Prospective Study

Extended vs. Traditional Operating Table in C-Arm-Guided Percutaneous Balloon Compression of the Gasserian Ganglion for Trigeminal Neuralgia: A Prospective Study

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Disclaimer: This study has received ethical approval (No. K2023-07-015) from the Fujian Provincial Hospital. All patients signed written informed consent forms. All data generated or analyzed during this study are included in this article.

Conflict of interest: Each author certifies that he or she, or a member of his or her immediate family, has no commercial association (i.e., consultancies, stock ownership, equity interest, patent/licensing arrangements, etc.) that might pose a conflict of interest in connection with the submitted article.

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Background: The degree of cervical extension required during percutaneous balloon compression (PBC) of the Gasserian ganglion for trigeminal neuralgia (TN) varies among patients, but the traditional operating tables often fail to fulfil each patient's individual requirements.

Objective: This study aimed to compare the clinical efficacy of an extended operating table to that of a traditional operating table in C-arm-guided PBC of the Gasserian ganglion for TN.

Study Design: This is a consecutively prospective comparative study.

Setting: Fujian Provincial Hospital.

Methods: This study consecutively enrolled patients with TN who were scheduled for PBC of the Gasserian ganglion between February 2020 and February 2023. Some patients who underwent the procedure were placed on an extended operating table, whereas others were placed on a traditional operating table. The primary outcome was the duration of the cervical extension. The secondary outcomes included the duration of patient positioning, operation duration, C-arm radiation exposure, and pressure pain threshold of the bilateral trapezius, levator scapulae, and upper trapezius muscles, as well as the occurrence rate of postoperative complications.

Results: A total of 76 patients (mean age of 53.18 ± 2.74 years old, 44 men) were enrolled, with 38 patients using the extended operating table. The baseline characteristics between the extended and traditional operating table groups were comparable ($P > 0.05$). The duration of the cervical extension was significantly shorter in patients who used an extended operating table than in those who used a traditional operating table (58.77 ± 2.11 vs. 76.49 ± 2.16, $P < 0.001$). Patients who used an extended operating table exhibited significantly shorter positioning time (3.40 ± 0.45 vs. 10.32 ± 0.66, $P < 0.001$), operation duration (50.88 ± 2.95 vs. 76.49 ± 2.16, $P = 0.020$), and C-arm radiation exposure (8.71 ± 1.06 vs. 10.87 ± 1.26, $P < 0.001$) and significantly higher postoperative 24-hour pressure pain thresholds of the bilateral trapezius muscle (left: 274.39 ± 10.42 vs. 187.05 ± 6.19, $P < 0.001$; right: 272.89 ± 11.62 vs. 185.42 ± 6.88, $P < 0.001$), bilateral levator scapulae (left: 357.71 ± 11.37 vs. 245.34 ± 12.87, $P < 0.001$; right: 353.71 ± 14.14 vs. 245.05 ± 13.20, $P < 0.001$), and bilateral upper trapezius (left: 253.63 ± 10.91 vs. 163.95 ± 8.44, $P < 0.001$; right: 255.66 ± 11.99 vs. 165.32 ± 7.93, $P < 0.001$) compared to those who used a traditional operating table. The occurrence of postoperative adverse events, such as headache, neck pain, back pain, and limb numbness, was significantly lower in the extended operating table group (2.63% vs. 13.79%, $P = 0.047$) than in the traditional operating table group.

Limitations: This is a single-center study with a small, homogeneous sample, limiting the generalizability of findings; the absence of randomization raises concerns about potential bias; long-term follow-up and recurrence rate measurements were lacking.

Conclusion: This study found that the extended operating table may be an alternative equipment option for C-arm-guided PBC of the Gasserian ganglion for TN.

