Harnessing cerebrospinal fluid circulation for drug delivery to brain tissues[J]. Adv Drug Deliv Rev, 2021, 173: 20-59.

[14] Ji SF, Yang JC, Xu GH, et al. Analysis of hydrodynamics of cerebrospinal fluid in children with tethered cord syndrome and syringomyelia[J]. J Xinxiang Med Univ, 2023, 40(2): 146-149. [In Chinese]

[15] Fultz NE, Bonmassar G, Setsompop K, et al. Coupled electrophysiological, hemodynamic, and cerebrospinal fluid oscillations in human sleep[J]. Science, 2019, 366(6465): 628-631.

[16] Lou YL, Yang JC, Gu HY, et al. A clinical study on the treatment of recurrent chiari (type I) malformation with syringomyelia based on the dynamics of cerebrospinal fluid[J]. Biomed Res Int, 2022, 2022: 9770323.

[17] Ye WK, Xie MX. Progress in clinical application of syringomyelia shunt[J]. Guizhou Med J, 2022, 46(5): 694-696. **[In Chinese]**

[18] Bertram CD, Heil M. A poroelastic fluid/structure-interaction model of cerebrospinal fluid dynamics in the cord with syringomyelia and adjacent subarachnoid-space stenosis[J]. J Biomech Eng, 2017, 139(1): 10.1115/1.4034657.

[19] Atchley TJ, Vukic B, Vukic M, et al. Review of cerebrospinal fluid physiology and dynamics: a call for medical education reform[J]. Neurosurgery, 2022, 91(1): 1-7.

[20] Li HL, Guo LB, Liang JR. Comparison of the efficacy of different decompressions treatment combined with posterior cervical fusion and internal fixation treatment on Chiari I malformation associated with syringomyelia and atlantoaxial instability[J]. Chin J Prim Med Pharm, 2019, 26(13): 1591-1595. **[In Chinese]**

Submission received: 2024-02-02 / **Revised**:2024-03-05

·论 著·

跨节段分流术治疗外伤和感染导致的脊髓空洞症

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摘要:目的 本研究结合脑脊液动力学,探讨脊髓空洞跨节段分流术治疗由于外伤和感染导致的脊髓空洞症的临床疗效。**方法** 收集 2019 年 7 月至 2021 年 6 月就诊于郑州市中心医院脊髓空洞专科的脊髓空洞症患者共 17 例的临床资料,入组者均行脊髓空洞跨节段分流手术。分析患者手术前后的临床特征、肌电图、影像学特征。使用芝加哥 Chiari 畸形预后评分(CCOS)、日本骨科协会(JOA)评分改善指数评估患者临床预后。采用 Pearson 法分析 JOA 评分改善指数及 CCOS 评分与脑脊液峰值流速差值的相关性。**结果** 跨节段分流术后,14 例临床症状明显改善,3 例术后症状未改善。术后 JOA 评分高于术前(17.65±1.80 *vs* 8.94±2.36, $t=11.609$, $P<0.01$)。手术后肢体麻木、分离性感觉障碍、步态障碍、头晕症状、下肢无力、共济失调、感觉神经传导、运动神经传导、空洞最大径及枕骨大孔区及中脑导水管收缩期、舒张期脑脊液峰值流速较术前改善($P<0.05$)。JOA 评分改善指数及 CCOS 评分与脑脊液峰值流速差值显著相关($P<0.05$)。**结论** 对于外伤和感染导致的脊髓空洞症患者,脊髓空洞跨节段分流术一定程度上改善患者的脑脊液动力学,促进脊髓空洞缩小,改善临床症状。

关键词: 跨节段分流术; 脊髓空洞症; 蛛网膜炎; 脊髓外伤; 脑脊液流体动力学
中图分类号: R651 **文献标识码:** A **文章编号:** 1674-8182(2024)05-0703-06

Trans-segmental shunt surgery for the treatment of syringomeylia resulting from trauma and infection

