Original Article

Surgical treatment of painful spasticity after spinal cord injury

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Study design: There are several conservative methods of painful spasticity treatment. However, conservative methods do not always provide long-term and complete antispastic effects in cases of spinal cord injury with severe painful spasticity.

Objectives: The aim of the present study was to analyse and compare the effectiveness of myelotomy by Bischof II and Pourpre in patients with paraplegia and severe painful spasticity in the late period after spinal cord trauma.

Setting: Spinal Care Unit, Meir General Hospital, Israel.

Methods: Twenty patients had longitudinal T-myelotomy by the Bischof II technique and 20 longitudinal myelotomy en croix (Pourpre). The spasticity was determined by evaluated muscle tone and muscle spasm according to the Ashworth and spasm–frequency scales. The pain was determined by McGill short questionnaire. The results were calculated by the Wilcoxon signed rank test, by Mann–Whitney *U*-test and Students *t*-test. Clinical outcomes after myelotomy in-patients with chronic spinal cord injury and painful spasticity were evaluated after 6 months, 5 and 10 year follow-up period.

Results: Pain was relieved in all cases. The best motor antispastic effect was achieved after Pourpre myelotomy in 18 of the patients (90%) were evaluated after a follow-up of 6 months, 15 patients (75%) after 5 years, and 11 patients (64.7%) after 10 years. Following Bischof II myelotomy results were classified as good: in 13 patients–(65%) at 6 months; in nine patients (45%) at 5 years and in six patients–(40%) at 10 years. Statistical analysis showed no reliable relationship between the level of Spinal cord lesion (T4–T10) and the type of operation. No instability occurred as a result of antispastic operation in any patient.

Conclusion: A higher rate of beneficial outcome was achieved after Pourpre myelotomy. We recommend this operation for patients with paraplegia and painful spasticity, who do not have hope of regaining voluntary motor function. However, transections of basic pathways of spasticity are not always sufficient for complete antispastic effects. Good results after the operation may deteriorate in time. Therefore further investigations into the mechanism of the spasticity syndrome in the spinal cord injured patient are required.

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Keywords: spastic syndrome; myelotomy; spinal cord injury; painful spasticity

Introduction

The mechanism of development of painful spasticity has not been thoroughly investigated, although some experience in clinical treatment has been gathered. There are several conservative methods of painful spasticity treatment: spinal cord hypothermia,^{1,2} electrical stimulation^{3,4,5,6} intrathecal introduction of baclofen⁷ and intrathecal phenol block.⁸ However, conservative methods do not always provide long-term

and complete antispastic effects in cases of spinal cord injury with severe painful spasticity. Moreover, there are patients with severe side effects after antispastic medicine. Chronic intrathecal baclofen infusion has recently been reported as an effective treatment for paraplegic spasticity. The results of antispastic operations suggest that this approach is an efficacious alternative to chronic baclofen infusion in reducing spasticity. As baclofen therapy necessitates long-term medical supervision, it appears that myelotomy is superior for this select group of patients who have no hope of regaining voluntary motor function. The early attempts at surgery for spasticity led to severe tissue

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dystrophy and pelvic organ functional disturbances.^{9,10} Other methods of operative treatment of spasticity, such as dorsal longitudinal myelotomy^{11,12,13} one of its versions – called ‘myelotomie en croix’,¹⁴ and dorsolateral bilateral longitudinal myelotomy¹⁵ were recommended. The aim of the present study was to analyze and compare the effectiveness of myelotomy by Bischof II and Pourpre in patients with paraplegia and severe painful spasticity in the late period after spinal cord trauma. An additional indication for these kinds of myelotomy is the associated pain syndrome, since the operation is in fact a combination of an antipain commissurotomy and antispastic myelotomy.

Materials and methods

Operations of 40 patients suffering from painful spasticity following paraplegia of the lower extremities due to spinal cord lesions in the thoracic level are analyzed in the present study. Research was carried out in the Spinal Care Unit of Meir General Hospital, Kfar-Sava, Israel and Spinal Neurosurgery Center, Moscow, Russia during the period between 1987 and 1997 (Table 1).

In painful spasticity Bischof II and Pourpre type myelotomies were performed, not only on pathways for influencing spasticity, but also on the spinothalamic tract for pain relief.

Results of operations were evaluated following 6 months, 5 years and 10 years after operations. Only 32 patients could be studied after 10 years, as two patients had died at the time of follow-up and six patients were lost for follow-up.

