

## Review Article

## Percutaneous Minimally Invasive Treatment for the Trigeminal Neuralgia: A Review

Xiang-Fei Guo, and Jun Ma

## ABSTRACT

**Aim of review:** The objective of this review is to evaluate the effect of percutaneous minimally invasive treatment for the trigeminal neuralgia (TN).

**Method:** We systematically searched for clinical studies on the TN. We searched the MEDLINE (PubMed) and EMBASE database, using the free text terms: minimally invasive treatment, TN and combination of these. Date of last electronic search was 30 December 2012.

**Recent findings:** From the available evidence, we can concluded that: 1) Percutaneous glycerol gangliolysis is very effective and applicable to a wide variety of patients with TN. The presence of cerebrospinal fluid (CSF) outflow during puncture predicts better immediate and long-term outcomes; 2) It may be quite obvious that the high-speed real-time CT fluoroscopic method enables better imaging compared to X-ray fluoroscopy; 3) Computed tomography (CT) images are by far superior, when combined with neuronavigation, which allows trajectory visualization in three dimensions and multiple planes at the surgeon's choosing, and use of real-time annulations. Three dimensional (3D)-CT and electrophysiology Gasser's ganglion locations can raise the success rate of puncture, enhance the safety and reduce the incidence of complication, showing high academic value and its promising future; 4) Balloon Compression causes only a mild sensory loss with immediate pain relief in practically all patients; 5) Ultrasound-guided technique for the blockade of trigeminal nerve peripheral branches is very rational.

**Summary:** For both treatment methods, the fused CT and magnetic resonance imaging (MRI) scans are used for improved treatment planning in the treatment for the TN. While the MRI scans provides better details on the anatomical situation, CT scans are required for dissymmetric assessment. In the future, other imaging methods like spectroscopy and evoked-potential imaging will become available to better shape the target volume and spare critical normal tissue structures.

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**T**rigeminal neuralgia (TN) is a well-recognized neuropathic pain syndrome characterized by brief paroxysms of facial pain in the distribution of the trigeminal nerve. The syndrome can occur secondary to a number of medical conditions including multiple sclerosis, basilar artery aneurysm, and brain tumor (1). The disorder can also be idiopathic, the latter instance being known as tic douloureux. TN can strike persons of any age but typically affects older individuals. Treatment options include a number of neuropathic pain medications as well as neurosurgical and radio surgical interventions. The mainstay of treatment for most individuals, however, remains medication.

TN is characterized by recurrent facial pain in the distribution of the trigeminal nerve. The trigeminal nerve is divided into three branches, V1, V2, and V3, providing sensory innervations to the forehead, cheek, and chin respectively. The pain of TN most frequently occurs in the distribution of V2 or V3. The pain is usually laminating in nature, occurring as fleeting shocks. This pain can be extremely intense, producing a great deal of distress in sufferers. The pain is typically triggered by chewing, ingesting cold foods or liquids, cold winds, or simple tactile stimulation on the face (2). At the present time, pharmacotherapy remains the mainstay of treatment of TN. It is recommended to begin with only one medical substance as a monotherapy. In a second step, a combination of two or more substances is indicated in case of treatment failure or insufficient response. The dose is slowly reduced after 4-6 weeks of pain reduction to assess any clinical remission. All invasive procedures--percutaneous procedures, including injection, radiofrequency thermocoagulation, and balloon compression of the gasserian ganglion, and neurosurgery or radiotherapy--are only indicated in case of insufficient pharmacological pain relief or in cases of symptomatic TN. The objective of this review is to evaluate the effect of percutaneous minimally invasive treatment for the TN.

### Methods of Percutaneous Minimally Invasive Treatment for the Trigeminal Neuralgia

#### Percutaneous Glycerol Gangliolysis

For this procedure, a needle is inserted into the

trigeminal cistern through the foramen ovale using similar trajectories as in radiofrequency lesioning and balloon compression. Under fluoroscopic control, sterile anhydrous glycerol is injected in the trigeminal cistern. Pain relief is usually immediate, but it may take up to 7 days or more to occur in some patients (3). The procedure results in an initial pain relief in over 80% of patients. Long-term results are highly variable. At 12 months, reported recurrence rates vary from 10% to 53%. However, at 5 years, 34-83% of the patients will have experienced recurrence of neuralgia (4).

This non-invasive method is generally well tolerated, and mortality is negligible. There are anecdotal reports of meningitis, cranial nerve palsies and local haematomas. Activation of herpes labialis occurs in one third, and permanent masseter weakness is seen only in a very small proportion of patients (4). Postoperative sensory loss was directly correlated with a good long-term outcome (5). Keratitis related to corneal sensory loss is very rare.