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Abstract: Objective To investigate the clinical effect of trans-segmental shunt surgery in the treatment of syringomyelia due to trauma and infection in perspective of cerebrospinal fluid dynamics. **Methods** A total of 17 syringomyelia patients admitted to the Syringomyelia Department in Zhengzhou Central Hospital from July 2019 to June 2021 were collected, all patients underwent trans-segmental shunt surgery for syringomyelia. The clinical features, electromyography and imaging features of patients before and after operation were analyzed. The Chicago Chiari outcome scale (CCOS) and Japanese Orthopaedic Association (JOA) score improvement index were used to evaluate the clinical prognosis of patients. Pearson method was used to analyze the correlation between the JOA score improvement index, CCOS score and the difference of peak velocity of cerebrospinal fluid. **Results** After trans-segmental shunt, the clinical symptoms of 14 cases were significantly improved, and 3 cases did not improve. The JOA score was significantly higher after surgery than before surgery (17.65±1.80 *vs* 8.94±2.36, $t=11.609$, $P<0.01$). Limb numbness, dissociative sensory disorder, gait disorder, dizziness, lower limb weakness, ataxia, sensory nerve conduction, motor nerve conduction, maximum diameter of cavity and peak cerebrospinal fluid flow in the foramen magnum and the midbrain aquaquet during systolic and diastolic periods were significantly improved after surgery ($P<0.05$). JOA score improvement index and CCOS score were significantly correlated with the difference of cerebrospinal fluid peak velocity ($P<0.05$). **Conclusion** For patients with syringomyelia caused by trauma or infection, trans-segmental shunt of

DOI: 10.13429/j.cnki.cjcr.2024.05.011
基金项目: 河南省科技攻关项目(222102310652)
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出版日期: 2024-05-20

QR code for English version

syringomyelia can improve the cerebrospinal fluid dynamics of patients with syringomyelia to a certain extent, promote the reduction of syringomyelia and improve the clinical symptoms of patients.

Keywords: Trans-segmental shunt surgery; Syringomyelia; Arachnoiditi; Spinal cord injury; Cerebrospinal fluid dynamics

Fund program: Science and Technology Research Project of Henan Province (222102310652)

脊髓空洞症是源于脊髓实质或中央管内潜在腔隙,由于各种原因被液体填充[1]。大多与先天性疾病如 Chiari 畸形有关,也可由后天肿瘤、创伤、感染、脊髓栓系或蛛网膜炎导致。蛛网膜下腔粘连会导致蛛网膜下腔脑脊液流动扭曲,在创伤事件发生数年后导致脊髓空洞症[2]。脊髓空洞症临床症状主要以空洞水平脊髓受压产生的一系列运动和感觉障碍为主,是一种慢性进展性神经损伤的疾病。本研究对入组患者行跨节段分流术治疗,对比患者术前及术后临床症状、肌电图变化及脑脊液动力学改变,探讨跨节段分流术治疗由创伤和感染引发的脊髓空洞症的临床疗效,为脊髓空洞症患者的手术治疗提供更具有科学的依据。

1　资料和方法

1.1　一般资料　收集 2019 年 7 月至 2021 年 6 月就诊于郑州市中心医院脊髓空洞专科的 17 例脊髓空洞症患者的临床资料,男 10 例,女 7 例,年龄 28~76 岁,平均 47.29 岁,病程 1~12 年,平均 5.70 年。

纳入标准:(1) 患者术前行核磁共振检查提示脊髓空洞症[3];(2) 具有明显的临床症状体征,包括但不限于颅压高、神经进行性损害、共济失调、肌力感觉障碍等;(3) 患者及其家属在了解跨节段分流的目的、风险和效果后,自愿寻求跨节段分流术治疗;(4) 无脑积水及先天发育畸形。排除标准:(1) 其他病因导致的脊髓空洞症,如 Chiari 畸形、肿瘤、脊髓栓系、手术等;(2) 合并寰枢关节脱位及半脱位、脑积水、扁平颅底、脊柱侧弯等;(3) 合并心肺功能不全及重要器官功能严重损害不能配合手术者。

1.2　资料收集　患者术前及术后均行肌电图和磁共振相位对比电影成像(PC-MRI)检查。所有的入组患者术前术后均行日本骨科协会(Japanese Orthopaedic Association, JOA)评分[4],并计算 JOA 评分改善情况[JOA 评分改善指数=治疗后评分−治疗前评分,治疗后评分改善率=(改善指数/ 29−治疗前评分)×100%]。术后均行芝加哥 Chiari 畸形预后评分(Chicago Chiari outcome scale, CCOS)[5]评估患者预后情况,以 10 分为分界,将>10 分定义为预后良好,≤10 分定义为预后不良。

1.2.1　肌电图　取丹麦丹迪 KEY POINT 肌电图/诱发电位仪完成相关神经肌电图检查操作。使患者取仰卧位,采用肌电图/诱发电位仪检测患者双侧正中神经、胫神经、腓浅神经的感觉传导、运动传导、F 波及 H 反射检查,均用表面电极刺激和记录。

