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Prospective Study

A Prospective Comparison of CT-Epidurogram Between Th1-Transforaminal Epidural Injection and Th1/2-Parasagittal Interlaminar Epidural Injection for Cervical Upper Limb Pain

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Background: Cervical epidural injections for treating neck and upper limb pain are performed by 2 methods: transforaminal and interlaminar. Many serious complications caused by inadvertent intravascular injection have been reported with the use of cervical transforaminal epidural steroid injection through the anterior-lateral approach. Despite international practical guidelines that have been proposed, cervical transforaminal epidural injection is still less recommended than cervical interlaminar epidural injection.

Objectives: The objective of this study is to introduce Th1-transforaminal epidural injection (Th1-TFEI) through the posterior-lateral approach, compare the injectate spread in Th1-TFEI with that of Th1/2-parasaggital interlaminar epidural injection (Th1/2-pILEI), and clarify the clinical characteristics of Th1-TFEI.

Study Design: This research involved a prospective study of 30 patients receiving both Th1-TFEI and Th1/2-pILEI.

Methods: Thirty patients with unilateral upper limb pain were enrolled for this prospective study. Th1-TFEI and Th1/2-pILEI were administered on each case in random order under fluoroscopy, and computed tomographic (CT) epidurograms were compared. Changes in circulatory dynamics, presence of Horner's syndrome, changes in the Numerical Rating Scale (NRS-11), and adverse events were investigated.

Results: Patients included 15 men and 15 women and included 24 cases of cervical spine disease and 6 cases with other upper limb pain. The Th1-TFEI group had significantly higher rates of "Th1 root filling" (100%), "ventral spread" (70.0%), and "lateral limitation" (26.7%) compared to the Th1/2-pILEI group. In the Th1-TFEI group, cephalad spread averaged 2.97 vertebral bodies, reaching approximately up to C6. The Th1/2-pILEI group had an average of 4.76 vertebral bodies, approximately up to C4. The 2 groups showed significant differences in cephalad spread. Horner's syndrome appeared in the Th1-TFEI group at a rate of 56.7%, significantly higher than that in the Th1/2-pILEI group at 17.2%. The presence of Horner's syndrome showed significant correlations with "ventral spread" and "spread up to C6." There were no significant differences in NRS-11 improvement and changes in circulatory dynamics between the groups. There were no major complications.

Limitations: The components of injectate were standardized; however, the needle gauge numbers were varied. In addition, interpretation of the CT-epidurogram was not blinded. The sample size was small; therefore, multivariate analysis was not possible.

Conclusions: CT-epidurogram comparison revealed that Th1/2-pILEI was not localized on the injection side, and there was better dorsal spread – although ventral spread was small. Contrarily, Th1-TFEI was localized on the injection side, and better ventral spread was shown while cephalad spread was limited. We expected the addition of a sympathetic block effect suggested by the Horner's syndrome as well as the merits of the ventral spread. However, short-term clinical effects were equal to those of Th1/2 pILEI. In future research, we need to standardize the diseases to include and to increase the number of cases to enable evaluation of clinical effectiveness.

Key words: Epidural, cervical, transforaminal, interlaminar, fluoroscopy, CT-epidurogram, dorsal, ventral, cephalad, Horner's syndrome

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There are 2 routes to reach the cervical epidural space: transforaminal (TF) and interlaminar (IL). The former uses the anterior-lateral approach, advancing the needle through the cervical intervertebral foramen, which is the exit of the nerve root. The latter uses the posterior approach, advancing the needle through the interlaminar space, reaching the epidural space by the loss-of-resistance technique.

Generally, both procedures move the needle under real-time fluoroscopy to confirm the position of the needle and the spread of contrast medium over the epidural space. To inject drugs accurately by confirming radiculogram and epidurogram, and to avoid complications by detecting intravascular and intrathecal injections, are essential (1).

Reportedly, since around 2000, many cases of inadvertent intraarterial injection occurred during cervical transforaminal epidural steroid injection (CTFEI) (2,3). Those cases developed serious ischemic lesions in the brain and spinal cord. The major cause of these lesions was determined to be the corticosteroid, especially water-insoluble particulate steroid that was injected mistakenly into the artery, causing embolization of the feeding artery in the central nervous system. In addition, mechanical injury of the spinal cord by the mispuncture of the needle, and hematoma due to vascular injury, can lead to sequelae (4).

International practical guidelines for the procedure have been proposed, and safer technique and nonparticulate steroid were made the standards (5). Recently, the number of serious complications has decreased; however, CTFEI is, at present, less recommended than cervical interlaminar epidural injection (CILEI) (6,7).

In Japan, since around 2000, we have been treating cervical pain with transforaminal epidural injection at the first thoracic (Th1) vertebrae using the posterior-lateral approach (8). This method is the application of a Th1 nerve root block to the alternative technique of cervical epidural injection. Although there have been some reports about a similar technique, that is, computed tomography (CT)-guided CTFEI through the posterior approach (9,10), there have been no reports on transforaminal epidural injection at the Th1 level.

Generally compared with ILEI, TFEI can administer medical solution around the nerve root, especially at the ventral portion (11-16). Therefore, we expected that TFEI at the Th1 level might have some therapeutic implications compared with ILEI at the same level.

The purposes of this study are as follows:

1. To introduce the technique of Th1-transforaminal epidural injection (Th1-TFEI);
2. To observe the spread of injectate using 3D-CT imaging after prospectively giving Th1-TFEI and Th1/2-parasaggital interlaminar epidural injections (Th1/2-pILEI) in random order to each patient with unilateral upper limb pain;
3. To compare both procedures for clinical characteristics such as frequency of Horner's syndrome, change of circulatory dynamics, treatment effects, and adverse effects.

Methods

Study Design

This study employed a prospective design, with 30 patients receiving both Th1-TFEI and Th1/2-pILEI.