Percutaneous glycerol injection into Meckel's cavity is widely used to treat TN. Reports published to date summarized clinical experiences in small or intermediately sized groups of patients. The efficacy of this procedure in a large group of patients has not been evaluated so far. From December 1983 to November 2008, patients with primary TN (PTN) were treated in clinic using percutaneous glycerol injection into Meckler's cavity which was conducted according to the Hokinson's anterior puncture method with some modifications. In total, 4,012 patients (2,205 female) with a mean age of 56.5 (23-87) years were treated. The majority of patients (99.23%) experienced unilateral pain, while a small cohort of patients (0.77%) had bilateral pain. The immediate success rate of the procedure was 97.1%. There was a significant positive correlation between the presence of cerebrospinal fluid (CSF) outflow and the curative effect. Follow-up was done in 3,157 patients for the period of 1-25 years. The long-term success rate was 81.18%. No serious adverse effects were observed. The procedure is very effective and applicable to a wide variety of patients with TN. The presence of CSF outflow during puncture predicts better immediate and long-term

outcomes (6).

### Other Peripherally Targeted Procedures

Other methods of producing controlled peripheral neural trauma include radiofrequency lesions, cryotherapy and injections using alcohol, glycerol, phenol, high concentration of tetracaine or a mixture of lignocaine and streptomycin. In all, the average reported pain relief is measured in months, and many of these methods are associated with a high number of initial failures (6). A stereotactic frame is fixed to the patient's head. Magnetic resonance imaging (MRI) is used to identify the trigeminal nerve. Radiosurgery is then carried out with the patient supine and the head attached under the specific collimator helmet. The different beams of the collimator helmet can be blocked to shape the individual treatment target volume. In linac radiosurgery, radiation is delivered by means of a linear accelerator, and the beam is collimated with individually adapted a 4-5 mm collimator. The treatment target volume can be approached by several fixed beams in a non-coplanar setting or the linear accelerator head is moved around its isocenter in several spherical arcs. Similar to the gamma knife approach, the patient's head is also fixed in a stereotactic frame for better targeting which is attached under local anesthesia.

### Radiofrequency Gangliolysis (Thermocoagulation of the Gasserian Ganglion)

This minimally invasive procedure was first explored by Kirchner, whose large clinical series was published in 1942. Essentially, it involves a selective partial lesioning of the affected ganglion or retrogasserian root (7). The radiofrequency needle is inserted through the foramen ovale into Meckel's cave using bony landmarks. Thermal lesioning is performed in cycles of 45 to 90 seconds at temperatures of 60-90°C. Immediate pain relief in typical TN is high (>90%). Fortunately, severe complications (like cerebral haemorrhage, carotid-cavernous fistula, meningitis and cranial nerve lesions) are very rare. Dysaesthesia can occur in up to 25%, but is mostly of mild intensity. Dysaesthesia requiring medical treatment is seen in approximately 8% of all cases. Unfortunately, the quality of life in these pa-

tients is not improved even if the original pain has been controlled. There is some indication that this adverse effect is more common in patients with atypical TN. However, frank anaesthesia dolorosa is a rare situation (<1%). Corneal anaesthesia is a potentially serious complication as it may lead to keratitis in 1-2% of cases. Other rare complications include meningitis, carotid-cavernous fistula, intracranial haemorrhage and cranial nerve deficits. A systematic review of ablative neurosurgical techniques for the treatment of TN evaluated 166 studies reporting radiofrequency thermocoagulation, glycerol rhizolysis, balloon compression of the gasserian ganglion, and stereotactic radiosurgery, concluded that radiofrequency RF thermocoagulation offers the highest rates of complete pain relief (8). Pulsed radiofrequency (PRF) treatment, as a less neurodestructive modality, soon became more attractive due to the possibilities of fewer complications. Case reports have generated mixed results (9). A randomized controlled trial (RCT) by Erdine et al. (10) compared the efficacy of conventional radiofrequency treatment with PRF treatment of the trigeminal ganglion for patients suffering from idiopathic TN. Their results demonstrated significant pain reductions in all the patients treated with conventional radiofrequency, while only 2 of 20 patients in the PRF group experienced this level of pain relief. Radiofrequency thermocoagulation rhizolysis (RTR) is very effective and therefore is often ethically difficult to withhold this treatment from this patient. However many patients with pain are desperate and will say initially that they understand and agree to the potential side effects in exchange for relief of pain. This frequently becomes a difficult challenge, especially when faced with a procedure we believe in, perform regularly and are studying. With RTR being a selective neuroablative procedure, it can be performed in a differentially graded fashion. This can give pain relief without the more troublesome side effects. Pain recurrence after a successful RTR may not be related to the technique of the procedure but is more likely to the property of the disease process. Once a successful thermal lesion is made, the long term anatomic, histologic, and neurophysiologic outcomes that occur are not known. This most likely has some clini-

cal relevance to long term pain relief and recurrence rates, along with possibly altering the pathophysiologic process that is responsible for producing TN (11).