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Trigeminal neuralgia (TN), characterized by recurrent, brief, paroxysmal, and intense pain, is confined to the distribution area of the trigeminal nerve (1,2). This highly distressing condition is notorious for the diagnostic and therapeutic challenges it poses (3-5). TN is a common cranial nerve disorder seen in clinical practice, with an incidence rate of approximately 10 to 182 per 100,000 patients, a figure that increases in proportion to the patients' age (6). The prevalence of TN in the general population ranges from 0.01% to 0.3% (7), significantly impacting patients' quality of life, ability to work, and social interactions (8). Treatment modalities for TN primarily encompass medical therapy and surgical interventions (9-11). Among these modalities is percutaneous balloon compression (PBC), a minimally invasive surgical approach that is considered a safe, effective, and well-tolerated procedure with a short duration (12-16).

When C-arm-guided PBC for the trigeminal nerve Gasserian ganglion is conducted on patients reclining on traditional operating tables, those patients are required to achieve a specific degree of cervical extension to enhance oval foramen exposure (12). However, the necessary degree of cervical extension varies from patient to patient. Although simple cervical pillows have been employed (17), they often fall short of fulfilling the personal cervical extension requirements of diverse patients. Existing research suggests that using the extension brackets of operating tables to stabilize the trunks and heads of patients undergoing C-arm-guided procedures significantly enhances the beds' stability and safety while reducing the frequency of C-arm exposures to some extent (18). However, research in this area remains limited. This innovation caters to patients' individual requirements, facilitating the identification of the ideal puncture angle for the oval foramen during the procedure and enhancing the visibility of the surgical site under fluoroscopy. Extension brackets are easy to assemble on existing operating tables and affordable for both major hospitals and small local ones. With this device, a new improvement to PBC may be on the horizon.

This study aimed to investigate the clinical efficacy of a novel extended operating table as compared to a traditional operating table during C-arm-guided PBC of the Gasserian ganglion for TN.

Methods

Study Design and Patients

This study was a prospective comparative study that enrolled patients who had TN and were scheduled for PBC of the Gasserian ganglion at Fujian Provincial Hospital between February 2020 and February 2023. Inclusion criteria were: 1) being between 50 and 80 years of age; 2) having been diagnosed with primary or secondary TN; 3) possessing adequate communication skills and normal cognitive function; 4) having complete intraoperative and postoperative data; 5) having signed informed consent forms. Exclusion criteria consisted of the following: 1) preoperative symptoms such as headache, neck pain, back pain, limb numbness; 2) severe organ dysfunction in the heart, liver, lungs, kidneys, or other vital organs; 3) drug dependency or mental disorders. This study received ethical approval (No. K2023-07-015) from the Fujian Provincial Hospital, and all patients signed written informed consent forms.

Procedures

In our institution, a novel operating table extension bracket has been devised (patent number: ZL202121695247.1) based on clinical practice, enabling one-touch adjustment of the cervical extension angle (Fig. 1A). The main difference between the extended and traditional operating tables is shown in Fig. 1B.

Traditional operating table: A large surgical drape was placed horizontally on the traditional operating table. The patient lay supine on the table, with a soft pillow approximately 5 cm thick positioned under the scapulae. The patient's head was gently tilted backward, and a circular pillow with a diameter of about 7.5 cm was placed under the neck to prevent neck suspension. A head ring was positioned under the head, which was secured with the surgical drape. Both arms were fixed by side guards alongside the patient's body, and soft pillows were placed at the knee joints. The patient's legs were secured with leg straps. The imaging position of the patients who underwent the procedure