1.2.2　PC-MRI 扫描　本研究扫描采用西门子 Skyra 3.0T 超导核磁共振机。在回顾性心电门控下,选择中脑导水管和枕骨大孔的中央段进行头颈部的 PC-MRI 扫描,高信号提示收缩期脑脊液向下移动,信号强度表示脑脊液流量,低信号表示舒张期脑脊液向前运动。见图 1。

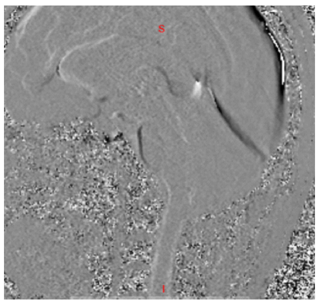


图 1　PC-MRI 图像
Fig. 1　PC-MRI image

1.3　脊髓空洞跨节段分流术　所有患者均行脊髓空洞跨节段分流术治疗。患者气管插管全身麻醉后,取左侧卧位,三钉头架固定头部,常规消毒铺巾,根据术前核磁共振定位,选择在脊髓空洞直径最大平面及脊髓最薄处的合适脊柱节段进行半椎板切开(不影响脊柱稳定性)。解剖对应皮下筋膜,纵行逐层切开约 8 cm,暴露定位胸椎右侧椎板,咬骨钳咬除减压。肌肉组织止血(图 2A),术中彩超探查定位粘连部位(探头置于硬膜囊表面),让患者位于头低脚高位(避免脑脊液大量丢失导致术后低颅压性头痛),纵行切开硬脊膜及蛛网膜,切口 1~3 cm。向两侧悬吊硬膜,见下方脊髓与周围组织粘连,充分松解粘连神经(图 2B),同样方法在粘连部位下游定位处逐层切开、松解粘连组织。术中彩超再次探查见脊髓背侧有明显间隙,应用标准直行脑脊液分流管(法国,型号:B019-10)一端在上游定位椎板下缘左侧放入蛛网膜

下腔，另一端在下游定位椎板下缘右侧放于蛛网膜下腔，将缝线先穿过分流管坚韧一侧，然后将分流管缝合固定于硬脊膜、肌肉组织（图2C）。逐层缝合蛛网膜及硬脊膜（注意缝合时不能张力过大导致术后缝线崩开导致脑脊液漏），应用生物型硬脑（脊）膜补片（烟台正海生物科技，型号：4 cm×6 cm）修补缝合硬脑膜（图2D）。用吸引器将术野中血液吸净，生理盐水冲洗至清亮，注意吸引器不要垂直于硬脊膜以免负压使硬脊膜破损，加大缝合难度。在手术视野内止血后，用Prolene 6.0线水密缝合手术切口，逐层缝合各层皮下组织，手术结束。所有手术均由具备资质的高年资术者操作，手术中使用神经电生理监测［运动诱发电位（MEP）和体感诱发电位（SSEP）］，观察神经功能变化，及时对脊髓切开部位进行调整。

1.4　*术后评价*　对所有入组患者术后6个月进行随访，随访时对患者进行查体并复查肌电图及常规MRI和PC-MRI。利用CCOS评分评估手术的效果[6-7]，利用JOA评分变化反映患者术后运动功能、感觉及膀胱功能的改变。利用常规MRI检查T2相正中矢状位评估空洞大小，体积缩小≥50%判定为明显改善，缩小≥10%判定为空洞改善，缩小<10%判定为无改善（图3）。利用PC-MRI拍摄脑脊液评价术后脑脊液动力学的变化。改善指数=治疗后评分-治疗前评分，治疗后评分改善率=［改善指数/29-治疗前评分］×100%。

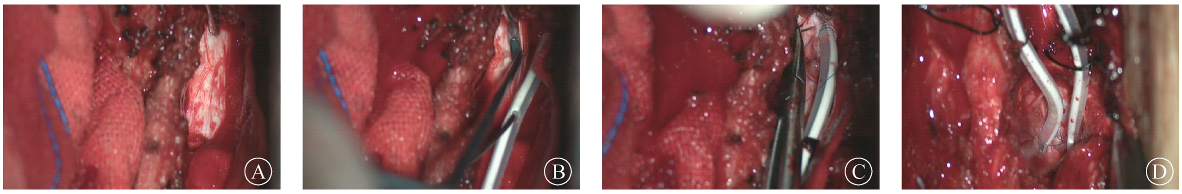
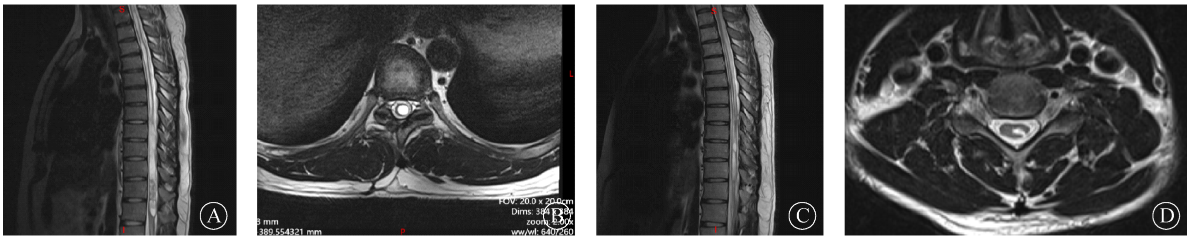


