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Long Term Results of Microsurgical Dorsal Root Entry Zonotomy for Intractable Pain Associated with Brachial Plexus Injury

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Objective : Brachial plexus injury can produce a intractable chronic neuropathic pain. This study was undertaken to assess the long term outcome of microsurgical dorsal root entry zonotomy(MDT).

Methods : Between October 1997 and December 2002, 21 patients received MDT because of a intractable pain resulting from brachial plexus injury. Of these, 19 patients were followed for more than 2 years. Fourteen of 19 patients were male and patient ages ranged from 22 to 69 years. Mean pain duration was 36.8 months and all patients had severe pain of 9~10 visual analogue scale. To achieve complete destruction of abnormal dorsal horns, thermocoagulation of the posterolateral sulcus were performed and careful gluing was done to prevent postoperative adhesion and pain recurrence.

Results : Of the 19 patients, 15 patients had excellent (>75% reduction in pain) and good (51~75% pain relief) results in a average postoperative period of 4.1 years. One patient had a poor (less than 25% pain relief) result. Three patients were considered to have a fair result (26~50% pain relief). Postoperative complications were 2 transient ipsilateral ataxia and 1 CSF fistula that resolved without surgical revision.

Conclusion : These results indicate that MDT provides excellent long-term pain relief in medically intractable chronic neuropathic pain following brachial plexus injury without significant complications.

KEY WORDS : Brachial plexus injury · Intractable pain · Microsurgical dorsal root entry zonotomy · Long term results.

Introduction

Brachial plexus injury produces a characteristic constant crushing and intermittent electrical shock-like shooting pain, which is often intractable. The pain may begin immediately after the trauma as a deafferentation pain, but it can also begin months later[19]. Ninety percent of patients with traumatic cervical root avulsion suffer significant early pain, as opposed to only 20% of patients with peripheral lesions. According to the literature, early pain subsides to tolerable levels in up to 25% of patients with avulsion injuries, but 27 to 40% of patients continue to experience pain at significant or intolerable levels[31].

When medical therapies fail, functional neurosurgery should be considered. Neurostimulation is first choice for most intractable neuropathic pain. One of its major benefits is that it allows the parameters of stimulation system to be adjusted according to the change in pain after surgery. On the other hand, ablative procedures permanently disrupt a portion of the nervous system either through surgical resection or through chemical or radiofrequency lesioning attempted to alleviate pain[30]. Microsurgical lesioning of dorsal root entry zone(DREZ) was designed to selectively destroy nociceptive fibers grouped in the lateral bundle of the dorsal rootlet, the excitatory medial portion of the Lissauer' tract and the deafferented hyperactive neurons of the dorsal horn[25]. But from previous experience with neuroablative procedures demonstrates that immediate pain relief does not necessarily guarantee permanent pain reduction[5].

The purpose of the present study was to assess the long term

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outcome of microsurgical dorsal root entry zonotomy(MDT) for the treatment of medically intractable pain following brachial plexus injury.

Materials and Methods

The records of 21 patients who underwent MDT by one operating neurosurgeon (SHK) from October 1997 to December 2002 were retrospectively reviewed by other investigator (YBP) who had no role in the management of these patients. Of the 21 patients, 19 with intractable pain after brachial plexus injury were followed for more than 2 years and these 19 constituted the subjects of the present study (Table 1).

Types of brachial plexus injury were divided into four groups according to complete or incomplete brachial plexus avulsion or injury, i.e., 8 cases of incomplete brachial plexus avulsion, seven cases of complete brachial plexus avulsion, two cases of incomplete brachial plexus injury and two cases of complete brachial plexus injury. Pain characteristics were divided as follows; a continuous burning pain and an electrical shock-like paroxysmal pain, and the presence of an evoked pain. Their mean preoperative pain duration of 19 study subject was 36.8 months (range 4-180)

With regard to surgical technique, Dr. Sindou's MDT method[22] was used to completely destroy abnormal dorsal horns, which comprised of making a 2.5mm deep incision and meticulous bipolar thermocoagulation of the posterolateral sulcus. When the posterolateral sulcus was not identifiable due to severe root avulsioin, lesion was made at the imaginary dorsal root entry zone using above or below intact roots of injured roots or contralateral posterolateral sulcus. To prevent postoperative complications operations were performed under electrophysiological monitoring, and to avoid postoperative adhesion