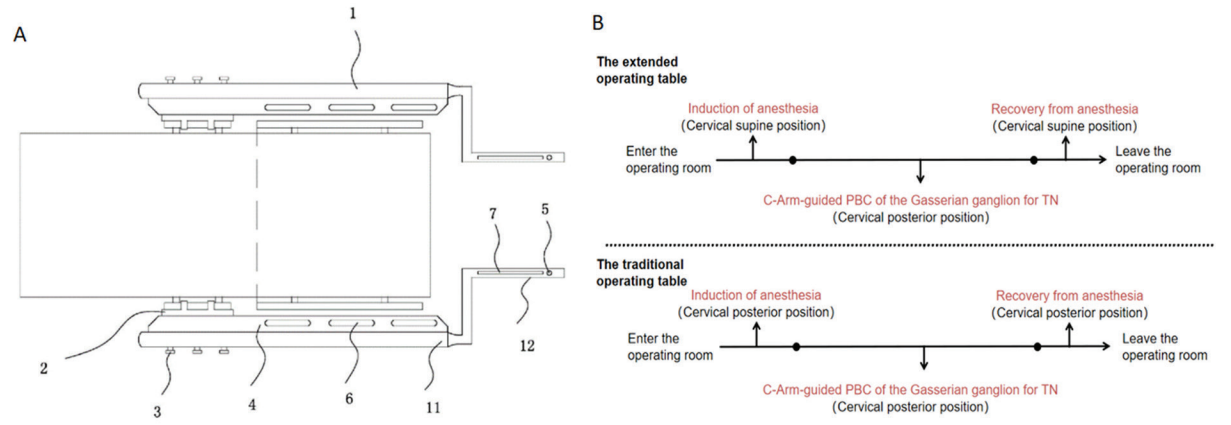

Fig. 1. *Patent for utility model. A) A novel extended operating table comprising extension components located on one or both sides of the operating table. These extension components consist of side rails, side insertion plates, securing bolts, and reinforcing plates. The side rails comprise 2 integrally connected parts, with the second part exhibiting an L-shaped configuration. The reinforcing plate is positioned on one lateral side of the first part. The side insertion plate is embedded into the tracks provided by the operating table itself. The first part is connected to the side insertion plate and the tracks of the operating table itself using securing bolts. The upper surface of the second part features mounting holes for secure attachment. B) The main difference between the extended and traditional operating tables.*

and balloon placement on the traditional table appears in Fig. 2A-F.

Extended operating table: In this approach, the patient began in a supine position on the extended operating table. The operating table's angle of cervical extension was adjusted as needed to meet the surgical requirements. The imaging position of the patients who underwent the procedure and balloon placement on the extended operating table appears in Fig. 3A-H.

Outcomes

The primary outcome was the duration of cervical extension. The secondary outcome measures included the duration of patient positioning for surgery, thee total surgical time, the number of C-arm exposures, the pressure pain threshold of the bilateral trapezius, levator scapulae, and upper trapezius muscles, and the occurrence rate of postoperative complications.

Upon admission, patient data, including age, gender, the side affected by TN, the duration of the surgery for TN, and the subtypes of TN (V1/V1-2/V2-3) were collected. Intraoperatively, the duration of cervical extension, duration of patient positioning for surgery, total surgical time, and number of C-arm exposures were documented. The pressure pain thresholds of the bilateral trapezius, levator scapulae, and upper trapezius muscles were measured using a handheld electronic pressure algometer (Medoc Ltd.) both before surgery and 24 hours afterward (19). Additionally, the occurrence of postoperative headache, neck pain, back pain, and limb numbness was recorded at 24 hours after the procedure.

Statistical Analysis

Statistical analysis was conducted using IBM® SPSS® Statistics 24.0 (IBM Corporation). Continuous data following a normal distribution were reported as means ± standard deviations and analyzed using Student's t-test. Data that did not follow a normal distribution were presented as medians (interquartile range, IQR) and analyzed using the Wilcoxon rank-sum test. Categorical data were expressed as n (%) and analyzed using the chi-square test or Fisher's exact test. A two-tailed *P*-value of < 0.05 was considered statistically significant.

