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Original Article

Percutaneous endoscopic cervical medial branch neurotomy for chronic cervical zygapophyseal joint pain: a pilot study

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Abstract: Percutaneous radiofrequency neurotomy (PRN) is a neurosurgical technique for chronic cervical zygapophyseal joint (Z-joint) pain. However, its failure of some 30% of patients to respond may be compatible with inadequate patient selection, anatomic variation of MB, malposition of electrode, incomplete ablation, and regeneration of MB, etc. In theory, pain will return when the axons regenerate and nociceptive transduction is reinstated. This study aims to evaluate the effect and safety of a newly established percutaneous endoscopic cervical medial branch neurotomy (PECMBN) technique for chronic cervical Z-joint pain. 25 patients of cervical Z-joints pain diagnosed by means of placebo-controlled, diagnostic triple anesthetic medial branch blocks (MBB) were non-randomly divided into conservative group (11 cases) receiving conservative treatment and operation group (14 cases) receiving PECMBN in which target MBs were exposed endoscopically and cut off with micro-punch and ablated with tip-flexible radiofrequency electrode. Visual analogue score (VAS) of neck pain and referred pain were followed up. The MacNab score was recorded at 12 months postoperatively. Results show that the percentage of pain relief (neck/referred) at any time point postoperatively in operation group was higher compared to that in conservative group. MacNab outcomes in operation group were significantly better than that in conservative group. So we concluded that PECMBN for chronic cervical Z-joint pain is an accurate, effective and safe minimally invasive spine surgery. Higher success rate can be achieved compared with reported outcomes of PRN without complications increased.

Keywords: Cervical zygapophyseal joint pain, neck pain, radiofrequency, neurotomy, endoscopic rhizotomy

Introduction

The cervical zygapophyseal joints (Z-joints) are diarthrodial joints formed by the articulation of the superior articular process with the corresponding inferior articular process of the cephalad vertebrae [1]. Each Z-joint is surrounded by a fibrous capsule, lined by a synovial membrane, and contains articular cartilage and menisci [2]. Formal studies have demonstrated proprioceptive mechanoreceptors in the capsules of cervical Z-joints [3]. Three types of synovial folds with varying amounts of fibrous and adipose tissue were found which might play a role in cervical facet joint pain [4]. Protein gene product 9.5, substance P, calcitonin gene-related peptide was also found in Z-joint capsules [5]. All these finding suggests that the Z-joints may directly be involved as a pain generator in the cervical spine.

Cervical Z-joints are innervated by the cervical medial branches (MBs) of the dorsal rami. Bogduk and Marsland [6] conducted one of the earliest studies to confirm cervical Z-joint pain with diagnostic medial branch blocks (MBB). Studies have shown a wide variability in the prevalence of cervical Z-joint pain. Studies [7-9] using a more specific double blind, double-block paradigm described by Barnsley et al [10] have estimated the prevalence of cervical Z-joint pain to range from 36% to 55%.

Cervical Z-joint pain can originate from traumatic hyperextension injuries such as whiplash or degenerative processes such as osteoarthritis. But there is no treatment capable of reversing the pathophysiology of a painful Z-joint. Intra-articular therapy using depot corticosteroid was once advocated but failed to survive rigorous evaluation by a randomized, double blind, controlled trial [11]. An alternative palliative neurosurgical approach is that even if the underlying lesion cannot be identified or remedied, the painful structures can nonetheless be anesthetized by interrupting the nerves that transmit the nociceptive information from the painful structure, thereby blocking the perception of nociception and, hence, the experience of pain. Percutaneous radiofrequency neurotomy (PRN) is one such neurosurgical technique. If the target nerve is incorporated in the radiofrequency lesion, its component proteins will he denatured and the distal axon will die [12, 13]. In theory, pain will return when the axons regenerate and nociceptive transduction is reinstated.

On the basis of systematic reviews [14-18], the evidence for cervical PRN is moderate [19, 20] for short-term and long-term pain relief or level II-1 to level II-2 [15]. Similarly, PRN can provide an effective treatment for persistent neck pain after ventral cervical spine surgery [21]. If the procedure is performed with multiple lesions as described by Lord et al [16], McDonald et al [17], Boswell et al [22], and Barnsley [14], evidence is strong. Even then, Lord et al [16] reported complete pain relief only in 58% of patients; McDonald et al [17] reported this outcome in 71% of patients; and Barnsley [14] did so in 80% of patients.

However, cervical PRN is not universally successful. The failure of some 30% of patients to respond may be compatible with inadequate patient selection, anatomic variation of MBs, malposition of electrodes, incomplete ablation, and regeneration of MBs, etc.

Anatomic variations of MBs in lumbar region have been found in cadaver study and endoscopic study [23, 24]. The variations in the location of facet innervation can explain the variability of clinical results in fluoroscopically guided PRN. This observation dictates a need for visually guided minimally invasive spine surgery for best results. Endoscopically guided Z-jointneurotomy provides more consistent ablation of the medial and lateral branches of the lumbar dorsal ramus compared to radiographically guided PRN. At one-year follow-up, VAS and ODI was significantly improved, most patients had VAS improvement equal or greater than injection. Approximately 2.2%-10% of the patients returned at one and two year follow-up with mild recurrence of their axial back pain, but none to the original level of pain [23, 24].