### Balloon Compression

This procedure is always performed under general anaesthesia. Using fluoroscopic control, a guide needle is inserted into the foramen ovale. Through the needle, the Fogarty catheter is advanced until its tip lies in the Meckel's cave, and the balloon is slowly inflated. Total compression time varies from 1-6 minutes. This produces only a mild sensory loss with immediate pain relief in practically all patients. Masseter weakness is very common, although, in most cases, there is complete recovery in a few weeks (12). Recurrence is reported in 6-14% in the first year. Long-term recurrence of pain occurs in 20-33% after 5 years (13). Troublesome dysesthesia following the procedure is reported in all series in a frequency between 1.5-15% (12).

### Fluoroscopic Image-Guidance for Trigeminal Neuralgia

Percutaneous radiofrequency thermocoagulation is a safe and effective means for treatment of TN. It seems that a repeat percutaneous radiofrequency thermocoagulation does not pose a significant problem because the procedure is easily repeated with minimal risk. With the aid of fluoroscopic image-guided cannulation of the foramen ovale, it can minimize a complication related to procedure (14).

The field of neurosurgery has a rich history of technological innovations, of which percutaneous stereotactic rhizotomy for TN claims a unique longevity. In fact, there have been only two major modifications to technique since its original description by Kirschner (15). The first and most substantial advance was made in 1969 when White and Sweet (16) refined the procedure with the use of a short-acting anesthetic agent, electrical stimulation, a reliable radiofrequency current for lesion production, and temperature monitoring of tip of the electrode. The next innovation made by the Tew, van Loveren, and Keller group included both the introduction of the Tew curved-tip electrode (17) and the modification of the technique for cannulation of

the foramen ovale using image-guided fluoroscopy. Common to the techniques is a skin marker over the ipsilateral zygoma that approximates the lateral projection of the foramen ovale onto the skin. Tew and Keller place this "zygomatic point" 3 cm anterior to the external auditory meatus, Nugent and Berry at a point 2.5 cm anterior to the auditory canal, and Robit at two-thirds of the distance between the lateral canthus and the external auditory meatus. However, Gerber (18) pointed out some limitations inherent in all approaches. Even with ideal positioning of the patient's head, it could be difficult to clearly visualize the foramen ovale. He explained this difficulty for osteoporosis involving a target structure, increased calcification of the skull or dura, and technical difference in imaging equipment. To facilitate radiological visualization of the foramen ovale, he studied the basilar aspects of dried skull and proposed technique of improved fluoroscopic identification of the foramen ovale. After taping of a metal ring (5 mm in diameter) over each zygomatic point (2.5 cm anterior to the external meatus), the head is rotated 20° away from the ipsilateral side, with the axis of fluoroscopy tilted at an angle 55° caudal to the orbitomeatal line. With this 55° caudo-cephalic tilting of fluoroscopy and 20° head rotation, the foramen ovale is just lateral to a line through that lateral wall of the orbit. With this technique of fluoroscopic image-guided cannulation, it did not experience any difficulty during puncture of foramen ovale and could minimize the risk of inadvertent puncture of adjacent structures around the foramen ovale. While current authors are adopting the fluoroscopic image-guided cannulation to overcome the problem of conventional technique of puncturing the foramen ovale, others have tried to develop new techniques of cannulation using frame-based stereotactic method, frameless stereotactic cannulation with real-time computed tomography (CT) scans (19).