Results

A total of 92 patients with TN who were scheduled for PBC of the Gasserian ganglion were initially recruited for this study. Of these patients, 4 were not involved with the research team, one patient didn't undergo assessment, 5 patients presented with preoperative symptoms such as headache, neck pain, back pain, and limb numbness, 3 patients had severe organ dysfunctions in the heart, liver, lung, or kidney, and one

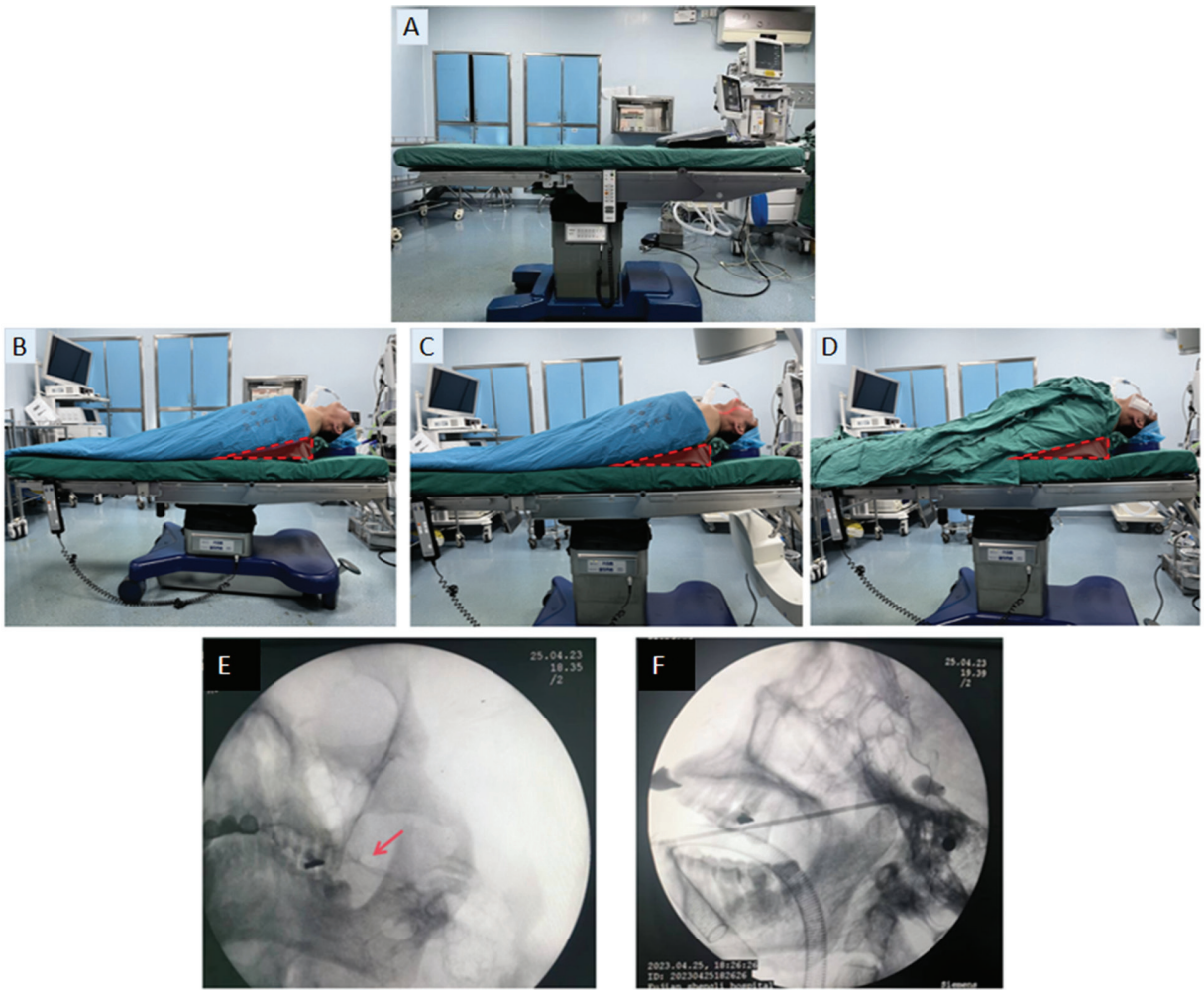

Fig. 2. *The imaging position of the patients who underwent the procedure and balloon placement on the traditional operating table. A) A traditional operating table, with the illustration of a cervical supine position pad in use; B) Position assumed by the patient until anesthesia is complete on the traditional operating table; C) Cervical posterior position at the start of PBC surgery on the traditional operating table; D) Cervical supine position maintained during anesthesia recovery on the traditional operating table; E) C-arm-guided position of foramen ovale; F) PBC morphology.*