Patients

Thirty patients with unilateral upper limb pain were prospectively enrolled between October 2015 and October 2017. Inclusion criteria were the following: patients who were confirmed without abnormality at the Th1/2 level by roentgenogram and MRI; ages ranging from 20 to 89 years old regardless of gender; and targeted diseases, specifically cervical spinal diseases and neuropathic pain of the upper limb. Exclusion criteria included the following: severe cervical spinal canal stenosis with an anterior-posterior (AP) diameter of < 12 mm measured with roentgenogram, history of surgery of cervical or upper thoracic vertebrae, under anti-

thrombotic/anti-coagulant therapy, allergy to contrast medium and local anesthetics, and malignant tumor presently treated.

After selecting the patients, the content of the study was explained and written consent was obtained from the patients. The patients were divided randomly into Th1-TFEI-first and Th1/2-pILEI-first groups using the envelope method.

This study was approved by the Institutional Review Board of Koseikai Takai Hospital (No. 2017-9) and registered in the University Hospital Medical Information Network (ID: UMIN000019108).

Injection Techniques

We used a floor-type digital x-ray fluoroscope, AXIOM Artis dBA™ (SIEMENS AG, Wittelsbacherplatzs 2, DE-80333, Muenchen, Germany).

Th1-TFEI (Figs. 1-3)

1. The patient is placed in the prone position on the table with a pillow under the chest and the neck is slightly bent forward.
2. A C-arm fluoroscope is used to observe the cervicothoracic junction on the AP view while continuing to tilt the axis of imaging 30° to 45° cephalad. Then the first rib and transverse process of Th1 begin to overlap each other and eventually the interspace of the Th1 transverse process and Th2 transverse process comes into sight.
3. The entry point is the tip of the Th1 transverse process, that is, 4 to 6 cm away from the midline. Under skin anesthesia, a 25-gauge 60- or 80-mm needle is punctured inward to touch the junction of the transverse process and the articular process of Th1. Next, the needle tip is bent caudally and

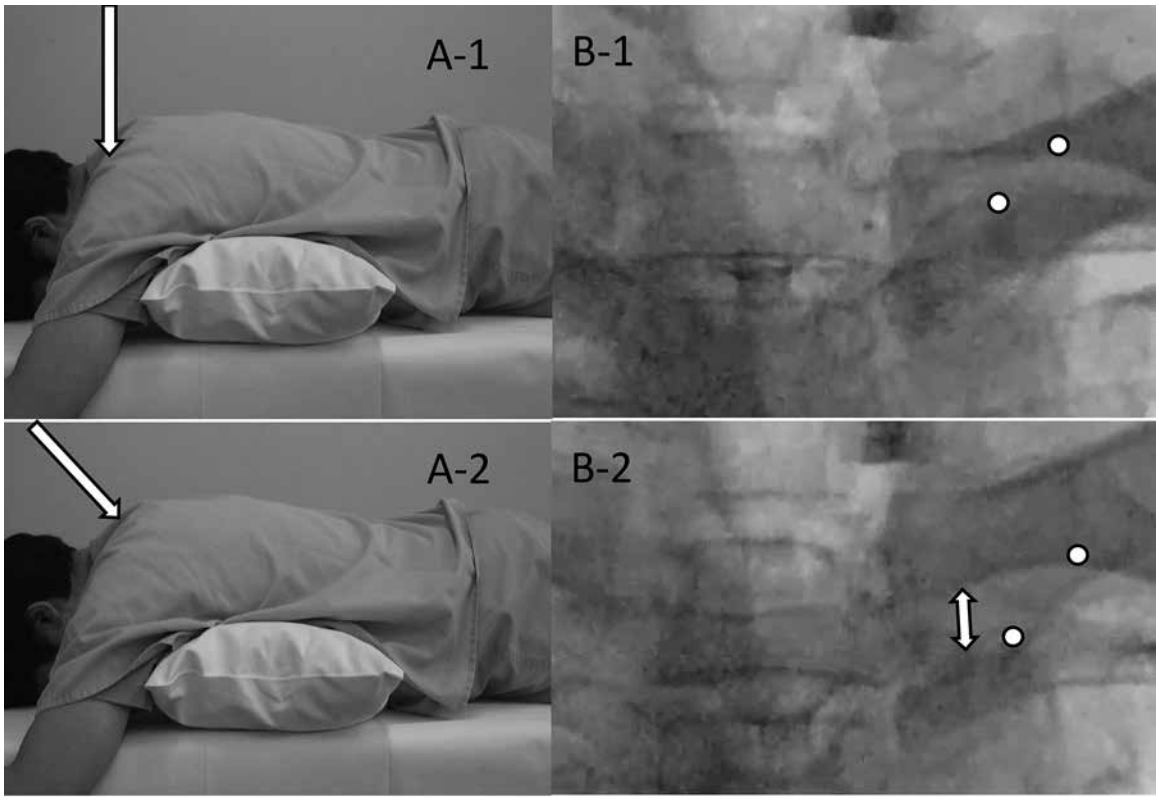

Fig. 1. *A) Schema of body position and direction of fluoroscopy in Th1-TFEI: The prone position was taken with a pillow placed under the chest and cervical spine was slightly bent forward (A-1). Direction of fluoroscopy (white arrow) is bent cephalad by 30° to 45° (A-2). B) Fluoroscopic AP view of Th1-TFEI (a 67-year-old male, preinjection). White circles indicate the caudal edge of Th1 transverse process and the cephalad edge of Th2 transvers process (B-1). As the fluoroscopic axis is bent cephalad gradually, the space (double-pointed arrow) between Th1 transverse process and Th2 transverse process comes into sight (B-2).*