The senior author carried out all operations during the period between 1987 and 1997. The spasticity was determined by muscle tone and muscle spasms according to the Ashworth and spasm-frequency scales; the pain was determined by the McGill short questionnaire pain grade.

Bladder function was determined by clinical and urodynamic parameters, defecation and erection – on the basis of clinical information.

Myelotomy was indicated if conservative antispastic and antipain therapy produced either no or short-term effect, or undesired side effects. Contraindications for myelotomy were cardiovascular and/or kidney insufficiency. Bischof or Pourpre type was chosen randomly, since it was unknown which of the operations would prove to be more effective for the patient's symptomatology.

Operative technique

Twenty patients had longitudinal T-myelotomy by the Bischof II technique and 20 – longitudinal myelotomy en croix (Pourpre) (Figure 1).

The operation was carried out under endotracheal anesthesia with the patient placed in supine position.

Figure 1 Plan of operation. (A) Longitudinal dorsal myelotomy by Bischof II technique. The midline sagittal section is performed in a dorso-ventral direction to the depth until central canal. (B) Longitudinal dorsal myelotomy by Pourpre technique. The section passes in the same dorso-ventral direction, round the central canal and exits onto the anterior surface of spinal cord thus completely sectioning the spinal cord into two halves. Lateral section is performed in the same way in both methods. The section is started from the central canal and is continued from caudal to rostral to extent of myelotomy in the frontal direction

Table 1 Age, sex and characteristics of pain syndrome in patients with painful spasticity before operation by Pourpre and Bischof methods

Characteristic	Pourpre (n = 20)	Bischof (n = 20)	P-value†
Age – years	27.6 ± 7.8	27.1 ± 8.3	0.8
Sex – M/F	15/5	14/6	0.7
Years of spasticity – median (interquartile range)	2.75 (2 – 3.375)	2.75 (2.5 – 3.725)	0.6
VAS score	95.5 ± 6.0	97.5 ± 4.4	0.24
SF – MPQ score			
Sensory	11.3 ± 1.0	10.6 ± 1.6	0.07
Affective	8.9 ± 0.9	8.9 ± 0.3	0.8
Total	20.2 ± 1.3	19.5 ± 1.5	0.1
PPI – median (interquartile range)	5 (4 – 5)	5 (4 – 5)	0.8

*VAS denotes Visual Analog Scale, SF-MPQ - Short Form McGill Pain Questionnaire, PPI - Present Pain Intensity. †P values for age, VAS score, sensory, affective and total were calculated by Student's *t*-test; all other P values were calculated by the Mann – Whitney *U*-test

Before surgery the relevant vertebra is marked under radiographic control and a tack or lead plate is attached to the skin over the marked point at the T10 level. A standard laminectomy is then performed from T10 to the articular processes of L2. The dura is opened by a linear incision. The operations are performed under $18\times$ magnification, using the operating microscope.

An important element of the operation is the determination of the precise level of spinal cord sectioning. The first step in doing this is the preoperative radiographic marking of the operative area as described above. The second step is intraoperative localization of the T12 segment. To this end, the intervertebral foramen of T12 is identified and the ascending course of the 12th pair of thoracic roots toward T10 (the area where the spinal T12 segment occurs) is determined. It should be remembered that dorsal roots enter the spinal cord above the ventral roots. The junction of the lowest of the dorsal rootlets of T12 with the spinal cord marks the upper limit of the myelotomy. The major landmark for defining the lower extent of the spinal cord for myelotomy is the conus medullaris. Variant dispositions of the conus may be encountered. After identifying the segment that occurs 4–7 mm above the conus apex, the roots of the segment are identified by electrostimulation of nerve roots and by recording the responses. The dorsal rootlets of successive lumbosacral nerve roots are identified (until the S-1 nerve root is located), marking the inferior aspect of the myelotomy. In Bischof II a longitudinal dorsal myelotomy (Figure 1A) to a depth of 3 mm is made from the L1-S1 cord segments. A myelotomy knife with a 3-mm blade is inserted to 4 mm, the depth of the central canal. At the level of the central canal the section passes across the gray matter between ventral and dorsal horns. The reflex areas are severed bilaterally by moving the knife gently up and down the L1-S1 segments of the spinal cord.

With the Pourpre myelotomy (Figure 1B) sectioning of the spinal cord is started in the midline down to the central canal. The midline of the cord is identified, using as a guide either the arachnoidal septum or the fine arteries that exit from the mediodorsal incisura. The midline incision completely severs the right from the left half of the spinal cord. Then, at the level of the central canal the section passes across the gray matter between the ventral and dorsal horns. The incision plane must not pass across the sulcomissural artery or extend beyond the spinal gray matter to the motor nuclei of the ventral horns. If it does, the anatomic integrity of the lateral pyramidal tract and their connections with motor neurons may be disrupted.