图2　脊髓空洞症患者跨阶段分流术术中图像
Fig. 2　Intraoperative image of trans-segmental shunt surgery for syringomyelia patients



注：A、B为术前MRI影像；C、D为术后MRI影像。

图3　脊髓空洞症患者术前术后MRI影像
Fig. 3　Preoperative and postoperative MRI images of syringomeylia patient

1.5　*统计学方法*　采用SPSS 27.0软件处理数据。符合正态分布的计量资料以$\bar{x}\pm s$表示，组间比较采用配对t检验；不符合正态分布的计量资料以$M(P_{25}, P_{75})$表示，组间比较采用Wilcoxon符号秩检验。计数资料以例（%）表示，组间比较采用McNemar's检验。采用Pearson法分析血术后脑脊液峰值流速差值与JOA评分改善指数及CCOS评分相关性。$P<0.05$为差异有统计学意义。

2　结　果

2.1　*一般资料*　17例患者均行跨节段分流术，术后无感染、新发神经功能损伤、分流管堵塞、术后瘫痪、呼吸功能衰竭及死亡病例。14例患者症状明显缓解，总体症状好转率82.35%（14/17）。3例患者症状无明显改善。根据CCOS评分评估患者预后情况，预后良好14例，预后不良3例。

2.2　*术前临床资料特征*　术前患者的临床症状，下肢无力及对应部位的感觉异常（麻木和分离性感觉障碍）最常见（90%～100%），腰部疼痛、上肢无力及对应部位的感觉异常（麻木和分离性感觉障碍）次之（53%～65%），颈部疼痛、声音嘶哑、饮水呛咳、眼球震颤及头晕发生率最低（0～35%）。见表1。

2.3　*术后临床症状及肌电图改善情况*　与术前相比，手术后患者颈部疼痛、腰部疼痛、抽搐、上肢无力、眼球震颤、吞咽困难、声音嘶哑、饮水呛咳症状无改善，差异无统计学意义（$P>0.05$）。手术后患者肢体麻木、分离性感觉障碍、步态障碍、头晕症状、下肢无力、共济失调较术前改善（$P<0.05$）。与术前相比，手术后患者的肌电图（感觉神经传导、运动神经传导、F波及H反射）较术前改善（$P<0.05$）。见表1。

2.4　术后的 MRI 检查及 JOA 评分改善情况　与术前相比,手术后患者的空洞最大横径有所减少,枕骨大孔区脑脊液收缩期峰值流速(peak systolic velocity, PSV)、舒张期末流速(end diastolic velocity, EDV)(图 4A)及中脑导水管的中央段 PSV 和 EDV(图 4B)较术前减慢,JOA 评分较术前升高($P<0.05$)。见表 2。

2.5　JOA 评分改善指数及 CCOS 评分与脑脊液峰值流速差值的相关性　脊髓空洞症患者 JOA 评分改善指数、CCOS 评分均与枕骨大孔峰值流速差值及中脑导水管的中央段峰值流速差值呈正显关关系($P<0.05$)。见表 3。

2.6　术后并发症情况　术后 17 例脊髓空洞症患者有 6 例出现并发症。其中 1 例患者出现切口脂肪液化,经局部麻醉后,充分放出皮下积液后,碘伏水反复冲洗干净,再次紧密缝合切口,应用表皮生长因子及加强换药,切口愈合良好,未发生感染;2 例患者出现头痛,予以腰椎穿刺放液加头孢曲松抗感染治疗 1 d 后好转出院;3 例患者出现术后发热,体温均<38.5 ℃,可能是剥离硬脊膜外层时少许血液流入蛛网膜下腔,血细胞代谢产物产生刺激性发热和头痛,行腰椎穿刺术可见淡黄色或黄褐色脑脊液,经脑脊液放液 10 mL,保守治疗后症状消失。所有患者术后均未发生颅内感染、切口感染、分流管堵塞及脑脊液漏等症状。