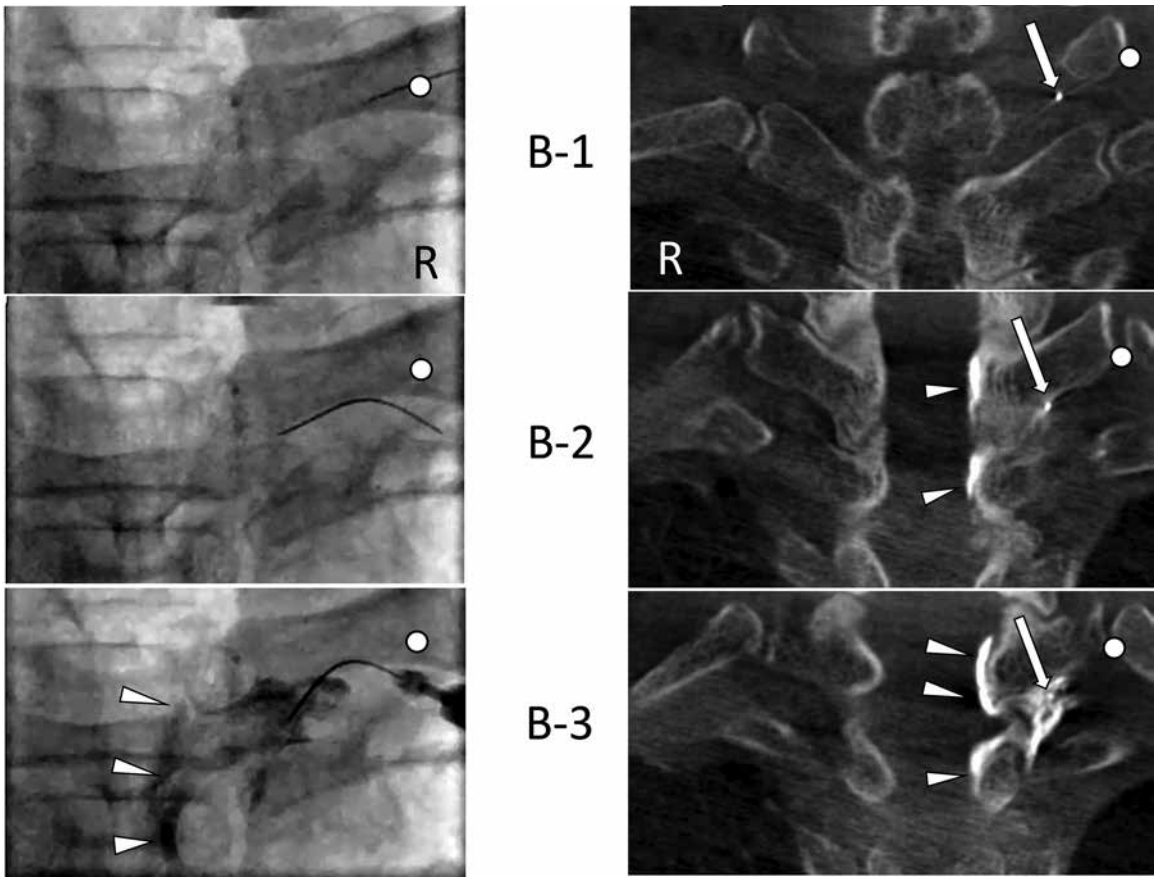

Fig. 2. *A) Fluoroscopic AP view of Th1-TFEI (a 67-year-old male). Insert the needle at the caudal edge of the tip of Th1 transverse process (white circles) (A1), and touch the junction of Th1 transverse process and Th1 articular process (A2). Bend the needle caudally and slip off around the external edge of the junction and reach Th1/2 intervertebral foramen exit, Th1 radiculogram and epidurogram (white arrow heads) come into sight (A3). B) CT-coronal view of Th1-TFEI (a 47-year-old male). White circle indicates caudal edge of Th1 transverse process tip, and white arrow, the needle. The needle advances along the inferior edge of Th1 transverse process, reaches Th1/2 intervertebral foramen exit, and Th1 radiculogram and epidurogram (white arrow heads) come into sight. Note the needle route and the lung apex are separated with enough space (B1, 2, 3).*

slipped off around the outer edge of the above mentioned junction to reach the Th1 nerve root located at the exit of the Th1/2 intervertebral foramen. At this time, on the AP view, the needle tip is located in the Th1/2 intercostal space and at the outer edge of the articular pillar. The lung apex is located further caudally and laterally than the needle pathway. The reason for using a 25-gauge needle is that it is easily bent as needed.

4. When parasthesia is strong at the radicular puncture, the needle can be slid a little in the cephalad or caudal direction.
5. This study used 0.5 mL of saline plus 0.5 mL of Iohexiol 240 mg I/mL injected to confirm the Th1-radiculogram, and the cervico-thoracic epidurogram can be continuously observed.
6. When the needle tip strongly touches the articular process, the facet arthrogram is sometimes seen. In this case, by advancing the needle 1 to 2 mm, we can often reach the Th1 nerve root.
7. When the needle tip is located at the paravertebral fascia layer, we can often see the injection into the vertebral venous plexus. In such a case, advance the needle 1 to 2 mm to let the needle pass through this layer and reach the nerve root.
8. When the needle reaches the nerve root layer