To our knowledge, percutaneous endoscopic cervical medial branch neurotomy (PECMBN) has not been reported to treat chronic cervical Z-joint pain. It was implied that the relevant anatomy was the same as for the lumbar region. However, although the anatomy may be homologous, it is not identical. In particular, the cervical transverse processes are short, and their roots are tucked in front of the articular pillars. We designed a new endoscopic technique to ablate a larger area of lateral aspect of cervical Z-joints where the MBs cross to innervate the cervical Z-joint. Endoscopically guided visualization provides confirmation of nerve ablation or transection in the most common location of the MBs of the dorsal ramus innervating the cervical Z-joints. The preliminary outcome of PECMBN for chronic cervical Z-joint pain was inspiring and one-year results of a prospective comparative study were consisted in this report.

Patients and methods

Participants

From April 2012 to April 2014, 25 patients of chronic cervical Z-joint pain meeting the inclusion criteria at the Department of Orthopedics Surgery of the First Affiliated Hospital of PLA's General Hospital were included in this prospective comparative study and 1-year follow-up. The patients were non-randomly divided into two groups according to patient's will and selection: Operation group (14 cases) receiving PECMBN, and Conservative group (11 cases) receiving conservative treatment, including non-steroidal anti-inflammatory drugs (NSAIDs), physical therapy and recognition therapy.

Inclusion criteria: 1) Patients who were more than 18 years of age with a history of chronic, function-limiting neck pain with or without referred pain to the head or shoulder girdle, and in whom it was suspected that the source of the patient's pain may be a cervical Z-joint of at least 3 months duration; Patients suspected of disc-related pain with radicular symptoms were excluded based on radiologic testing and symptomatology involving predominately the upper extremity, and by neurologic examination including reflex suppression and focal neuro-

Figure 1. Patient's positioning and operation room arrangement. A. Positioning the target points under movable G-arm fluroscope with prone position; B. Operation room arrangement with the surgeon standing cephalolateral to the neck.

logic deficits. 2) Patients included for the diagnosis of cervical Z-joint pain were not satisfied with conservative management, including physical therapy, chiropractic manipulation, exercises, drug therapy, and bed rest. 3) Patients who were able to provide voluntary, written informed consent to participate in this evaluation. 4) Patients willing to return for follow-ups. 5) Above of all, diagnosis of cervical Z-joint pain was achieved by means of placebo-controlled, diagnostic triple anesthetic blocks [16] with more than 80% pain relief. Patients with painful C2-3 to C6-7 zygapophyseal joints were included and previous surgery does not preclude PECMBN [21, 25].

Each patient underwent three MBBs of the two dorsal rami supplying the putatively symptomatic joint. On the first occasion, one of two local anesthetics (2% lidocaine or 0.5% bupivacaine) was randomly used. Diagnostic blocks were initiated at segments suggested by matching the distribution of the patient's pain with the maps described by Cooper et al [26]. If initial blocks didn't achieve 80% pain relief, further blocks were performed at adjacent segments above or below until more than 80% pain relief was achieved, otherwise excluded. On the second occasion, either normal saline or the other local anesthetic was used. On the third occasion, the agent that was not used in the second test