patient had a history of drug dependency and a mental disorder. Ultimately, a total of 76 patients (53.18 ± 2.74 years old, 44 men) were enrolled in this study, 38 of whom utilized the extended operating table (Fig. 4). There were no significant differences in age, gender ratio, affected side, duration of TN, or TN subtypes between the extended and the traditional operating table groups ($P > 0.05$, Table 1). Patients who used the extended operating table exhibited significantly shorter durations of cervical extension (58.77 ± 2.11 vs. 76.49 ± 2.16, $P < 0.001$), positioning (3.40 ± 0.45 vs. 10.32 ± 0.66, $P < 0.001$), operation (50.88 ± 2.95 vs. 76.49 ± 2.16, $P = 0.020$), and C-arm radiation exposure (8.71 ± 1.06 vs. 10.87 ± 1.26, $P < 0.001$) (Table 2) as well as significantly higher 24-hour postoperative pressure pain thresholds of the bilateral trapezius muscle (left: 274.39 ± 10.42 vs. 187.05 ± 6.19, $P < 0.001$; right: 272.89 ± 11.62 vs. 185.42 ± 6.88, $P < 0.001$), bilateral levator scapulae (left: 357.71 ± 11.37 vs. 245.34 ± 12.87, $P < 0.001$; right: 353.71 ± 14.14 vs. 245.05 ± 13.20, $P < 0.001$), and bilateral upper trapezius (left: 253.63 ± 10.91 vs. 163.95 ± 8.44, $P < 0.001$; right: 255.66 ±1 1.99 vs. 165.32 ± 7.93, $P < 0.001$)