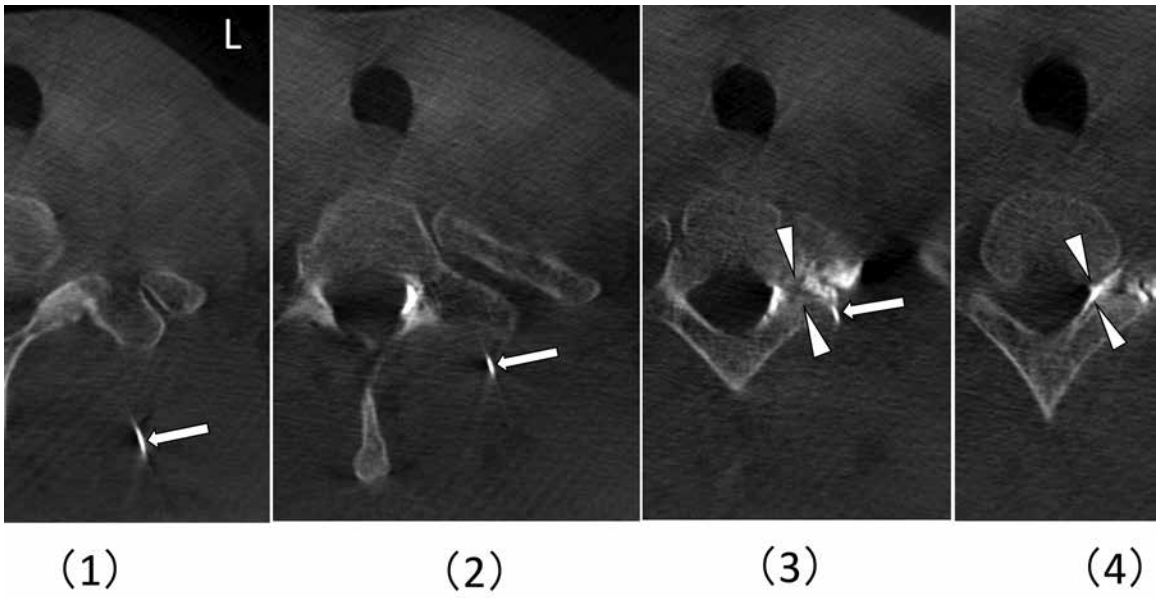

Fig. 3. *CT-axial view of Th1-TFEI (a 47-year-old male). (1) shows level of C7/Th1 intervertebral foramen, and (2), (3), and (4) are axial slices taken 2 mm each caudal from (1). The needle (arrows) is advanced using posterior-lateral approach and slipped off around the edge of the articular pillar, and proceeds to Th1/2 intervertebral foramen exit (1), (2). Flow of contrast into the Th1 root (arrow heads) and epidural space are seen (3, 4). Through this route, the needle does not reach inside the spinal canal, and there are no risks of dural puncture or spinal puncture. Note the lung apex is located further outside from the needle pathway.*

and the intravascular injection is seen, the needle position is adjusted only one time. However, if the intravascular injection continues, the operation is stopped and the case is counted as a complication. Later retrial is allowed.

9. When the Th1 radiculogram accompanied by epidurogram is confirmed, 2 mL of the mixture of contrast medium and 2% mepivacaine in equivalent amounts are further injected. Therefore, the total amount of injection becomes 3 mL: 0.5 mL of saline plus 0.5 mL + 1 mL of contrast medium plus 1 mL of mepivacaine. The concentration of mepivacaine becomes approximately 0.67%.

Th1/2-pILEI (Fig. 4)

1. The position of the patient is the same as in the Th1-TFEI group.
2. A C-arm fluoroscope is used to observe the cervicothoracic junction on the AP view, and the axis of imaging is kept tilted at 10 to 30° caudal. Then, the Th1/2-interlaminar space comes into sight.
3. The entry point is the caudal edge of the Th1/2-interlaminar space, slid 2 to 5 mm toward the affected side from the midline. Under skin anesthesia, a 22-gauge 60-mm needle is used to puncture. Maintaining the direction so that the needle can be seen at one point on the AP view and confirming the depth of the needle by checking the lateral view, the needle is advanced straight toward the epidural space. Using a glass syringe, 0.5 mL of saline plus 0.5 mL of contrast medium are injected to confirm the loss of resistance and epidurogram. The reason for using a 22-gauge needle is that it is more easily advanced straight and is easier to sense loss of resistance.
4. When the subarachnoid puncture leads to myelography, stop the operation and further injection. Although the case is counted as a complication, retrial is allowed a few days later.
5. When the epidurogram is confirmed, 2 mL of the mixture of contrast medium and 2% mepivacaine in equivalent amounts are further injected. Therefore, the total amount and concentration of the injectate are the same as in the Th1-TFEI group.
6. This study didn't use steroids; however, if a steroid is used, it should be limited to nonparticulate steroid in both injections.