The difference between methods of myelotomy by Bischof-2 and Pourpre is that with the Bischof-2 technique the midline sagittal section is performed in a dorso-ventral direction to the depth until central canal. In the Pourpre technique, the section passes in the same dorso-ventral direction, rounds the central canal and exits onto the anterior surface of spinal cord thus

completely sectioning the spinal cord into two halves. Lateral section is performed in the same way in both methods. The section is started from central canal and is continued from caudal to rostral to the extent of the myelotomy in the frontal direction.

Patients underwent post-operative rehabilitation treatment for 45 days in a standard manner. Rehabilitation treatment was considered successful if a patient gained more activity, which allowed him/her to adapt to life better.

Statistical methods

Using the short form McGill pain questionnaire (SFM): *P*-values for age and characteristic of pain syndrome (Vas score, sensory, affective and total) were calculated by Student's *t*-test; *P*-values of years of spasticity (median), Present Pain Intensity (PPI) (median) were calculated by Mann–Whitney *U*-test. *P*-value results of the operative follow-up at 6 months, 5 years and 10 years respectively were calculated by the Wilcoxon signed rank test.

Mann–Whitney *U*-test respectively calculated the efficacy of the Bischof II and Pourpre operations at 6 months, 5 years and 10 years.

Results

The outcomes after operations are summarized in Table 2 and Figure 2. Pain was relieved in all cases. The best motor antispastic effect was achieved after Pourpre myelotomy in 18 of the patients (90%) were evaluated after a follow-up of 6 months, 15 patients (75%) after 5 years, and 11 patients (64.7%) after 10 years. After the operation, pain and spasticity disappeared and sensory changes stayed at the level they were before the operation. However on follow-up examination, while there were two patients (10%) with motor spasticity at 6 months, 5 patients (25%) had return of spasticity at 5 years and 6 patients (35.3%) at 10 years.

The return of spasticity led to flexion of the lower extremities in hip and knee joints at an angle of 20–45°. This fact did not allow for effective rehabilitation. These results were recognized as 'bad'.

Following Bischof II myelotomy results were classified as good: in 13 patients – (65%) at 6 months; in 9 patients (45%) at 5 years and in six patients – (40%) at 10 years. Bad results were in seven patients at 6 months, in 11 patients at five years, and in nine patients at 10 years.

Antispastic operations in seven patients led to a decrease in sensation (during the entire follow-up period) of one segment:

Bischof II – three, Pourpre – two patients. In two segments: Bischof II – two patients. The rest of the patients remained with the same disturbances of sensation that were present before the operation. No instability occurred as a result of the antispastic operation in any patient.

Table 2 Characteristics of pain syndrome in patients with painful spasticity in 6 month, 5 year and 10 year follow up

Characteristic	Pourpre (n = 20)			Bischof (n = 20)			Between operations (n = 20)		
	6 months	5 years	10 years	6 months	5 years	10 years	6 months	5 years	10 years
	median	median	median	median	median	median	P ₁ value	P ₂ value	P ₃ value
VAS score	0 (0–10)	20 (2.5–50)	10 (8–60)	10 (10–67.5)	60 (10–77.5)	70 (10–70)	<0.0001	0.044	0.009
SF-MPQ score									
Sensory	0 (0–1)	1 (0–2.5)	1 (0–3)	2 (1–7.75)	4 (2–6)	5 (1–6)	<0.0001	<0.0001	0.002
Affective	0 (0–1)	1 (0–1)	1 (0–3)	2 (1–5.75)	3.5 (1–6)	4 (1–6)	<0.0001	<0.0001	0.002
Total	0.5 (0–2)	1 (0.25–3.25)	1 (0–6)	4 (2–12.5)	8 (3–12)	9 (2–11)	<0.0001	<0.0001	0.001
PPI	0 (0–0.75)	(0–3.25)	1 (0–4)	1 (1–4)	3 (1.25–4)	3 (2–4)	0.003	0.003	0.044

†P values were calculated by the Wilcoxon signed rank test for comparison before operation and 6 months, 5 years, 10 years respectively. 1,2,3-P-values were calculated by the Mann–Whitney U-test for comparison of efficiency Pourpre and Bischof operation in 6 months, 5 years, 10 years respectively

Statistical analysis (Chi-square) showed no reliable relationship between the level of spinal cord lesions (T4–T10) and the type of operation.