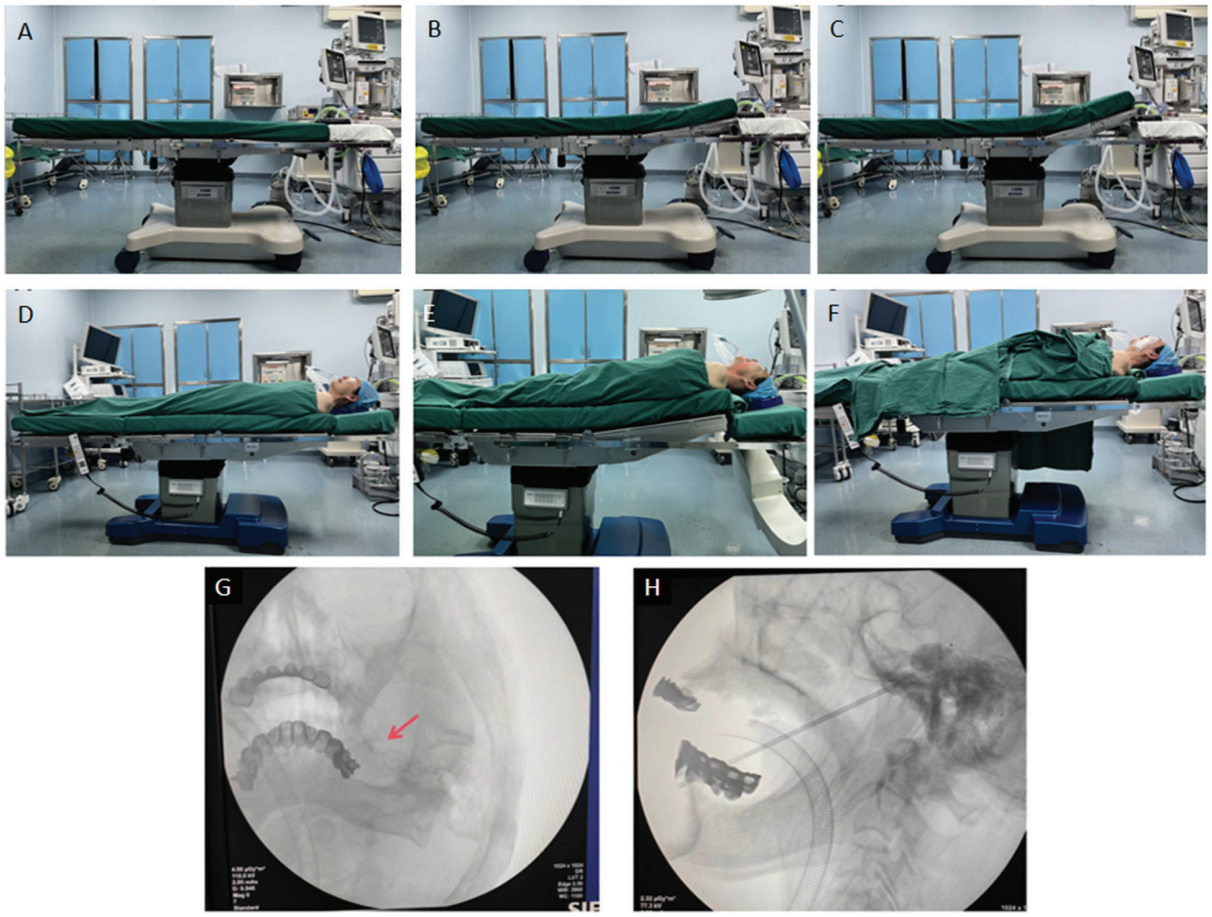

Fig. 3. *The imaging position of the patients who underwent the procedure and balloon placement on the extended operating table. A) The extended operating table, obviating the necessity for the cervical supine position pad; B) Depicts the extended operating table, wherein the operating table's inclination is adjusted to achieve a 5° angle in a supine position; C) The extended operating table, on which the operating table's inclination is adjusted to achieve a 15° angle in a supine position; D) The position assumed by the patient until anesthesia is complete on the extended operating table; E) Cervical posterior position, in which PBC surgery is begun on the extended operating table; F) Cervical supine position, in which anesthesia recovery occurs on the extended operating table; G) C-arm-guided position of foramen ovale; H) PBC morphology.*

than did those who used the traditional operating table (Table 3). The occurrence of postoperative adverse events, such as headache, neck pain, back pain, and limb numbness, was significantly lower in the extended operating table group (2.63% vs. 13.79%, $P = 0.047$) than in the traditional operating table group (Table 4).

Discussion

This study showed that the extended operating table significantly reduced the patients' cervical extension time, positioning duration, and number of C-arm exposures and complications. The extended operating table was also associated with improvements in the patients' pressure pain thresholds. For these reasons, the extension bracket may be a new alternative to PBC for TN patients.

As one of the most widely used therapeutic modalities for TN, PBC achieves its therapeutic goals primarily by mechanically damaging the pain sensory fibers within the trigeminal ganglion (20,21). The central, most challenging aspect of PBC surgery lies in accurately puncturing the foramen ovale at the appropriate angle and depth, entering Meckel's cave to effectively compress the Gasserian ganglion with the balloon (22-25).