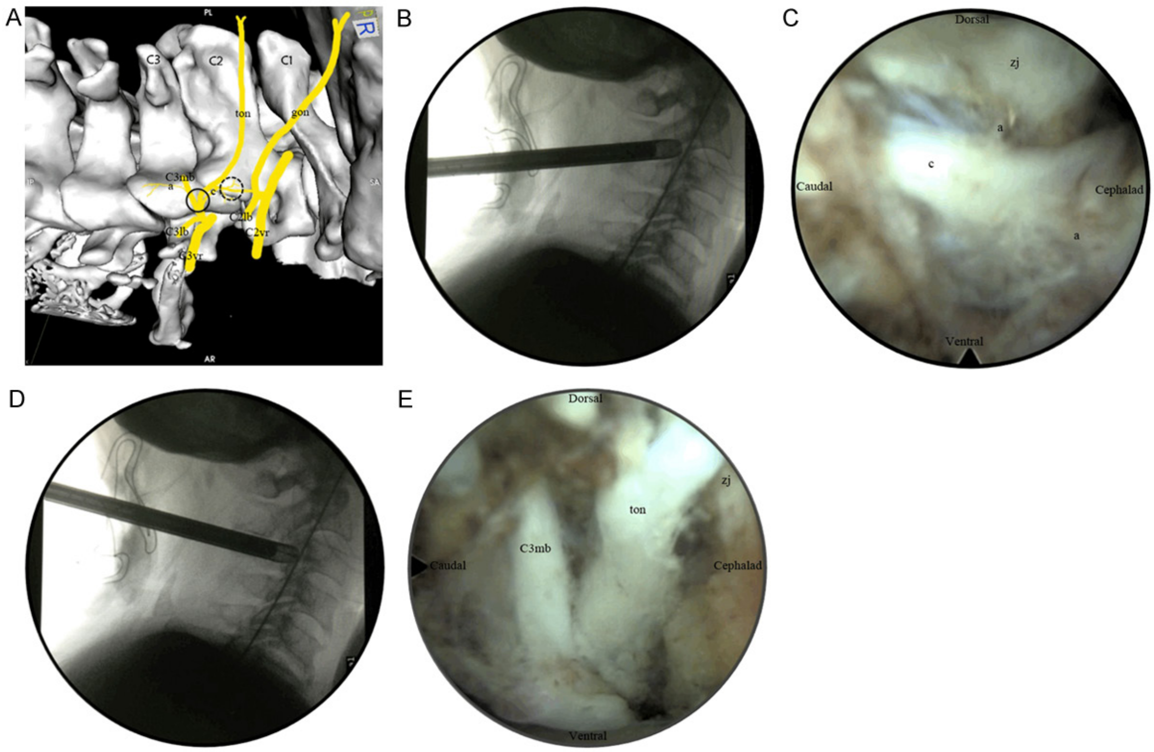


Figure 2. PECMBN for C2-3 ZJ pain. A. Schematic diagram of branches of right C3 dorsal ramus; B. Positioning working zone 1 (dotted circle in A) under G-arm; C. Endoscopic view of communicating branch and articular branches in working zone 1; D. Positioning working zone 2 (lined circle in A) under G-arm; E. Endoscopic view of TON and deep MB of C3 in working zone 2. C1: atlas; C2: axis; C3: the third vertebra; ton: third occipital nerve; gon: greater occipital nerve; mb: medial branch; lb: lateral branch; c: communicating branch; a: articular branch; vr: ventral ramus; zj: zygapophyseal joint.

(that is, normal saline or the remaining anesthetic) was used. All the blocks were performed under strict double-blind conditions, with the use of a posterior approach guided by an image intensifier, and with 0.5 ml of the assigned agent. The patient diagnosis was confirmed only if the patient had more than 80% relief of pain each time a local anesthetic was used, but no relief when normal saline was used.

Exclusion criteria: 1) Negative responses to placebo-controlled, diagnostic triple anesthetic blocks. 2) Uncontrolled major depression or psychiatric disorders, heavy opioid usage. 3) Acute or uncontrolled medical illness, chronic severe conditions that could interfere with the interpretations of the outcome assessments. 4) Women who were pregnant or lactating. 5) Patients unable to be positioned in a prone position. 6) Patients with histories of adverse reactions to local anesthetic. 7) Patients unwilling or unable to consent to the PECMBN. 8) Patients with systemic infection, bleeding diasthesis, or on anticoagulants with a high risk of bleeding. 9) Patients using pacemaker equipment. 10) Patients with unrealistic expectations, and in uncooperative patients.

Interventions

Approval to conduct the study was granted by the ethics committees of the first affiliated hospital of Chinese PLA's General Hospital. Institutional Review Board approved informed consent and protocols were provided to all the patients, which described details of the surgery including mechanism of treatment, predictive outcome, potential risks and side effects.

Operative technique

The technical details of PECMBN have not been described elsewhere. PECMBN is performed under aseptic conditions, and the standard universal precautions are taken. Repeated radiographic screening using a movable G-arm fluoroscope (Biplanar 500, Sweden) should monitor