Postoperative complications included wound infections in two patients, and thrombophlebitis of the lower extremities in three patients.

Discussion

Surgical treatment of painful spasticity after spinal cord injury has serious limitations because all types of operations are destructive. This has led to search for other, non-destructive methods of treatment for painful spasticity. Of these intrathecal administration of baclofen, hypothermia of the spinal cord^{1,2} and spinal cord electrostimulation^{3,4,5,6} are of great interest.

Treatment of painful spasticity with the instillation of intrathecal medications has undergone a renaissance with the development of continuous flow and programmable infusion systems.

Ablative chemotherapy (intrathecal phenol) has been used for many years.⁸ The disadvantages of intrathecal ablative chemotherapy are the difficulty of control in uncooperative patients, a high risk of bowel or bladder sphincter dysfunction, and production of a lower motor neuron bladder.¹⁶

It has been shown that the painful spasticity following spinal cord trauma could cause regression through local perfusion of the subarachnoid space with a cool (2–14°C) isotonic sodium chloride solution.^{1,2}

Although the mechanism by which spinal cord hypothermia influences painful spasticity is still not clearly understood, a transient conduction block is believed to result from the cooled liquid acting on the nerve cell membrane to make it 'rigid' with the result that impulse transmission in spinal cord synapses is blocked. It is possible that in painful spasticity the hypothermic solution acts on the spinal cord at the interneuronal level.

Complications during and after spinal cord hypothermia (elevated arterial pressure, headache, cerebral symptoms, etc.) can be avoided through careful monitoring of the subarachnoid pressure and its correction by means of adequate drainage. The beneficial effect from hypothermia treatment persists from several days to several months.

Spinal cord stimulation has been effective in reducing spasticity in selected patients.^{3,5,6} The implantation of stimulating electrodes over the cerebellar vermis or dorsal spinal cord presumably stimulates inhibitory pathways and inhibits facilitatory pathways. Long-term follow-up studies have not been encouraging, perhaps because of equipment failure and electrode impairment by fibrosis. These methods have the advantages of not interrupting voluntary movement or sphincter function. Their disadvantages include high failure rate, the requirement of either a posterior forsa exploration or cervical laminectomy and the expense of the systems.

Figure 2 Persistence of muscles spasm frequency and muscles rigidity (Ashworth scale) before and after operations

Penn and Kroin^{17,18} have proposed administration of baclofen by continuous infusion through a lumbar subarachnoid catheter using an implanted programmable pump. Good results were obtained after the use of this method, as well as the use of intrathecal phenol block in patients with spastic quadriplegia. These results increased the attractiveness of conservative treatment and reduced the interest for antispastic operations. However, as it became clear later, intrathecal administration of antispastic drugs has certain drawbacks. As with any implanted foreign body a chance of infection poses a potential risk. Accidental baclofen overdose resulting in transient disturbances in level of consciousness and the need for ventilatory support has been reported.¹⁹ On a practical level, the cost of the programmable pump and drugs is not insignificant. Furthermore, the use of this device necessitates the frequent charging of the reservoir, from 3 to 12 weeks.^{18,19,20}

Another consideration in selecting treatment for a spastic patient is the fact that the presence of decubitus ulcers generally precludes placement of lumbar catheters.

For the above mentioned reasons neurosurgical methods of treatment of painful spasticity, especially in patients with paraplegia, who do not have hope of regaining voluntary motor function still remains current. Lateral longitudinal frontal myelotomy in L1-S1 segments (Bischof I)⁹ was the first attempt to interrupt connections between the corticospinal tract and moto-neurons. Further investigations led to the creation of more rational antispastic operations. Bischof himself¹¹ modified his own method to one in which the approach was dorsal. The same type of

operations – longitudinal myelotomy with median approach,¹⁴ bilateral and dorsolateral longitudinal myelotomy,¹⁵ and dorsal longitudinal myelotomy via intermittent midline incision²¹ were also suggested. The dorsal approach is preferable to the lateral technique, confirming the work of Laitinen and Singounas.²²

These operations by limiting pain and spasticity increase the functional activity of the patients (Table 2).

Conclusion

A higher rate of beneficial outcome was achieved after Pourpre myelotomy. We recommend this operation in patients with paraplegia and painful spasticity, who do not have hope of regaining voluntary motor function. However, transections of basic pathways of spasticity are not always sufficient for complete antispastic effects. Good results after the operation may deteriorate in time. Therefore further investigations into the mechanism of the spasticity syndrome in the spinal cord injured patient are required.

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