表 1　术前和术后临床症状及肌电图改变　[$n=17$, 例(%)]

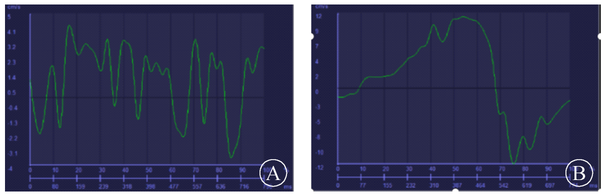
Tab. 1　Preoperative and postoperative clinical symptoms and electromyography　[$n=17$, 例(%)]

项目	术前	术后	χ^2 值	P 值
临床症状				
颈部疼痛	5(29.41)	2(11.76)	1.126	0.254
腰部疼痛	9(52.94)	5(29.41)	1.542	0.169
抽搐	3(17.64)	0	1.874	0.094
肢体麻木	15(88.23)	6(35.29)	3.329	0.003
上肢无力	11(64.71)	7(41.18)	1.064	0.198
下肢无力	16(91.12)	6(35.29)	3.632	0.001
眼球震颤	4(23.53)	1(5.88)	1.561	0.202
分离性感觉障碍	17(100.00)	10(58.82)	2.998	0.004
步态障碍	14(82.35)	7(41.18)	2.523	0.012
吞咽困难	3(17.64)	0	1.796	0.084
声音嘶哑	4(23.52)	2(11.76)	0.896	0.385
饮水呛咳	4(23.52)	3(17.64)	0.925	0.741
共济失调	13(76.47)	3(17.64)	3.942	0.001
头晕	6(35.29)	1(5.88)	2.295	0.026
肌电图				
感觉神经传导异常	14(82.35)	8(47.06)	2.012	0.036
运动神经传导异常	8(47.06)	1(5.88)	2.732	0.005
F 波异常	11(64.71)	3(17.64)	2.985	0.004
H 反射异常	13(76.47)	4(23.53)	2.652	0.003

表 2　17 例患者术前和术后相关参数比较　($n=17$, $\bar{x}\pm s$)

Tab. 2　Camparison of preoperative and postoperative parameters in 17 patients　($n=17$, $\bar{x}\pm s$)

参数	术前	术后	t 值	P 值
空洞最大径(mm)	8.16±3.00	5.26±3.12	4.085	0.002
枕骨大孔 PSV(cm/s)	7.84±0.86	5.68±0.72	8.097	<0.001
枕骨大孔 EDV(cm/s)	7.83±0.84	5.78±0.72	7.716	<0.001
中脑导水管中央段 PSV(cm/s)	6.80±1.50	4.72±0.91	5.801	<0.001
中脑导水管中央段 EDV(cm/s)	6.53±1.51	4.71±0.91	5.388	<0.001
JOA 评分(分)	8.94±2.36	17.65±1.80	11.609	<0.001



注:A 为枕骨大孔区流速曲线;B 为中脑导水管区流速曲线。

图 4　流速曲线

Fig. 4　Velocity curve

表 3　JOA 评分改善指数及 CCOS 评分与脑脊液峰值流速差值的相关性

Tab. 3　Correlation between JOA score improvement index, CCOS score and difference in cerebrospinal fluid peak flow velocity

变量	枕骨大孔 PSV 差值		枕骨大孔 EDV 差值		中脑导水管中央段 PSV 差值		中脑导水管中央段 EDV 差值	
	r 值	P 值	r 值	P 值	r 值	P 值	r 值	P 值
JOA 评分改善指数	0.476	0.008	0.602	0.001	0.466	0.009	0.415	0.023
CCOS 评分	0.634	0.001	0.741	0.001	0.534	0.002	0.473	0.008