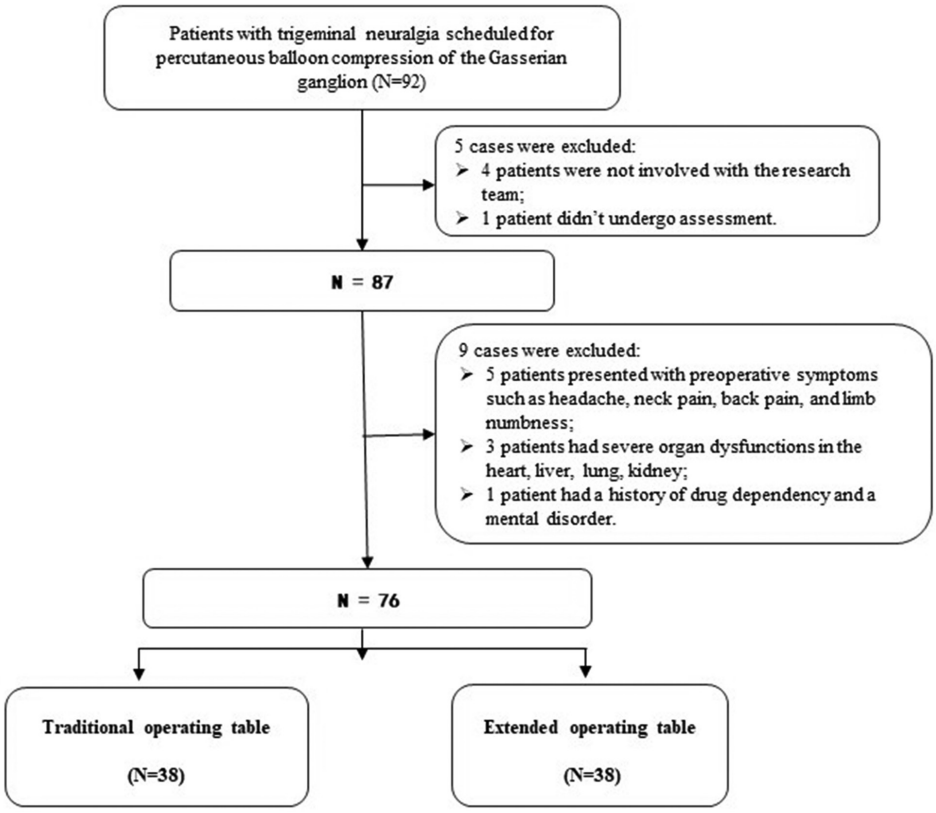

Fig. 4. *Flowchart of patients.*

Table 1. *Basic characteristics.*

Variables	Extended Operating Table (n = 38)	Traditional Operating Table (n = 38)	*P*
Gender (Male/ Female)	24/14	20/18	0.353
Age (Years)	53.68 ± 2.74	52.68 ± 2.67	0.112
Side (Left/Right)	17/21	19/19	0.646
Onset Time of Trigeminal Neuralgia (Months)	17.95 ± 2.87	16.97 ± 2.38	0.168
Subtype of Trigeminal Neuralgia (V1/ V1-2/V2-3)	0/2/36	1/2/35	0.602

Table 2. *Outcomes.*

Groups	Extended Operating Table (n = 38)	Traditional Operating Table (n = 38)	*P*
Duration of Cervical Extension (minutes)	58.77 ± 2.11	76.49 ± 2.16	< 0.001
Duration of Positioning (minutes)	3.40 ± 0.45	10.32 ± 0.66	< 0.001
Operation Duration (minutes)	50.88 ± 2.95	63.95 ± 4.65	0.02
C-arm Radiation Exposure	8.71 ± 1.06	10.87 ± 1.26	< 0.001

This process necessitates maintaining the patient's cervical extension angle and securing their head properly (26), thus avoiding superimposition of the left and right cranial bones in the C-arm images to accurately assess the needle insertion site and depth. However, cervical hyperextension will lead to some adverse effects, causing a decrease in cerebral oxygenation during the operation (27). In extreme cases, cervical hyperextension

may even cause issues like cervical cord contusion (28) and cervical cord neurapraxia (29). Although severe injuries are uncommon, the prolonged maintenance of cervical extension during surgery can lead to pain in the neck, shoulders, and back and numbness in the limbs. The extended operating table effectively lowers the duration of cervical extension maintenance and total surgery time, which subsequently reduces the occurrence of complications.