Table 1. Clinical data of the patients with brachial plexus injury

Patient number	Age (Years)	Gender	Etiology	Pain duration (Months)	Pain type		Level of MDT
					Spontaneous	Evoked	
1	42	M	BPA-I	6	PE	No	C5-C7
2	62	M	BPA-C	30	PE/CB	Yes	C5-T1
3	50	M	BPA-C	27	CB	Yes	C5-T1
4	22	M	BPA-I	18	CB/PE	No	C7-T1
5	50	F	BPA-I	84	PE/CB	Yes	C6-C8
6	23	M	BPA-I	28	PE	Yes	C5-C7
7	42	M	BPA-I	29	PE/CB	No	C6-T1
8	30	M	BPI-C	26	PE/CB	Yes	C5-T1
9	54	F	BPI-C	40	CB	No	C5-T1
10	69	M	BPA-C	180	PE	Yes	C5-T1
11	50	F	BPA-C	50	CB	No	C5-T1
12	28	M	BPA-I	32	PE/CB	Yes	C6-C8
13	34	M	BPA-C	30	CB/PE	Yes	C5-T1
14	40	M	BPI-I	31	CB	No	C6-C8
15	36	M	BPA-C	4	CB/PE	No	C5-T1
16	44	F	BPA-I	19	PE/CB	Yes	C5-C8
17	52	M	BPI-I	27	PE	Yes	C6-T1
18	46	F	BPA-C	20	PE/CB	No	C5-T1
19	49	M	BPA-I	18	PE/CB	Yes	C5-C7

MDT, microsurgical DREZotomy; BPA-I, brachial plexus avulsion-incomplete injury; BPA-C, brachial plexus avulsion-complete injury; BPI-I, brachial plexus injury-incomplete injury; BPI-C, brachial plexus injury-complete injury; PE, paroxysmal, electrical shock-like; CB, continuous, burning

Table 2. Surgical outcome after Microsurgical Dorsal Root Entry Zonotomy for intractable pain with brachial plexus injury

Patient number	Pain level (VAS score)					Result	F/U (Months)	Drugs	Complications
	Preop.	PO3m	PO6m	PO12m	Last				
1	10	0	1	1	2	E	90	No	No
2	10	8	8	9	9	P	79	Yes	Ataxia
3	9	2	2	2	2	E	72	No	No
4	10	1	2	2	3	G	68	No	No
5	10	1	1	1	2	E	66	No	No
6	10	0	2	0	0	E	62	No	No
7	10	2	3	3	3	G	60	No	CSF leak
8	9	1	1	1	1	E	57	No	No
9	10	3	4	5	6	F	54	Yes	No
10	10	1	2	3	2	E	53	No	No
11	10	4	5	5	7	F	50	Yes	Ataxia
12	10	2	1	0	1	E	48	No	No
13	9	1	0	1	0	E	47	No	No
14	10	5	6	5	5	F	46	Yes	No
15	10	2	3	3	3	G	42	No	No
16	10	3	2	2	1	E	41	No	No
17	9	3	0	0	1	E	38	No	No
18	10	0	1	0	0	E	33	No	No
19	10	2	1	1	1	E	30	No	No

VAS, visual analog scale; F/U, follow-up; Preop., preoperative; PO3m, postoperative 3 months; PO6m, postoperative 6 months, Last, last follow-up after surgery; E, excellent(greater than 75% pain relief); G, good (from 51% to 75% pain relief); F, fair(from 26% to 50% pain relief); P, poor (less than 25% pain relief); CSF, cerebrospinal fluid

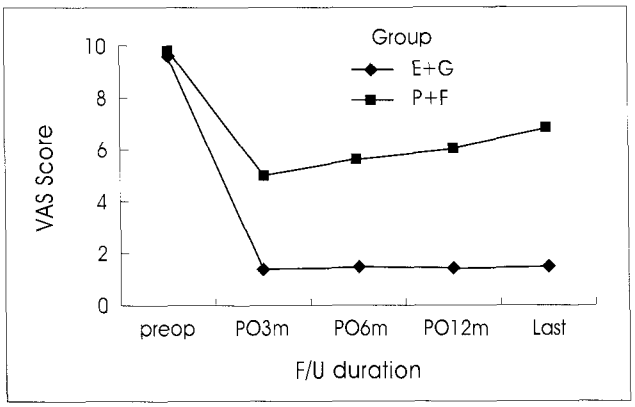

Fig. 1. Kaplan-Meier curves depicting probability of pain relief after microsurgical dorsal root entry zonotomy.

and pain recurrence, careful gluing was done on incised surface.

Patient pain levels were recorded before and after operation using the 0 to 10 visual analogue scale(VAS). Preoperatively, according to this scale, all patients had severe pain (average VAS score 9.8). Degree of pain relief was assessed immediately after surgery, and at 3 months, 6 months, 1 year and last follow-up, and was compared with the level of pain before surgery. When necessary, for clarification purpose, patients were interviewed by telephone. Pain relief was rated as "excellent" if pain relief was consistently >75%, "good" if 51~75%, "fair" if 26 to 50%, or "poor" if <25% according to VAS scores.