3　讨　论

脊髓空洞症患者常规分流手术的目的是通过减少空洞内液体来缩小空洞,降低脊髓张力同时避免空洞的进展导致脊髓进一步损伤和临床症状的恶化[8-11]。不同分流术式都有其优缺点,相关研究和评价缺少统一的标准。分流术将脑脊液通过分流管从蛛网膜下腔分流到胸腔、腹腔和蛛网膜下腔,以及近年来新出现的四脑室蛛网膜下腔分流术[12]。将脑脊液分流到胸腔和腹腔会带来胸部并发症,如胸膜感染、胸部疼痛、躯干麻木,以及腹腔常见并发症如大网膜阻塞分流。将脑脊液分流到胸腔和腹腔改变了原有的脑脊液循环通路,蛛网膜下腔分流未改变原有的脑脊液循环通路,脑脊液仍然在蛛网膜下流动,由蛛网膜下腔颗粒吸收,故蛛网膜下腔是更适合的分流部位[13]。脊髓空洞跨节段分流术是通过分流管改变脑脊液的循环通路,让脑脊液跨过因外伤或感染导致粘连的部位,重建粘连下方脑脊液的循环通路,增加粘连以下部位的脑脊液流量,从而改善因脑脊液循环不畅导致的神经组织损伤[14-15]。

SM的发生可导致多种神经损伤。本研究分析17例脊髓空洞患者术前术后的临床症状,结果显示术后肢体麻木、分离性感觉障碍、步态障碍、头晕症状、下肢无力、共济失调症状较术前显著改善,跨节段分流术可有效的改善SM症状。跨节段分流术通过将空洞中异常液体分流到蛛网膜下腔,缓解中央管扩张导致脊髓组织受压症状、缩小脊髓空洞,改善粘连部位下方的脑脊液循环,保护粘连下方的神经组织,从而使临床症状得到缓解[16-17]。Bertram等[18]认为当蛛网膜下腔狭窄时,狭窄下方脑脊液可进入脊髓空洞,导致脊髓空洞体积增加。研究发现脊髓空洞患者行后颅窝减压术后中脑导水管和枕骨大孔区的脑脊液峰值流速曲线与正常人差异较小,且脑脊液峰值流速较正常人较高。本次研究显示,通过脊髓空洞跨节段分流术,脊髓空洞患者枕骨大孔区收缩及舒张期脑脊液峰值流速较术前下降。此外,与术前相比,术后患者临床症状得到明显改善,空洞最大横径明显缩小,JOA评分明显升高。

PC-MRI对外伤、感染导致的脊髓空洞症患者的诊断、手术指征及术后疗效判断具有一定的临床价值[19]。本研究发现,通过17例患者术前术后行PC-MRI检查,术后患者脑脊液峰值流速明显低于术前,且脑脊液峰值流速差值水平与JOA评分改善率、CCOS评分密切相关。术前患者脑脊液流动异常,为病理状态,行脊髓空洞跨节段分流术后解除粘连对脑脊液通路的影响,脑脊液循环梗阻状态得到缓解,脊髓蛛网膜下腔的压力梯度减小,创造一个脊液流体动力学恢复正常生理状态的解剖空间,患者临床症状得到改善,脑脊液流体动力学趋于正常。研究表明,脊髓空洞直径与症状无相关性[20]。本研究中脊髓空洞跨节段分流术后脊髓空洞最大前后径与术前有明显差异,考虑为分流管重建空洞上端及下端脑脊液通路,使空洞周围脑脊液流速降低,由于文丘里原理,空洞周围脑脊液流体压力较前升高,空洞内液体相比术前减少,空洞随之减小。3个月后对17例患者进行随访发现患者导分流管均未脱落,笔者团队行脊髓空洞跨节段分流术时,依据术前PC-MRI检查及术中所见脊髓与周围组织粘连位置,精准放置引流管位置,并将分流管缝合固定于硬脊膜、肌肉组织,故分流管不易脱落。随访期间行PC-MRI检查显示脊髓空洞均维持在同一水平、脊髓空洞较前未进展,且患者症状未出现逐渐加重,可排除发生分流管堵塞情况。

但脊髓空洞跨节段分流术存在一定局限性:脊髓空洞跨节段分流术属于主动引流,需要有压力差的存在,随着病程的发展,分流管两侧的压力趋于相等,引流效果几乎消失,但依然能起到维持内外压力平衡的作用,所以脊髓空洞才能长期维持在较小水平,若去除分流管则会导致空洞短时间再次扩大。如改变术式解决这一问题,可尝试多根引流管同时引流,以期长期稳定有效引流,但多根引流管又会出现空间不足、手术难度增大、分流管脱落及堵塞几率增大等情况,最佳手术方式仍需继续探索。

总而言之,脊髓空洞跨节段分流手术可改善脊髓空洞患者粘连、外伤导致的脑脊液循环异常,重建脑脊液循环通路,显著改善临床症状,是一种较理想的手术方式。但本研究样本量较小,在今后仍需大样本的前瞻性研究对SM患者的手术决策提供更为科学有力的循证医学依据。

利益冲突　无

参考文献

[1] 徐光华,杨记超,姬杉峰,等.四脑室-蛛网膜下腔分流术治疗复发性、特发性脊髓空洞症疗效观察[J].新乡医学院学报,2023,40(8):744-748.
Xu GH, Yang JC, Ji SF, et al. Effect of shunt surgery with four ventricles-subarachnoid shunt on patients with recurrent and idiopathic syringomyelia[J]. J Xinxiang Med Univ, 2023, 40(8): 744-748.