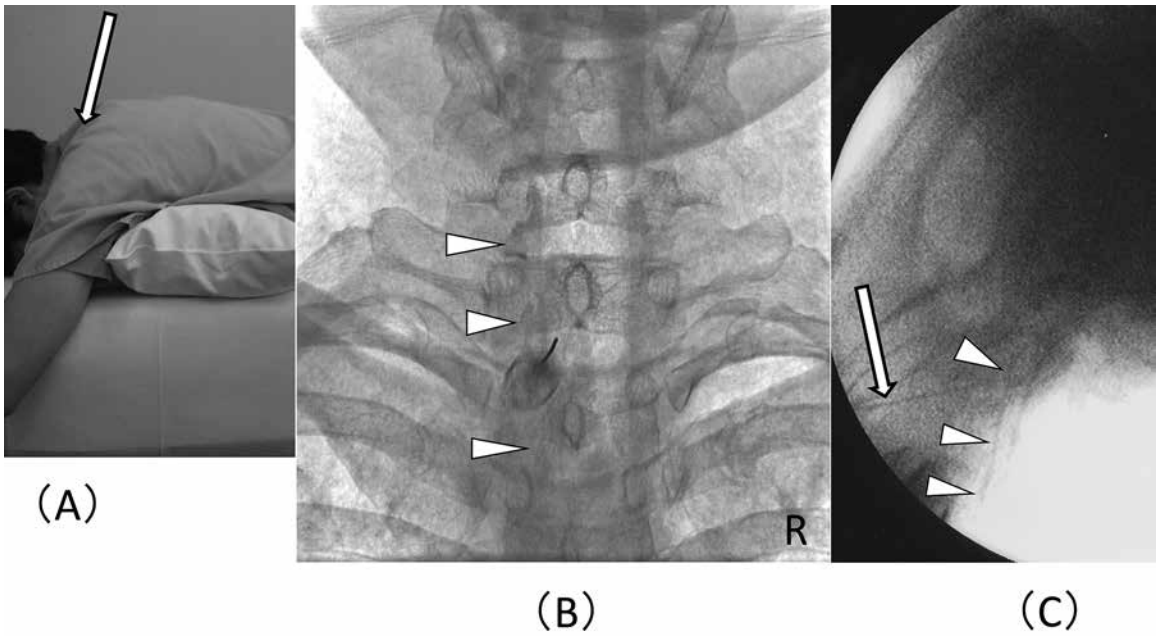

Fig. 4. *A) Schema of body position and direction of fluoroscopy in Th1/2-pILEI. The position is the same as Th1-TFEI. Bend caudal the direction of fluoroscopy (white arrow) by 10° to 30°, and the interlaminar space comes into sight. B) Fluoroscopic AP view of Th1/2-pILEI (a 57-year-old female). Advance using parasaggital approach from slightly left to the midline, confirm loss of resistance, and epidurogram (white arrow heads) mainly on the left side is seen. C) Fluoroscopic lateral view of Th1/2-pILEI. The depth of the needle (white arrow), and dorsal epidurogram (white arrow heads) are confirmed.*

Outcome Measurements

1. Before each technique, blood pressure (BP), heart rate (HR), and the Numerical Rating Scale (NRS-11) for pain were measured.
2. After injection, a cone-beam 3D-CT (Dyna CT) was used to take a cervico-thoracic epidurogram. All injections were performed by the first author (KH).
3. For 60 minutes after the operation, the patient was let to rest under monitoring. Every 5 minutes for 30 minutes, BP and HR were measured. Fifteen minutes post operation, the presence of Horner's syndrome (ptosis, miosis, or conjunctival hyperemia) was inspected visually.
4. A few days post operation, NRS-11 was measured.
5. One or 2 weeks after the first procedue, the second procedure was performed and evaluated in the same manner.

Primary Outcome: Analysis of CT-Epidurogram

1. Lateral limitation: When the epidurogram is absent on the noninjected side across the midline, it is judged "present."
2. Cephalad spread: Count the number of the cervical vertebral bodies from Th1 (inclusive Th1) to the level reached by the epidurogram on the saggital view.
3. Th1 root filling (injected side/noninjected side): When the epidurogram of the ventral edge and dorsal edge of the Th1 nerve root is observed, it is judged "present."
4. Ventral spread (injected side/noninjected side): When the epidurogram is observed at further ventral from the ventral edge of the Th1 nerve root, it is judged "present."
5. Dorsal spread (injected side/non-injected side): When the epidurogram is observed at further dorsal from the dorsal edge of Th1 nerve root, it is judged "present."

Secondary outcomes are as follows:

1. Systolic BP, diastolic BP, HR, and their maximum variation amounts before and after injection;
2. Presence of Horner's syndrome (injected side/non-injected side) 15 minutes after the injection;
3. NRS-11 score before and after injection and its variation amount, and the frequency of cases in which

the NRS-11 improved 50% or more after injection;
4. Frequency of intravascular injection and whether adjustment was appropriate or not;
5. Other adverse events.

The factors mentioned above were compared between the groups; and the CT-epidurogram findings, presence of Horner's syndrome, and NRS-11 improvement rate were analyzed for the presence of associations between those factors. The paired t test, Wilcoxon signed-rank test, and chi-square for independence test were used for statistical analysis; $P < 0.05$ was considered significant.

Results

Patients' Background

Patients included 15 men and 15 women aged between 41 and 86 (mean, 59.7) years old. Diseases included intervertebral disc herniation (18 cases), spinal canal stenosis (3 cases), spondylotic radiculopathy (3 cases), zoster-associated pain (3 cases), thoracic outlet syndrome (1 case), complex regional pain syndrome (1 case), and whiplash-associated disorder (1 case). Affected areas were right side (11 cases) and left (19 cases) and affected levels included C5 (1 case), C5 and C6 (2 cases), C6 (13 cases), C6 and C7 (6 cases), C7 (6 cases), C7 and C8 (1 case), and C8 (1 case).

A 43-year-old man with an intervertebral disc hernia did not receive Th1/2-pILEI because his pain had been alleviated by his first Th1-TFEI. As a result, our study had 30 cases in the Th1-TFEI group and 29 in the Th1/2-pILEI group. A 65-year-old woman with whiplash-associated disorder did not come back after her Th1/2-pILEI; therefore, her postoperative NRS-11 score and presence of adverse effects are unknown.

CT-Epidurogram (Table 1, Figs. 5,6)

Findings from the CT-epidurogram are shown in Table 1. There were significant differences between the groups with regard to the presence of "lateral limitation" ($P = 0.015$), "ventral spread on injected side" ($P = 0.00042$), "dorsal spread on noninjected side" ($P = 0.00032$), "Th1 root filling on injected side" ($P = 0.00014$), and in the number of vertebral bodies with "cephalad spread" ($P = 0.0014$); however, there was no significant difference between groups in the rate at which the injectate reached the affected level ($P = 0.35$).

Table 1. *Findings of CT-epidurogram and presence of Horner's syndrome.*

Items	Th1-TFEI group	Th1/2-pILEI group	P value
Presence of lateral limitation	26.70%	3.40%	0.015 *
Presence of ventral spread			
injected side	70.00%	24.10%	0.00042 *
non-injected side	30.00%	27.60%	0.84
Presence of dorsal spread			
injected side	96.70%	100%	0.51
non-injected side	56.70%	96.60%	0.00032 *
Presence of Th1 root filling			
injected side	100%	58.60%	0.00014 *
non-injected side	26.70%	31.00%	0.71
Cephalad spread			
mean number of the vertebral bodies	2.97 (up to C6)	4.76 (up to C4)	0.0014 *
reaching rate to the affected level	80.00%	93.10%	0.35
Presence of Horner's syndrome			
injected side	56.70%	17.20%	0.0017 *
non-injected side	3.30%	6.90%	0.49

*: statistically significant

Improvement in NRS-11

Before the procedure, there was no significant difference in NRS-11 scores between the groups ($P = 0.72$). After the procedure, NRS-11 scores had improved from 6.3 to 3.7 in the Th1-TFEI group, and from 6.4 to 3.8 in the Th1/2-pILEI group, a significant decline for both groups ($P = 1.7E-06$, $P = 5E-06$, respectively).