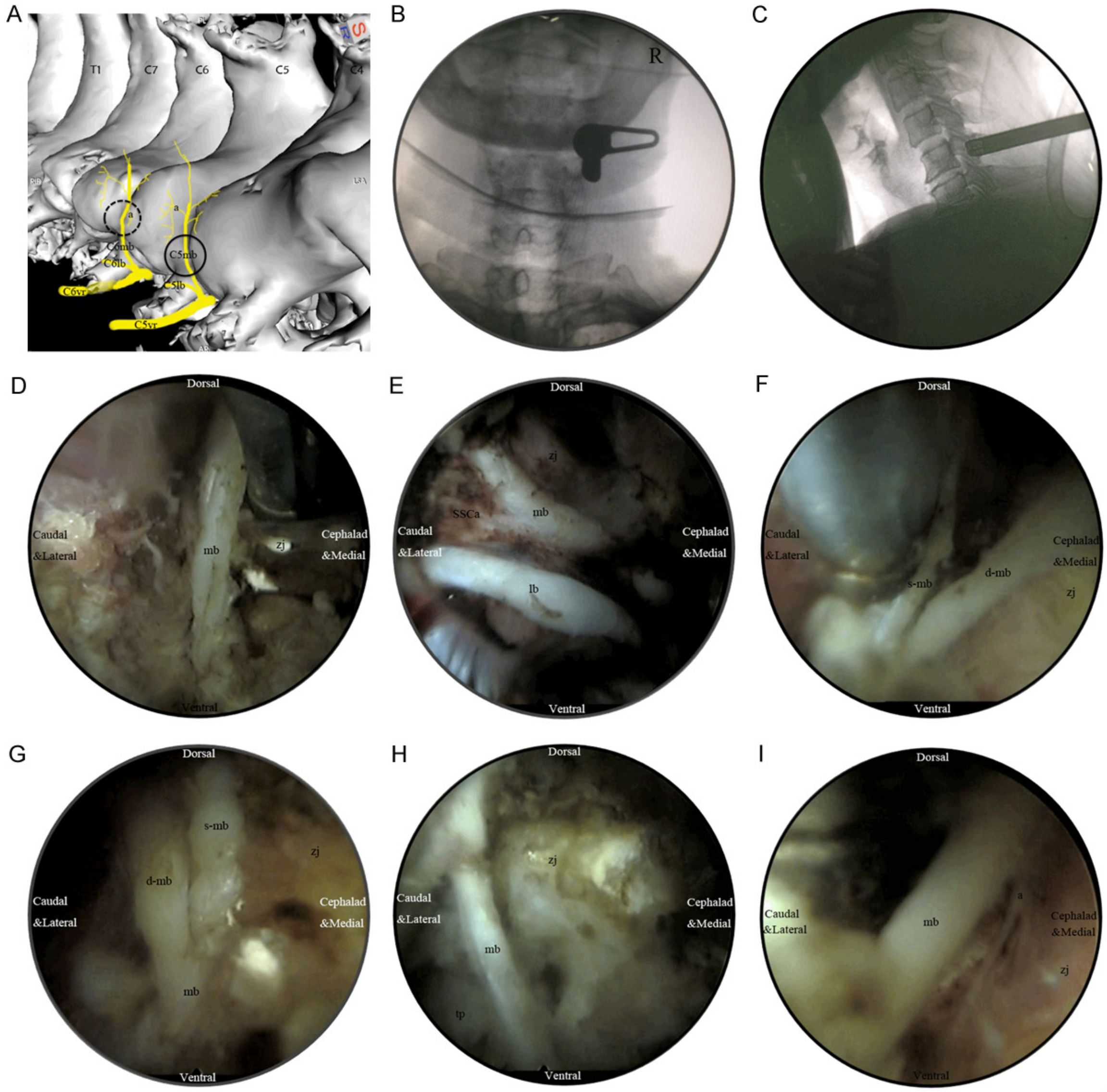


Figure 3. PECMBN for C3-7 ZJ pain. A. Schematic diagram of branches of right C5, C6 dorsal ramus; B. Positioning working zone (lined circle in A) for C5 medial branch under G-arm AP view; C. Positioning working zone under G-arm lateral view; D. Endoscopic view of medial branch in working zone; E. Endoscopic view of the tendinous fibers of origin of the semispinalis capitis segregate the medial and lateral branches; F. Endoscopic view of superficial MB and deep MB; G. Endoscopic view of two medial branches arise from the dorsal ramus; H. Endoscopic view of C7 medial branch at the junction of the base of SAP and transverse process just like the target point in lumbar spine; I. Endoscopic view of a C6 medial branch and articular branches in working zone (dotted circle in A). C5: the fifth vertebra; mb: medial branch; s-mb: superficial medial branch; d-mb: deep medial branch; lb: lateral branch; SSCa: semispinalis capitis; a: articular branch; vr: ventral ramus; zj: zygapophyseal joint; tp: transverse process.

all procedures. The patient should be positioned lying prone (**Figure 1A**). We performed PECMBN under local anesthesia without any sedation or systemic analgesia so that the patient can remain conscious throughout the procedure.

The target MB is first anesthetized by performing a standard local anesthetic block (0.5% lidocaine) layer by layer from skin to target nerve. A fluoroscopic lateral view of the target articular pillar and anteroposterior (AP) view of lateral waist of lateral mass was obtained. Then, under repeated fluoroscopic imaging, a 25-gauge spinal needle is inserted along a posterior approach toward the target point for the nerve. Approximately 1 ml of 0.25% bupivacaine is injected to anesthetize the target MB.

Table 1. Demographic characteristic

Index	Operation group	Conservative group
Sex (male/female)-no.	7/7	4/7*
Age (years)	54.64±12.81	54.00±16.52#
VAS score of neck pain	7.21±0.58	6.82±0.75#
Duration of neck pain (months)	39.36±42.71	38.91±44.10#
VAS score of referred pain	4.83±1.34	4.20±0.92#
Duration of referred pain (months)	3.13±4.25(14)	5.20±3.26(10)#
History of ACDF		*
No	12	8
Yes	2	3

*, Chi-square test: *P*>0.05; #, *t*-test: *P*>0.05.

The spinal needle was withdrawn. An 8 mm incision was made on the skin and deep fascia; soft tissue dilator was inserted to posterolateral aspect of lateral mass. Then working channel was inserted to target point under fluoroscopic monitoring, dilator was taken out and endoscope was inserted (**Figure 1B**). All surgeries were performed and monitored by a spine coaxial endoscopesystem (Spinendos GmbH, Germany) and tip-flexible electrode bipolar radiofrequency system (Elliquence LLC, USA) under continuous saline irrigation.

There is a dual nerve supply to the Z-joint. An ascending branch innervates the joint above and a descending branch innervates the joint below. The numbering is different from the lumbar spine. The MB carries the same name as the articular pillar it crosses. Thus, the C4 and C5 MBs innervate the C4-5 Z-joint. At the C3 level, 2 MBs are present. The deep one is involved in the innervation of the C3-4 Z-joint. The C3 superficial MB is known as the "third occipital nerve (TON)". This nerve wraps around the lateral aspect of the ipsilateral C2-3 Z-joint and supplies this joint in addition to providing cutaneous supply to the suboccipital region.

PECMBN for C2-3 Z-joint pain

During PECMBN for C2-3 Z-joint pain, working zone should be placed firstly at the dorsolateral aspect of the maximum convexity of the C2-3 Z-joint, where communicating branch and articular branches to C2-3 Z-joint can be found (**Figure 2A-C**) and cut off with micro-punch or tip-flexible radiofrequency ablation. After that, working zone was moved downwards to the point just above the waist of the C3 articular pillar, where TON and C3 deep MB can be found (**Figure 2A**, **2D**, **2E**). TON was cut off for C2-3 Z-joint pain while C3 deep MB was cut off for C3-4 Z-joint pain.