Statistical analysis was performed using the repeated measure of ANOVA. Statistical significance was accepted when a probability was <5% ($p<0.05$).

Results

Average patient age was 43.4 years (range, 22~69) and 14 of the 19 patients were male. No outcome differences were attributable to gender, age, or preoperative pain duration or the type of brachial plexus injury (Table 1).

Of the 19 patients, 15 patients (78.9%) showed "excellent (63.2%)" and "good (15.8%)" result at an average of 4.1 years (range 2-7). One (5.3%) patient had a "poor" result because of severe post-traumatic cord deformation. When there was difficulty in detecting the posterolateral sulcus, MDT was performed at non-visualized DREZs based on mirror imaging the contralateral posterolateral sulcus. Three (15.8%) patients were considered to have "fair" results and continued to require medication. These patients showed a tendency to have burning, continuous and non-evoked pain. But there was no statistically significance in outcome related to the pain characters. This lack of significance was attributed to low case numbers.

Kaplan-Meier curves depicting the probability of pain relief after MDT showed that the prognosis for long term pain relief is excellent in the absence of pain recurrence during the first 6 postoperative months and with a post operative pain relief VAS score of <2 (Fig. 1). No substantial number of recurrences were observed.

Postoperative complications were two cases of ipsilateral ataxia that recovered within 3 to 6 months and 1 cerebrospinal fluid fistula that resolved without surgical revision. But those who developed postoperative ipsilateral ataxia did not achieve good surgical outcomes (one was "poor" and the other "fair").

Discussion

The brachial plexus can be injured in many ways, though traumatic mechanisms such as stretch/contusion injury are most frequently encountered. However, nontraumatic injuries caused by tumors and various etiologies of thoracic outlet syndrome can also result in brachial plexus lesions. Obstetric birth palsy is yet another mechanism of brachial plexus injury in newborns[6]. After brachial plexus avulsion, pain may arise via multiple mechanisms. Traction on the brachial plexus may result in the rupture of cervical spinal cord rootlets. Gliosis and resultant scar formation in the dorsal horn, occurs in the substantia gelatinosa and has been proposed as a primary cause of pain perception. Afferent input deprivation caused by a lack of inhibition of the large caliber sensory fibers after dorsal rootlet division results in spontaneous discharges, which may be responsible for the pain perception associated with brachial plexus lesions[7], although some patients with simple brachial plexus stretch injuries without an accompanying avulsion, also experience chronic pain[21]. Some authors suspect that changes in the biochemical processes of the dorsal horn are responsible for perceived pain, and the observed up-regulation of substance P receptors after denervation supports this idea[9,16]. Moreover, the followings are also involved in pain generation; the recruitment of N-methyl-D-aspartate receptor activity, the summation of slow excitatory potentials mediated by substance P (and related peptides), and the facilitation of slow calcium channels by metabotropic glutamate receptors[1]. Central pain onset occures in most patients within 6 months after injury, and this delay in pain onset in some patients, may be due to the development of traumatic syringomyelia with subsequent pressure on the normal spinal cord above the lesion level[24]. In this study, we found that brachial plexus injury type and preoperative pain duration did not influence postoperative pain relief.

Pain associated with brachial plexus avulsion is particularly recalcitrant to therapy. Several investigators have noted that narcotic medications, sympathetic blocks, stellate ganglion blocks, and intravenous guanethedine are rarely successful at quenching pain, and that anticonvulsant and opioids are successful in only a small number of patients[32]. When medical

therapies have failed, functional neurosurgery should be considered. Neurostimulation is first choice for most intractable neuropathic pain but spinal cord stimulation(SCS) is effective in deafferentation pain syndromes only if the dorsal column/lemniscal system remains at least partially functional, as assessed by clinical examination, and especially, by electrophysiological testing, notably in terms of somatosensory evoked potentials[18,23]. Brachial plexus reconstruction after avulsioin injury is another potential surgical treatment, but the beneficial effect of neurotization on pain after traumatic cervical root avulsion is controversial[19]. One large study demonstrated that the majority of 204 monitored patients exhibited protective sensation and pain relief after direct neurotization or nerve grafting[27]. In addition, a series of 508 patients with traction injuries of the brachial plexus (birth trauma excluded) were studied over a period of 11 years, and the effects of neurotization or nerve grafting on pain were found to be sometimes ameliorative but in general unpredictable[10]. Thus, patients who have undergone unsuccessful trials of conservative measures and continue to experience severe pain are candidates for MDT (probably 5~10% of the total)[29]. We did not try SCS for intractable pain after brachial plexus injury before MDT, because it was not covered by medical insurance at the time.