The rate of NRS-11 improvement showed no significant difference between the groups (Th1-TFEI: -42.3% vs. Th1/2-pILEI: -41.5%, $P = 0.79$). NRS-11 scores improved 50% and more in 46.7% of the Th1-TFEI group, and in 41.4% of the Th1/2-pILEI group, showing no significant difference between the groups ($P = 0.91$). With regard to NRS-11 improvement, all findings from the CT-epidurogram showed no significant association.

Horner's Syndrome (Table 1)

There was a significant difference between the groups in the presence of "Horner's syndrome on injected side" ($P = 0.0017$). There were no significant associations between "presence of Horner's syndrome" and the age, gender, injected side (right or left), and

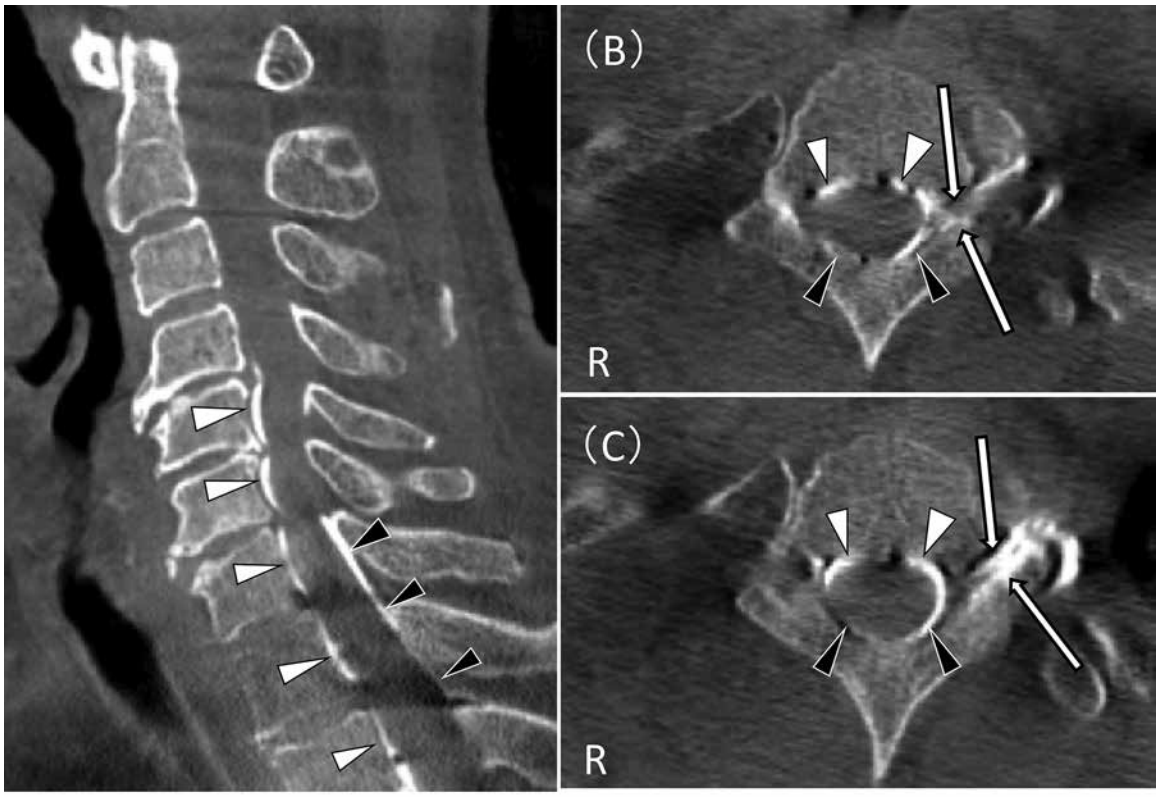

Fig. 5. *CT-epidurogram after Th1-TFEI given to a 68-year-old female with left upper limb pain associated with C5/6 disc hernia. A) Saggital view of CT-epidurogram. Ventral spread (white arrow heads) between C4 and Th2 and dorsal spread (black arrow heads) between C7 and Th2 are confirmed. B) Axial view of CT-epidurogram (a slice of Th1/2 intervertebral foramen). C) Axial view of CT-epidurogram (a slice of 2 mm caudal to B). Th1 root filling (white arrows), ventral spread (white arrowheads), dorsal spread (black arrowheads) are confirmed. No lateral limitation was present.*

NRS-11 improvement rate. There was a significant correlation between "ventral spread on injected side" and "presence of Horner's syndrome on injected side" (P = 0.014). With regard to the number of vertebral bodies spread cephalad that rated not more than 3 (below C6) or not less than 4 (above C5), there was a significant correlation between the number and "presence of Horner's syndrome" (19/31 vs. 3/28, P = 6E-05). Other CT-epidurogram findings did not show any significant associations with "presence of Horner's syndrome."

Circulatory Dynamics (Table 2)

Circulatory dynamics are shown in Table 2. Circulatory dynamics before the procedure showed no significant difference between the groups. After the procedure, all circulatory dynamics in both groups had declined significantly, and the amount of variation in these dynamics did not show any significant differences between the groups.

Adverse Effects and Complications

There were no major complications such as intraarterial injection, pneumothorax, dural puncture, and spinal cord puncture in either group. The Th1-TFEI group had 4 cases of injection at the vertebral venous plexus, which was adjusted by advancing the needle. The Th1/2 p-ILEI group had one patient who experienced transient discomfort. The frequency of these factors' appearance did not show any significant differences between the groups (intravenous injection: P = 0.06; discomfort: P = 0.49).

In the Th1/2-pILEI group, there were 4 cases that failed to detect the loss of resistance, and later retrial was necessary. The Th1-TFEI group did not need retrial.