Endoscopic anatomy of branches of C3 dorsal ramus: The C3 dorsal ramus arises from the C3 spinal nerve in the C2-3 intervertebral foramen and curves dorsally through the intertransverse space. There it divides into its branches, which are the MBs, the lateral branch, and a communicating branch (**Figure 2A**).

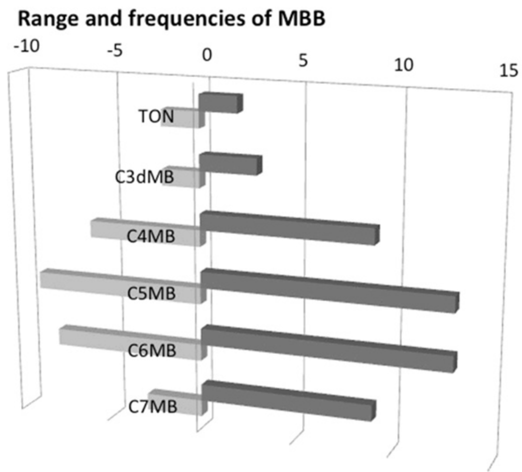
The two MBs arise separately from the dorsal ramus. The principal and constant MB is TON. The other is the deep MB (**Figure 2E**). The TON curves dorsally and medially around the superior articular process of the C3 vertebra. It crosses the C2-3 Z-joint either just below or across the joint margin. It then runs transversely medially through the fibroadipose tissue below obliquus inferior and dorsal to the C2 lamina. The deep MB curves dorsally and medially around the waist of the C3 articular pillar lying against bone. Continuing medially, it enters and supplies the uppermost fibers of multifidus.

An articular branch to the C2-3 Z-joint arises from the C3 dorsal ramus near the origin of the communicating branch or from the communicating branch itself (**Figure 2C**). It runs rostrally, embedded in the periarticular fibrous tissue surrounding the dorsal aspect of the joint. Articular branches to the C3-4 Z-joint arise from the C3 deep MB and run caudally through the periarticular fibrous tissue.

PECMBN for C3-7 Z-joint pain

During PECMBN for C4-7 MBs, working zone should be placed on the center of pillar from fluoroscopic lateral view and lateral to waist of lateral mass from fluoroscopic AP view (**Figure 3A-C**). MBs and articular branches can be found endoscopically (**Figure 3D**), cut off and ablated while lateral branches should be kept intact (**Figure 3E**).

Endoscopic anatomy of branches of C4-7 dorsal ramus: The C4-7 dorsal rami arise from their respective spinal nerves just outside their



	TON	C3dMB	C4MB	C5MB	C6MB	C7MB
Conservative Group	2	2	6	9	8	3
Operation Group	2	3	9	13	13	9

Figure 4. Distributions of target nerves in conservative group and operation group. TON: third occipital nerve; dMB: deep branch of medial branch; MB: medial branch.

intervertebral foramina. Each dorsal ramus curves dorsally through the intertransverse space to cross the root of the transverse process, medial to the intertransversarius posterior medialis. As it crosses the transverse process, each divides into a medial and lateral branch. The tendinous fibers of origin of the semispinalis capitis are constant at the C4-7 levels and, indeed, segregate the medial and lateral branches at these levels (**Figure 3E**). The lateral branches cross the tendons superficially, while the MBs lie deep in relation to them. Because of their relationship to the MBs, these tendinous slips are homologous to the lumbar mamilloaccessory ligaments.

The MBs of each of the C4-7 dorsal rami curve medially and dorsally around the waist of its related articular pillar, covered by the tendinous slips of origin of the semispinalis capitis. The MB of C4-5 dorsal rami may divide into a superficial and a deep branch (**Figure 3F**). This division occurs away from the dorsal rami, and so two MBs may appear to arise from the dorsal rami (**Figure 3G**). The two branches run together around the articular pillar but later assume a different muscular distribution. At the C6, 7 levels, the MB does not divide, and only a deep MB is represented (**Figure 3H**, **3I**).

Articular branches arise from each of the C4-7 MBs (**Figure 3I**). When the MB is double, they arise from the deep MB. There are rostral and caudal articular branches passing, respectively, to the Z-joint above and to that below the MB. Each articular branch is directed across the dorsal aspect of the joint capsule and runs through the pericapsular fibrous tissue deep to semispinalis capitis.

Outcomes measures and follow-up

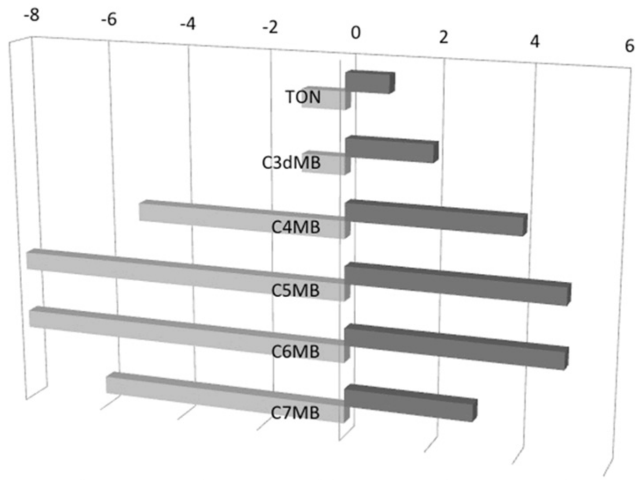
All patients were discharged 2 days after the operation. A surgeon who was unaware of the treatment assignments assessed all patients. Neck pain or referred pain was measured on a visual analogue scale (VAS) (range, 0-10) before MBB, after MBB, 1 day after surgery and at 3, 6, and 12 months postoperatively. A higher score on the VAS equates to a higher level of pain.