[2] Gruber MD, Weber M, Toop N, et al. Treatment of post-traumatic syringomyelia with placement of syringopleural shunt and resection of intrasyringeal hematoma: 2-dimensional operative video[J]. Oper Neurosurg, 2023, 25(6): e376-e377.

[3] Cho PG, Noh SH, Kim SH. A new surgical method for treating syringomyelia secondary to arachnoiditis following cervical spine surgery: the syringo-cisterna Magna shunt[J]. Eur Spine J, 2022, 31(12): 3724-3730.

[4] 张健豪,刘宝戈,桑大成,等.颈椎前路椎间盘切除融合术后C5神经根麻痹的危险因素[J].中国脊柱脊髓杂志,2023,33(1):1-8.
Zhang JH, Liu BG, Sang DC, et al. Risk factors of C5 nerve root palsy after anterior cervical discectomy and fusion[J]. Chin J Spine Spinal Cord, 2023, 33(1): 1-8.

[5] Zhang MC, Hu Y, Song DP, et al. Exploring the prognostic differences in patients of Chiari malformation type Ⅰ with syringomyelia undergoing different surgical methods[J]. Front Neurol, 2023, 13: 1062239.

[6] Yang M, Niu HT, Jiang HS, et al. Posterior fossa decompression and duraplasty with and without tonsillar resection for the treatment of adult Chiari malformation type Ⅰ and syringomyelia[J]. Medicine, 2022, 101(50): e31394.

[7] Wang B, Wang C, Zhang YW, et al. Long-term outcomes of foramen magnum decompression with duraplasty for Chiari malformation type Ⅰ in adults: a series of 297 patients[J]. Neurosurg

Focus, 2023, 54(3): E5.

[8] Lou YL, Yang JC, Wang LX, et al. The clinical efficacy study of treatment to Chiari malformation type Ⅰ with syringomyelia under the minimally invasive surgery of resection of Submeningeal cerebellar Tonsillar Herniation and reconstruction of Cisterna Magna [J]. Saudi J Biol Sci, 2019, 26(8): 1927-1931.

[9] Liu BL, Wang Y, Liu SJ, et al. Tonsillectomy with modified reconstruction of the cisterna Magna with and without craniectomy for the treatment of adult Chiari malformation type Ⅰ with syringomyelia [J]. Acta Neurochir, 2020, 162(7): 1585-1595.

[10] 孟超,常飘飘,李中林.不同范围骨性减压治疗 Chiari 畸形Ⅰ型的临床疗效比较[J].徐州医科大学学报,2023,43(7):480-484.
Meng C, Chang PP, Li ZL. Comparison of the clinical effectiveness of different ranges of bony decompression for the treatment of Chiari malformation type Ⅰ[J]. J Xuzhou Med Univ, 2023, 43(7): 480-484.

[11] Holste KG, Muraszko KM, Maher CO. Epidemiology of chiari Ⅰ malformation and syringomyelia[J]. Neurosurg Clin N Am, 2023, 34(1): 9-15.

[12] Emerson SN, Scott RM, Al-Mefty O. Resolution of primary or recalcitrant chiari-associated syringomyelia requires adequate cerebrospinal fluid egress from the fourth ventricle[J]. World Neurosurg, 2022, 163: 24.

[13] Naseri Kouzehgarani G, Feldsien T, Engelhard HH, et al. Harnessing cerebrospinal fluid circulation for drug delivery to brain tissues [J]. Adv Drug Deliv Rev, 2021, 173: 20-59.

[14] 姬杉峰,杨记超,徐光华,等.脊髓栓系综合征合并脊髓空洞症患儿脑脊液流体动力学分析[J].新乡医学院学报,2023,40(2):146-149.
Ji SF, Yang JC, Xu GH, et al. Analysis of hydrodynamics of cerebrospinal fluid in children with tethered cord syndrome and syringomyelia[J]. J Xinxiang Med Univ, 2023, 40(2): 146-149.