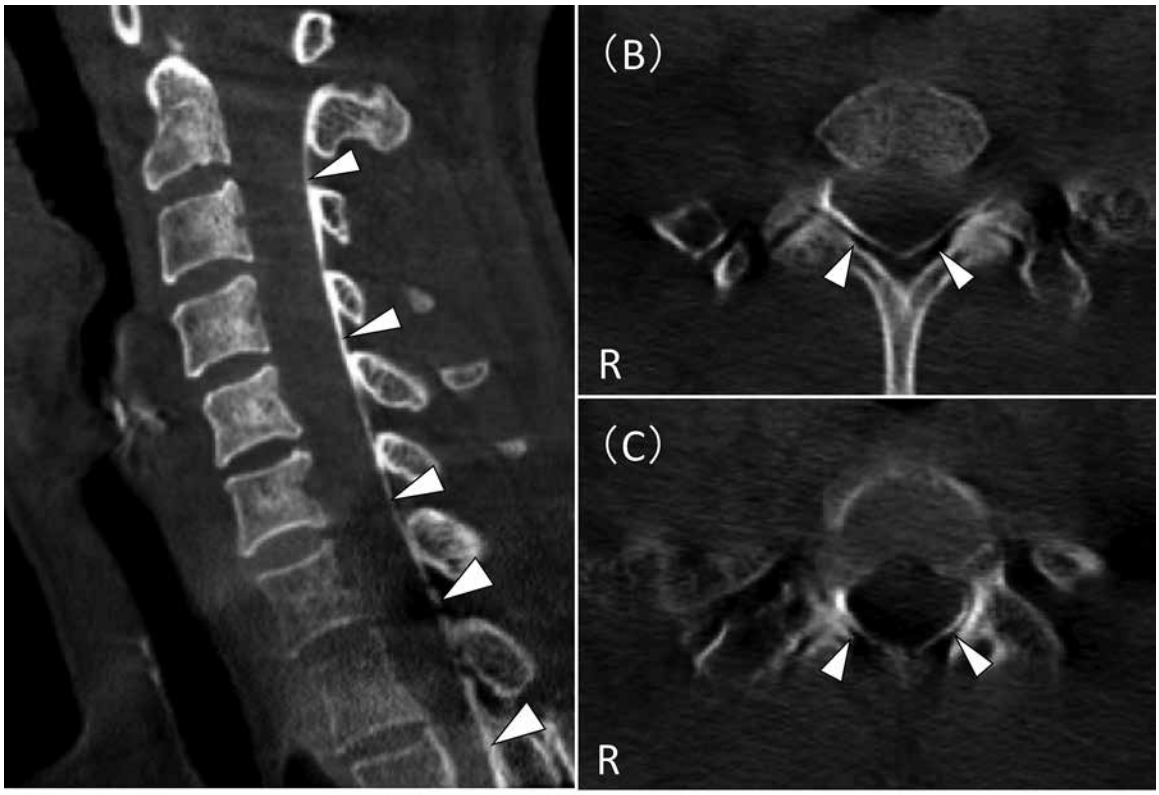

Fig. 6. *CT-epidurogram after Th1/2-pILEI given to a 54-year-old female with right upper limb pain associated with thoracic outlet syndrome. A) Saggital view of CT-epidurogram. Dorsal spread (white arrows) between C2 and Th2 is confirmed. B) Axial view of CT-epidurogram (a slice of Th1/2 intervertebral foramen). C) Axial view of CT-epidurogram (a slice of 2 mm caudal to B). Dorsal spread (white arrows) is confirmed although ventral spread is not seen. There were neither lateral limitation nor Th1 root filling.*

Discussion

CTFEI uses an anterior-lateral approach that makes the needle advance almost parallel to the radicular nerve and reach inside the intervertebral foramen (17). Th1-TFEI takes a posterior-lateral approach, and the needle is obstructed by the Th1 articular pillar inside and reaches only the exit of the Th1/2 intervertebral foramen; injectate flows into the epidural space from the needle tip that touches the Th1 nerve root. In other words, it is different from CTFEI even though the same word, "transforaminal," is used in the name. The manner of the needle's advancement is similar to that in the lumbar TFEI, which uses a posterior-lateral approach.

Although careless puncture could cause Th1 nerve root injury, the needle does not usually reach inside the spinal canal; therefore, the risks of dural puncture and spinal cord puncture are very low (8). Moreover, the lung apex is located caudal and external to the paravertebral part at the Th1 level; therefore, there is no risk of pneumothorax unless the needle direction is abruptly changed to caudal just after insertion.

Unfortunately, there is a risk of intravascular injection. At the shallow layer before the Th1 nerve root, vertebral venous plexus injection is often seen, and in this study also, 4 patients out of 30 experienced it. In such a case, advance the needle 1 to 2 mm to pass through this layer to reach the nerve root.

In case the needle reaches the Th1 nerve root layer and intravascular injection is seen, the precise differentiation between arterial injection and venous injection is critical. Although the great anterior radiculomedullary artery does not exist in the upper thoracic spine, there is a possibility of another radicular artery entering through the foramen of Th1/2 (18,19). There-

Table 2. *Change of circulatry dynamics*.

Items	Th1-TFEI group	Th1/2-pILEI group	*P* value between groups
Systolic blood pressure (mmHg)			
before injection	135 ± 18.1	136.2 ± 19.9	0.67
after injection	122 ± 19.6	120.4 ± 17	0.65
P value in the group	< 0.01 *	< 0.01 *	
The variation amount	13.1 ± 13.9	15.9 ± 10.9	0.13
Diastolic blood pressure (mmHg)			
before injection	78.9 ± 11.4	80.5 ± 11.7	0.75
after injection	72.6 ± 9.4	73.1 ± 10.9	0.68
P value in the group	< 0.01 *	0.0001 *	
The variation amount	6.3 ± 7.5	7.3 ± 8.7	0.32
Heart rate (beat/min)			
before injection	68.8 ± 9.0	69.4 ± 10.5	0.66
after injection	59.6 ± 5.9	59.9 ± 7.58	0.72
P value in the group	< 0.01 *	< 0.01 *	
The variation amount	9.1 ± 5.6	9.5 ± 8.7	0.65

Values are mean ± SD; *: statistically significant

fore, real-time fluoroscopy is essential to monitor the position of the needle and the inadvertent spread of contrast medium. It is fundamental that the steroid to inject be limited to the nonparticulate type.