DREZ is well known to have important role in the neurophysiologic balance between afferent and efferent pain impulses under the control of excitatory and inhibitory mechanisms[2,5,19]. The goal of the DREZ procedure is to destroy Rexed layers 1, 2, and 5, as well as the medial portion of the tract of Lissauer[30]. It is important to spare the lateral portion of Lissauer's tract, which has been recognized to possess an inhibitory inter-segmental function that modulates dorsal horn pain[22]. MDT based on microsurgical incisions and bipolar coagulations was introduced by Sindou in 1972[22], and since several authors have extended the technique to other lesion modalities, such as, thermocoagulation, laser light and ultrasounds[3,8]. Administered lesions are, on average, 2~3mm in depth with a 35° ventromedial obliquity (±10° according to the level). DREZ lesions are placed at the levels that correspond to the pain territory, and at one level above and below the painful dermatomes[24]. The majority of studies have used extended coagulation, and including all areas of avulsed roots in the cervical spinal cord after plexus injuries, to treat intractable pain, even when pain was projected only into a circumscribed area or a single dermatome[12]. The reason why some patients benefit from DREZ lesions whereas others do not, remains a mystery. A long term follow up study of DREZ thermocoagulation for brachial plexus avulsion showed greater than 75% pain reduction in 68% of patient[29]. In the present study, we found that 78.9% of patients obtained an "excellent (63.2%)" or a "good (15.8%)" result. But one patient showed "poor" result because of severe post-traumatic cord deformation. In this case, confirming the posterolateral sulcus was difficult, and MDT was performed based using the mirror image of contralateral posterolateral sulcus as a guide. We believe that intraoperative dorsal column somatosensory evoked potential is necessary for more accurate localization of a deformed DREZ. Three patients were considered to have a "fair" result and required continued pain medication. These patients showed a tendency to have a burning, continuous pain and non-evoked pain. In cases of severely deformed cord with burning, continuous and non-evoked pain, we believe that MDT is not effective.

Previous investigators have suggested that pain recurrence after DREZ thermocoagulation tends to follow one of two time sequences. One group of patients experienced pain recurrence abruptly within 3 months of operation, whereas the second group noted gradual pain recurrence within 7 months of operation. The prognosis for long term pain relief is therefore excellent, if there is no recurrence of pain within 7 months of operation. Many patients who experienced gradual pain recurrence have noted that the pain in less than that experienced preoperatively[5]. The present study also showed that the prognosis for long term pain relief is excellent if there has been no recurrence of pain within 6 months of operation and if the postoperative pain was less than VAS 2. To avoid postoperative adhesion and pain recurrence, we carefully glued incised surfaces.

Complications after the administration of DREZ lesions have been reported to include loss of bowel, bladder, or sexual function, sensory loss, dysesthesias and weakness of the lower extremities[20]. Nashold and Ostdahl[13] reported that 50% of patients developed a new motor weakness and 67% experienced new sensory changes after DREZ lesions produced with 70mA of current. Thomas and Jones[28] in their series of 38 patients noted that minor changes in motor or sensory function were detectable in 50% of their patients, and 12% of their patients were reported to have a significant new postoperative neurological deficit, although no patient lost the ability to ambulate. One serious complication of early DREZ operation is muscular weakness in the ipsilateral leg, which is often associated with an area of reduced sensation extending into the dermatomes below the level of the last lesion[11]. Post-DREZ motor deficit is due to the involvement of the spinocerebellar track, which lies near the dorsal root entry zone[11]. However, these symptoms tend to subside within a few weeks after surgery. It was recently demonstrated that intraoperative monitoring could limit thermal effects of thermocoagulation on the long tract[19]. In addition, coagulation of superficial vessels can produce long tract trauma. Paresthesias are most frequently reported for bilateral DREZ lesions[28]. After DREZ lesions performed to treat any kind of pain, patients have noted a slightly "numb" sensation over a small number of dermatomes

caudal to the treatment area. In this study, postoperative complications were limited to two cases of transient ipsilateral ataxia that recovered within 3 to 6 months, and a single CSF fistula that resolved without surgical revision. Those that developed postoperative ipsilateral ataxia with severely avulsed roots and cord deformation had unsatisfactory surgical outcomes.

Conclusion

MDT provides excellent long-term pain relief in cases of medically intractable chronic neuropathic pain following brachial plexus injury, and it is remarkably free of significant complications despite its destructive nature. At postoperative 6 month evaluation, both no evidence of recurrence and pain intensities less than VAS 2 may suggestive excellent surgical outcome. However, MDT is a destructive form of surgery, and thus proper preoperative evaluation and strict application of surgical indication are needed. We presume that the factors of a poor outcome are; a burning, continuous and non-evoked pain, and severe preoperative cord deformity. To avoid postoperative complications, preoperative spinal cord condition should be carefully evaluated, the DREZ accurately localized, and patients should be electrophysiologically monitored perioperatively.

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