[15] Fultz NE, Bonmassar G, Setsompop K, et al. Coupled electrophysiological, hemodynamic, and cerebrospinal fluid oscillations in human sleep[J]. Science, 2019, 366(6465): 628-631.

[16] Lou YL, Yang JC, Gu HY, et al. A clinical study on the treatment of recurrent chiari (type Ⅰ) malformation with syringomyelia based on the dynamics of cerebrospinal fluid[J]. Biomed Res Int, 2022, 2022: 9770323.

[17] 叶维坤,谢明祥.脊髓空洞分流术的临床应用进展[J].贵州医药,2022,46(5):694-696.
Ye WK, Xie MX. Progress in clinical application of syringomyelia shunt[J]. Guizhou Med J, 2022, 46(5): 694-696.

[18] Bertram CD, Heil M. A poroelastic fluid/structure-interaction model of cerebrospinal fluid dynamics in the cord with syringomyelia and adjacent subarachnoid-space stenosis[J]. J Biomech Eng, 2017, 139(1): 10.1115/1.4034657.

[19] Atchley TJ, Vukic B, Vukic M, et al. Review of cerebrospinal fluid physiology and dynamics: a call for medical education reform[J]. Neurosurgery, 2022, 91(1): 1-7.

[20] 李怀龙,郭立彬,梁建荣.不同减压术式联合颈后路融合内固定术治疗 Chiari Ⅰ型畸形合并脊髓空洞症、寰枢关节不稳的疗效比较[J].中国基层医药,2019,26(13):1591-1595.
Li HL, Guo LB, Liang JR. Comparison of the efficacy of different decompressions treatment combined with posterior cervical fusion and internal fixation treatment on Chiari Ⅰ malformation associated with syringomyelia and atlantoaxial instability[J]. Chin J Prim Med Pharm, 2019, 26(13): 1591-1595.

收稿日期:2024-02-02　**修回日期**:2024-03-05　**编辑**:叶小舟

(上接第 702 页)

[20] 周文静,李华杰,孙欢,等.单侧经皮椎体后凸成形术联合针刀治疗单节段骨质疏松性胸腰椎压缩性骨折的临床观察[J].中华全科医学,2023,21(11):1823-1826.
Zhou WJ, Li HJ, Sun H, et al. Efficacy of percutaneous unilateral balloon kyphoplasty combined with small-needle knife in the treatment of postoperative pain from single-level osteoporotic thoracolumbar vertebral compression fractures[J]. Chin J Gen Pract, 2023, 21(11): 1823-1826.

[21] 安忠诚,陈晨,董黎强,等.经皮椎体后凸成形术后邻近节段再骨折的危险因素分析[J].中华全科医学,2022,20(4):591-593,712.
An ZC, Chen C, Dong LQ, et al. Risk factors for adjacent segment refracture after percutaneous kyphoplasty[J]. Chin J Gen Pract, 2022, 20(4): 591-593, 712.

[22] Abelin-Genevois K. Sagittal balance of the spine[J]. Orthop Traumatol Surg Res, 2021, 107(1S): 102769.

[23] Egea-Gámez RM, Galán-Olleros M, Alonso-Hernández J, et al. Improvement of the sagittal alignment of the spine in patients with achondroplasia after subtrochanteric femoral lengthening[J]. Spine Deform, 2022, 10(6): 1443-1452.

[24] 刘洋,王志伟,赵冲,等.基于脊柱-骨盆解剖学和腰椎滑脱力学评估两种椎间融合术对老年退行性腰椎滑脱的疗效[J].中国临床研究,2024,37(1):79-84.
Liu Y, Wang ZW, Zhao C, et al. Therapeutic effects of two types of interbody fusions on degenerative lumbar spondylolisthesis in the elderly based on spinal pelvic anatomy and lumbar spondylolisthesis mechanics[J]. Chin J Clin Res, 2024, 37(1): 79-84.

[25] Liu JY, Huang PZ, Jiang GW, et al. Spinal-pelvic sagittal parameters in patients with gluteal muscle contracture: an imaging study [J]. PeerJ, 2022, 10: e13093.

[26] 纪春磊,马迅,李强.颈椎矢状位平衡在颈椎病诊断和治疗方式选择中应用的研究进展[J].中国医药导报,2022,19(22):46-49,65.
Ji CL, Ma X, Li Q. Research progress in the application of cervical spin sagittal balance in the diagnosis and treatment of cervical spondylosis[J]. China Med Her, 2022, 19(22): 46-49, 65.

收稿日期:2024-01-16　**修回日期**:2024-02-10　**编辑**:李方