X-rays from C-arm fluoroscopy produce free radicals that can cause cell death or destroy the DNA structure directly (30), and the cumulative effect of low doses may increase this risk (31,32), so the reduction of radiation exposure is always a major goal when the C-arm is used (33). The results of this study indicated that the use of the extended operating table significantly reduced intraoperative C-arm exposures, thus minimizing radiation exposure and reducing the risks thereof to both the patients and health care personnel.

The extended operating table designed in this study offers the following advantages. Firstly, the table design significantly reduces the time needed for patient positioning while shortening the overall surgery duration and ensuring precise irradiation of the surgical site, which helps simplify utilization and reduce workload. Surgeons are required only to install the extended operating table and place the patient in a supine position on the operating table. Secondly, the extended operating table helps with the effective adjustment of cervical hyperextension and allows for a one-touch adjustment of the cervical hyperextension angle, catering to individual patients' specific demands and enhancing exposure of the foramen magnum. This arrangement facilitates the surgeons' manipulations. Thirdly, the extended operating table is suitable for patients of various body types and ages, and its utility extends beyond PBC of the Gasserian ganglion for TN. The table design is also equally applicable to various minimally invasive procedures involving the craniofacial and cervical regions, such as thyroid surgery and a range of minimally invasive cervical spine surgeries. Finally, the extended operating table has received unanimous acclaim from health care professionals and patients alike, making it worthy of clinical adoption.

However, this study is not without limitations. Firstly, this is a single-center study with a small homogeneous sample, limiting the generalizability of the findings. Secondly, the absence of randomization raises concerns about potential bias. Thirdly, long-term follow-up and recurrence rate measurements were lacking. Further randomized trials with larger samples and extended follow-up times will be needed to validate these findings.

Conclusion

In conclusion, this study revealed that the extended operating table could serve as a viable alternative equipment option for C-arm-guided PBC of the Gasserian ganglion in TN treatment. This possibility opens avenues for refining and personalizing treatment approaches and may contribute to advancements in the field of neurosurgical procedures for treating TN.

Author Contributions

Yunyou Feng and Ri Chen carried out the stud-

Table 4. *Complications*.

Complications	Extended Operating Table (n = 38)	Traditional Operating Table (n = 38)	*P*
Overall, n (%)	1 (2.63%)	6 (13.79%)	0.047
Headache	1	2	-
Neck Pain	0	2	-
Back Pain	0	1	-
Limb Numbness	0	1	-

Table 3. *Comparison of pressure pain thresholds in the bilateral trapezius, levator scapulae, and upper trapezius muscles.*

Groups		Extended Operating Table (n = 38)		Traditional Operating Table (n = 38)			
		Preoperative	Postoperative	Preoperative	Postoperative	P1	P2
Trapezius Muscle	Left (kPa)	276.86 ± 10.22	274.39 ± 10.42	274.44 ± 13.04	187.05 ± 6.19	0.061	< 0.001
	Right (kPa)	277.36 ± 9.33	274.74 ± 11.00	274.57 ± 9.41	185.42 ± 6.88	0.067	< 0.001
Levator Scapulae Muscle	Left (kPa)	362.73 ± 16.28	357.71 ± 11.37	358.81 ± 13.59	245.34 ± 12.87	0.206	< 0.001
	Right (kPa)	358.02 ± 13.79	353.71 ± 214.14	357.63 ± 13.72	245.05 ± 13.20	0.757	< 0.001
Upper Trapezius Muscle	Left (kPa)	255.73 ± 12.73	253.63 ± 10.91	255.65 ± 12.10	163.95 ± 8.44	0.723	< 0.001
	Right (kPa)	260.42 ± 13.50	255.66 ± 11.99	259.89 ± 11.64	165.32 ± 7.93	0.762	< 0.001

P1: Preoperative comparison between the 2 groups; P2: postoperative comparison between the 2 groups.

ies, participated in collecting data, and drafted the manuscript. Huake Zeng and Meirong Chen performed the statistical analysis and participated in its design. Ruohan You and Xiu Jiang and Xueru Xu participated in acquisition, analysis, or interpretation of data and draft the manuscript. All authors read and approved the final manuscript.

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