Percentage of pain relief (%) was calculated as: (VAS score before MBB-VAS score after treatment) ×100/VAS score before MBB.

The MacNab score was recorded at 12 months postoperatively. MacNab criteria was applied to each patient by characterizing pain relief of 75-100% as excellent, 50-74% as good, 25-49% as fair, and 0-24% as poor. Success is based on an excellent, good outcome. Besides, any potential complications were also evaluated at each visit.

Statistical analysis

All analyses were performed using SPSS software (SPSS, version 20, Chicago, IL, USA). Qualitative data were expressed as frequency and percentage. Chi-square test was used to examine the relation between qualitative variables. Normally distributed continuous data are presented as means ± standard deviation (SD) and were compared using *t*-tests. Non-normally distributed continuous data are presented as the median and range, and were compared using the Wilcoxon rank sum test.



	TON	C3dMB	C4MB	C5MB	C6MB	C7MB
R	1	1	5	8	8	6
L	1	2	4	5	5	3

Figure 5. Distributions for each target nerves involved in operation group. R: right side; L: left side; TON: third occipital nerve; dMB: deep branch of medial branch; MB: medial branch.

Differences within groups between patients' preoperative and postoperative VAS scores were analyzed for significance using one-way analysis of variance and LSD test. Using *t*-tests assessed difference between 2 groups. Differences were considered statistically significant when $P<0.01$.

Results

Patient's demographic characteristics

The mean age of patients receiving PECMBN was 54.64±12.81 years and 54.00±16.52 years for those who underwent conservative treatment. In operation group, 7 were males (50%) and 7 females (50%), while in conservative group, 4 were males (36.4%) and 7 females (63.6%). The average pre-operative VAS score of neck pain for operation group was 7.21±0.58 compared to 6.82±0.75 for conservative group, while the mean pre-operative VAS score of referred pain was 4.83±1.34 and 4.20±0.92 in the two groups, indicated in our questionnaire as severe and constant pain. The VAS scores before MBB were not found to have significant difference in operation group as compared to conservative group (all $P>0.05$). 52% of patients reported a duration of pain of 1 year or less, whereas 20% reported 1 to 4 years, and 28% suffered pain for longer than 4 years. The average duration of pain including neck pain and referred pain was not found to have significant difference in operation group than that in conservative group ($P>0.05$). No statistically significant difference in age, sex, referred pain duration, history of previous anterior cervical discectomy and fusion (ACDF) was observed between the two groups ($P>0.05$) (see **Table 1**). **Figure 4** shows no significant difference in the distribution for each Z-joint involved between the two groups (Chi-squre test, $P>0.05$). In the 14 patients underwent PECMBN, the surgical target MBs were predominantly performed at the C5-6 Z-joint. An amount of 49 target MBs have been endoscopically explored.

Operation group include 1 bilateral C3-6 Z-joint pain, 1 left C2-3+C5-7 Z-joint pain, 1 left C3-4 Z-joint pain, 1 left C4-6 Z-joint pain, 1 left C4-7 Z-joint pain, 1 left C5-6 Z-joint pain, 1 right C2-3 Z-joint pain, 4 right C4-7 Z-joint pain, 1 right C5-6 Z-joint pain and 2 right C5-7 Z-joint pain. In summary, C5-6 Z-joint has been the most frequently involved (12 level-36.4%) followed by C6-7 Z-joint (8 levels-24.2%) and C4-5 (8 levels-24.2%), C3-4 (3 levels-9.1%) and C2-3 Z-joint (2 levels-6.1%). **Figure 5** summarizes the distribution for each target point involved.

Postoperative outcomes

In operation group, all the 14 patients completed the PECMBN. During operation, we found all target MBs and anatomical variants of the MBs of dorsal ramus, including the number, the thickness and the positioning of MBs (**Figures 2**, **3**). During the follow-up period, 2 cases of C2-3 Z-joint pain experienced persistent numbness in the cutaneous distribution of the third occipital nerve; but they treated this side effect as little consequence compared with the benefits associated with pain relief; no other complications were observed.

Table 2 summarized the VAS score of the neck pain and referred pain before MBB, after MBB, 1 day after surgery and at 3, 6, and 12 months postoperatively in the two groups. In operation group, the neck pain and referred pain showed

Table 2. VAS score change of the neck pain and referred pain (means ± standard deviation)

Time point	Operation group		Conservative group	
	Neck pain$	Referred pain$	Neck pain$	Referred pain$
Before MBB	7.21±0.58	4.83±1.34	6.82±0.75	4.20±0.92
After MBB	0.36±0.50*	0.50±0.52*	0.64±0.50*	0.80±0.63*
Postoperative 1 day	0.21±0.43*	0.25±0.45*	5.45±1.04*,#	3.00±1.15*,#
Postoperative 3 months	0.14±0.36*	0.08±0.29*	5.45±1.04*,#	3.00±1.15*,#
Postoperative 6 months	0.29±0.47*	0.17±0.39*	6.18±1.40#	3.80±0.92#
Postoperative 12 months 1	0.29±0.47*	0.25±0.45*	5.64±1.21*,#	3.20±1.03#

MBB, medial branch block; $, one-way ANOVA: $P<0.01$; *, LSD: $P<0.01$, versus before MBB; #, LSD: $P<0.01$, versus after MBB.