When the blood vessel is punctured, there is a possibility of later formation of hematoma. In Th1-TFEI, the needle tip does not reach inside the spinal canal; therefore, hematoma is most likely to occur outside the canal. It is estimated that Th1-TFEI is less risky than ILEI, which has a possibility of hematoma inside the canal.

In this study, Th1/2-pILEI was employed for comparison with Th1-TFEI. Conventionally, ILEI uses the loss-of-resistance technique to confirm the epidural space; however, the blind technique sometimes fails (20). In ILEI, as well, fluoroscopy makes it possible to guide the needle precisely and the lateral view is useful for determining the depth of the needle tip. Detection of loss of resistance and confirmation of epidurogram are needed to reach the epidural space accurately. To standardize the injection amount, this study used 0.5 mL of saline plus 0.5 mL of contrast medium for detecting loss of resistance. This amount, however, was quite small; therefore, detection of loss of resistance failed in 4 cases out of 29 in this study. At the clinical scene, a little larger amount would be better.

Generally compared with ILEI, TFEI can administer medical solution around the nerve root, especially at the ventral portion. Therefore, TFEI has been expected to be more effective at suppressing pain (11-16). With regard to the lumbar spine, some have concluded that lumbar ILEI is better (21,22), while others have concluded that lumbar TFEI brings about more effective pain reduction (23,24). With regard to CTFEI for the cervical spine, attention was focused on the complications caused by intravascular injection; therefore, CILEI is more frequently recommended for its greater balance of clinical benefits with possible danger (6,7,25-27).

As mentioned above, Th1-TFEI uses a different posterior-lateral approach from CTFEI, and spread of injectate is unknown. We compared the injectate spread of Th1-TFEI with that of Th1/2-pILEI. Both Th1 root-filling on the injected side in Th1-TFEI and dorsal spread on the injected side in Th1/2-pILEI rated 100%, which is natural when we consider the characteristics of each technique. Compared with Th1/2-pILEI, Th1-TFEI had signifiantly larger amounts of lateral limitation, Th1 root-filling on the injected side, and ventral spread on the injected side, while dorsal spread on the noninjected side was significantly smaller.

Reportedly, cephalad spread in CILEI was varied with an average of 3.14 vertebral bodies when 2 mL was injected (28), and 3.61 to 3.88 when 2.4 mL was injected (29). In this study, 3 mL was injected and Th1/2-pILEI averaged 4.76 vertebral bodies, spreading approximately up to C4, and Th1-TFEI averaged 2.97 vertebral bodies, spreading approximately up to C6; this was a significant difference. Although the rate of injectate reaching up to the affected level did not show a significant difference, it is appropriate to designate Th1-TFEI as a therapy for the lower cervical spine level.

Although both procedures showed significant changes in circulatory dynamics, the changes were not at the level that causes clinical problems. It may have been caused by the low concentration of local anesthesia used.

In cervical and high thoracic spinal nerve block, Horner's syndrome is often seen. Sympathetic preganglionic fibers arise from the thoracic to upper lumbar segments of the spinal cord, and the highest fibers pass through the anterior root of the Th1 spinal nerve. Horner's syndrome observed in the well-known stellate ganglion block indicates relative parasympathetic dominance caused by sympathetic blockade of the stellate ganglion. Th1-TFEI had a significantly higher rate of Horner's syndrome appearance, and the presence of Horner's syndrome showed significant correlations with "ventral spread" and "spread below C6." It is estimated

that the collection of injectate at the lower cervical spine and the spread of injectate to the ventral portion of Th1 nerve root may result in the development of Horner's syndrome more frequently. Sympathetic block may improve the blood flow at the lesion site and offer treatment effects for sympathetically maintained pain (30).

In this study, we did not use steroid and assessed only the short-term clinical effects. Both procedures were performed in random order, and NRS-11 scores before and after the procedures showed significant differences in both groups; however, there were no significant differences between the groups in the NRS-11 improvement rate, and there were no significant associations, either, among the findings of the CT-epidurogram, presence of Horner's syndrome, and NRS-11 improvement. Th1-TFEI and Th1/2-pILEI showed the same short-term clinical effects.

Limitations

1. We cannot deny the influence of needle size on the spread of the solution. We routinely use a 25-gauge needle for transforaminal injections, in which we bend the needle intentionally, and we use a 22-gauge needle for epidural block, in which the needle is advanced straight. It might have been better if we had used a 22-gauge needle for Th1-TFEI in this study.
2. There is a possible bias arising because interpretation of the CT-epidurogram was not blinded.
3. This was a single hospital study and the sample size was small. Therefore, multivariate analysis was impossible.

Conclusion

Compared with Th1/2-pILEI, Th1-TFEI was localized on the injection side, had better ventral spread (although cephalad spread was limited), and had a significantly higher rate of Horner's syndrome appearance. There was a significant correlation between either "ventral spread" or "spread up to C6" and appearance of Horner's syndrome. We expected additional effects of the sympathetic blockade suggested by the Horner's syndrome as well as the merits of the ventral spread. However, short-term clinical effects were equal to those of Th1/2 pILEI. For further analysis of the clinical effectiveness, we need a prospective study in which the targeted diseases are selected, and sample size is increased.

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Author contributions: Drs. Hashizume, Fujiwara, and Kamihara had full access to all the data in the study and take responsibility for the integrity of the data and accuracy of the data analysis. Drs. Hashizume, Watanabe, and Yamagami designed the study protocol.

Drs. Hashizume, Fujiwara, and Iwasaki managed the literature searches and summaries of previous related work and wrote the first draft of the manuscript.

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