Table 3. Comparison of percentage of pain relief (neck/referred) at different time point in the two groups (means ± standard deviation)

Time point	Neck pain		Referred pain	
	Operation group	Conservative group	Operation group	Conservative group
After MBB	95.03±6.94	90.80±7.41	86.81±14.42	81.33±13.49
Post 1 day	96.94±6.08*	19.91±13.55	86.81±14.42	81.33±13.49
Post 3 months	98.21±4.54*	19.91±13.55	97.92±7.22*	29.83±15.18
Post 6 months	96.17±6.30*	9.97±14.67	96.53±8.30*	9.17±12.08
Post 12 months	96.17±6.30*	17.21±16.35	93.75±11.85*	23.50±19.70

MBB, medial branch block; Post, postoperative; *, *t*-test: $P<0.01$, compared to conservative group.

a lower score at any time point postoperatively ($P<0.01$), as compared to the VAS pain score obtained before MBB, while showed no statistically different ($P>0.05$) as compared to the VAS pain score obtained after MBB. In conservative group, the neck pain and referred pain showed a lower score at most of the time points postoperatively ($P<0.01$), as compared to the VAS pain score obtained before MBB, while showed a higher score ($P<0.01$) as compared to the VAS pain score obtained after MBB. The VAS neck pain or referred pain score after MBB in the two groups was not statistically different ($P>0.05$).

Table 3 illustrated comparison of percentage of pain relief after MBB, 1 day after surgery and at 3, 6, and 12 months postoperatively in the two groups. There was no statistically different in respect to the relief of pain (neck/referred) after MBB in the two groups. All patients experienced more than 80% pain relief after MBB in both groups with 100% pain relief in 9 cases out of 14 cases in operation group and 4 cases out of 11 cases in conservative group. The relief of pain (neck/referred) at any time point postoperatively in operation group was better in comparison to that in conservative group (*t*-test, all $P<0.01$). At 1-year follow-up, no patient in conservative group achieved more than 50% pain relief while all patients achieved more than 80% pain relief with complete pain relief in 10 cases out of 14 cases in operation group.

As shown in **Table 4**, excellent McNab outcomes of the 1-year postoperative evaluation in operation group were recorded for 100%, which was significantly better than that in conservative group ($P<0.01$).

Discussion

Cervical PRN is an effective treatment for cervical Z-joint pain that can be relieved by controlled, diagnostic MBB of one or more of the MBs of the cervical dorsal rami. The purpose of PRN is to ablate the MBs of the dorsal rami at high temperatures and provide longer pain relief than simple nerve blocks. The rationale is that, if it can be shown that a MB mediates a patient's pain, and then destroying the nerve to prevent the conduction of nociceptive impulses can relieve the pain. By this means, the procedure does not treat the actual cause of pain; nevertheless, it provides pain relief. Both the physician and the patient must realize that the effects of PRN are usually not permanent [27]. When effective, the procedure was supposed to relieve pain, restores normal activities, and eliminates the need for other neck pain-related health care [16, 17]. Although serious studies [14, 16, 17, 28, 29, 30] used PRN only in patients who obtain complete relief of pain following controlled diagnostic blocks, used large

Table 4. MacNab score of the 1-year postoperative evaluation in two groups

MacNab score	Operation group*	Conservative group
Excellent	14 (100%)	0 (0%)
Good	0 (0%)	0 (0%)
Fair	0 (0%)	4 (36.4%)
Poor	0 (0%)	7 (63.6%)

*, Chi-square test: $P<0.01$, compared to conservative group.

electrodes, placed parallel to the target nerves, with several lesions made in order to encompass all possible variations in the location of the nerve, and in order to encompass a maximal length of nerve, they indicated that complete and enduring relief of pain can just be achieved in about 70% of patients and the median time to a recurrence was about 400 days. If pain recurs, the treatment can be repeated in order to reinstate relief [14, 16, 17, 29-31]. When applied to TON, There is limited evidence to support PRN for management of cervicogenic headache [32, 33]. Although PECMBN share the same therapeutic mechanism as PRN, much higher success rate was achieved in this study with all patients had VAS improvement equal or greater than MBBs. Rigorous patients selection, accurate surgical anatomy, complete neurotomy and avoidance of iatrogenic nerve injuries may be factors contributing to excellent outcome of PECMBN.

In this study, we considered PECMBN as an irreversible surgical procedure with potential neurological risk. So a precise diagnosis is required, as in the case of major surgical therapy, there is no substitute for stringent, placebo-controlled triple blocks [34]. Only then can the physician be assured that the response to diagnostic blocks is not false positive. A single diagnostic block carries a false-positive rate of 27% [7] and is an unreliable means of establishing a diagnosis of cervical Z-joint pain. Even double comparative local anesthetic blocks carry an 11% risk of a placebo effect [34].

Variations of cervical MBs have been confirmed in cadaver studies [35, 36] and in endoscopic views as in this study. The variation of nerve size between subjects was slight; in contrast, the distance between the bony articular pillar and MBs was more variable. The courses of the C4 and C5 MBs were relatively constant following the concavity of the waist of their respective articular pillars. However, the C3, C6 and C7 MBs exhibited a much wider anatomic variation. The C6 and C7 MBs also exhibited considerable variation in their cephalocaudad position relative to the underlying bone and adjacent Z-joints. The C6 MBs coursed either around the waist of the articular pillar or above it, between the waist and the superior articular process. Most of the C7 MBs were high on the C7 articular pillar and crossed the lateral image of the C6-7 Z-joint. However, a few C7 MBs were located laterally on the C7 transverse process and, thus, appeared to be lower on the lateral image of the C7 articular pillar [35]. Because the lesions made with radiofrequency electrodes in PRN are small, their placement adjacent to the target nerve must be precise. The target point for typical cervical MBs is the centroid of the ipsisegmental articular pillar. For TON, three closely proximate target points are used to accommodate the size of this nerve and possible variations in its position [37]. Therefore, variations in the anatomy of the MBs of the cervical dorsal rami could constitute a basis for technical failure of PRN [38]. Lord et al [39] report 12 patients who underwent TON neurotomy for treatment of C2-3 Z-joint pain, only 5 obtained long-lasting relief. The other 7 patients all reported early return of their pain and constituted technical failures; TON was inadequately coagulated and recovered in the immediate postoperative period. The median duration of complete pain relief was 22 days for the 12 procedures and 161 days for the 5 successes. In all cases of treatment failure, return of pain was accompanied by return of sensation in the territory of the third occipital nerve, indicating that the nerve was inadequately coagulated. Possible reasons for the high rate of failures include the relatively larger diameter of the nerve and its variable anatomic course. TON lies superficial to the joint capsule; an electrode placed immediately adjacent to the bony margin of the joint may fail to incorporate the nerve by passing deep to the capsule, thereby displacing the nerve from the electrode. In PECMBN, all the target nerves and their possible variations can be fully exposed endoscopically, so the target nerves are sure to be reached. All the patients in PECMBN achieved VAS improvement equal or greater than MBBs with 71.4% (10/14) patients experience complete pain relief at 1-year follow-up.

TON or cervical MBs were cut off and ablated with nerve transection and defect was made so that target nerve regeneration became impossible in patients after PECMBN. No pain recurred in patients after PECMBN at 1-year follow-up. Nerve injuries caused by PRN can be considered as 1-2 degree injury according to Sedden classification, in which the neural and perineural proteins are coagulated but neither the axons nor their sheaths are disrupted. Consequently, nerve regeneration with pain recurrence is theoretically inevitable [40, 41].

PECMBN was performed endoscopically under local anesthesia with continuous saline irrigation so that iatrogenic nerve injuries can be avoided. Given the proximity of the courses of TON and C3 deep MB with variation of the courses of the two nerves overlapped, PRN coagulate the C3 deep MB must risk inadvertently coagulating TON, and vice versa. So cutaneous numbness in the territory of TON is a common side effect of PRN addressing the C3-4 Z-joint [39]. In this study, TON and C3 deep MB were dissected and differentiated with PECMBN in 3 cases with C3-4 Z-joint pain, C3 deep MBs were cut off with TONs kept intact. No cutaneous numbness in the territory of TON was found in them. Cervical lateral branch of dorsal ramus is another nerve likely inadvertently injured in PRN. Dropped head syndrome after multi-level cervical PRN may be caused by wide paraspinous muscle denervation with medial and lateral branches injured simultaneously [42, 43]. We must remain alert to the possible appearance of this weakening complication and its possible association with protocols that recommend larger denervation volumes in PRN [44, 45]. During PECMBN, MBs and inadvertently exposed lateral branches were differentiated endoscopically; MBs were cut off with lateral branches kept intact. We didn't find any neck weakening in operation group with PECMBN.

Persistent cutaneous numbness is an inevitable sequelae of technically successful third occipital neurotomy [39]. 2 cases with C2-3 Z-joint pain involved treated with PECMBN experienced persistent cutaneous numbness in the cutaneous distribution of TON, but they treated this side effect as little consequence compared with the benefits associated with pain relief. Painful neuroma formation is a potential complication of PECMBN in which neurotomy was performed; consequently, neuroma formation is theoretically likely. Although this complication has not been found in this study, further long-term prognosis should be followed up. Other complications after PRN such as ataxia, unsteadiness, spatial disorientation, dysesthesias [29] and neuropathic pain [46] were not found in patients after PECMBN.

The shortcomings of this study include non-randomizedstudy design, relative small sample, and short-term follow-up. The effect and safety of PECMBN need further evaluation by large sample randomized, controlled trials with long-term follow-ups.

Conclusion

PECMBN for chronic cervical Z-joint pain is an accurate, effective and safe minimally invasive spine surgery. Higher success rate can be achieved compared with reported outcomes of PRN without complications increased. All target cervical MBs can be differentiated endoscopically and cut off without possible nerve regeneration while cervical lateral branches in all levels or TON in C3-4 Z-joint pain can be prevented from iatrogenic injures.

Disclosure of conflict of interest

None.

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