### CT Fluoroscopy for Trigeminal Neuralgia

Gasserian ganglion block is an established treatment for idiopathic TN. The gasserian ganglion is located on the floor of the middle cranial fossa, which is surrounded by cranial nerves. For this reason, many textbooks and review articles

recommend the use of X-ray fluorography or sequential film radiography when advancing the nerve block needle into the foramen ovale. Needle malposition can result in serious neurologic complications. The precise location of the foramen ovale, however, is difficult to find using uniplanar fluoroscopy. In some patients, the foramen cannot be clearly visualized by fluoroscopy or X-ray radiography because of atypical skeletal configurations (20). Hakanson (21) reported that the first attempt to puncture and visualize the trigeminal cistern radiographically was unsuccessful in 15% of patients. In contrast, however, the configuration of bones and soft tissue can be clearly visualized by CT imaging. Recent advances in CT technology have enabled physicians to manipulate a needle under CT guidance quickly and accurately in a real-time manner (CT fluoroscopy) (22, 23). Imaging-guided techniques with CT fluoroscopy may increase the efficacy and safety of several types of nerve block, especially trigeminal nerve block (24). Several recent reports describe the use of CT imaging for needle guidance when visualization of the foramen ovale in the anteroposterior view is difficult using classical X-ray fluoroscopy (20). More recently, Gusmao et al. (24) reported CT guided gasserian thermogangliolysis in which the axial view was obtained intermittently to confirm the location of the needle tip. The amount of radiation energy exposure might be a concern in CT guiding procedures. Gusmao et al., however, reported that the amounts of the radiation energy exposure to the patient and staff are smaller with the CT guiding technique than with the conventional X-ray fluoroscopic guiding technique for percutaneous trigeminal nerve radiofrequency rhizotomy because CT guiding allows the physicians to advance the needle quickly and accurately. Teeuwisse et al. (25) reported that the amount of radiation in CT fluoroscopy was acceptable. The CT equipment used in the case radiated 0.176 mGy/second (10 mA, 120 kV, per 3-mm section) in the gantry area, and this radiation energy was much lower than that produced in normal CT scanning for cranial examination. Decreasing the insertion time can further reduce exposure to radiation energy. Theoretically, it will be important to compare the efficacy of the

CT fluoroscopic method with the classical X-ray fluoroscopic method for this procedure in a double blind prospective manner. However, it is very difficult to perform this type of study in a double-blind manner. In addition, it may be quite obvious that the high-speed real time CT fluoroscopic method enables better imaging compared to X-ray fluoroscopy.

The ideal surgical treatment for PTN in elderly patients would be minimally invasive; it would also immediately and completely relieve the painful attacks, lack complications, have minimal side effects, have no failures or recurrences, eliminate the need for medication, significantly improve quality of life (QOL), and be widely available and cost-effective (8). The CT-guided radiofrequency thermocoagulation for PTN (RTPTN) procedure fulfilled many of these conditions. Although RTPTN may damage the trigeminal nucleus, minor loss of function is acceptable to most patients if their chronic pain is relieved. Moreover, RTPTN is highly selective for trigeminal ganglion damage, leading to a low complication rate. CT guidance ensures accurate puncture of the trigeminal ganglion, thereby improving therapeutic efficacy and reducing injury to surrounding tissues (26). With CT-guided methods, there is precise localization of the target and precise identification of the lesion within the pathological division, and the configuration of bones and soft tissues is clearly visualized in real time. The foramen ovale is deep, and anatomical variations are large, so the key step for successful treatment is the location of the foramen ovale and semilunar ganglion. It is possible to pierce the optic nerve or other cranial nerves if the wrong track is taken between the surface and the foramen ovale. In another direction, the extracranial internal carotid artery, jugular foramen, or other cranial nerves can be damaged. If the radiofrequency electrode descends beyond the foramen ovale or it is too close to the inside, it can damage the internal carotid artery, the cavernous sinus, and the lateral wall of the cranial nerves. Although the incidence of such complications is low, they are a source of concern. Therefore, during the radiofrequency operation, it is vital that the needle accurately reaches the semilunar ganglion. The thermocoagulation time and temperature con-

trol are the other key factors for ensuring effective pain relief and mitigating postoperative recurrence. With CT-guided RTPTN, a frontal slice of the foramen ovale is visualized, and an insulated nerve block needle is guided by CT fluoroscopy. By means of these correction measurements, it is possible to establish both the differences due to anatomical variation and the exact target in relation to the direct image.

TN is a condition of intense chronic pain that can lead to secondary psychological and physical problems, and CT-guided RTPTN is the least invasive option available at present. RTPTN is less likely than microvascular decompression (MVD) to cause death, stroke, facial weakness, or hearing loss. It is a viable option for patients who are not good surgical candidates or who refuse open brain surgery. There is little effect on the cardiopulmonary circulation; and verbal communication with a conscious patient can help pinpoint the target. In addition, by using low-intensity radiofrequencies, sensory and motor potentials allow even more precise target identification. Although TN is not fatal, the reduced QOL justifies at least minimally invasive treatment. Fortunately, percutaneous procedures are available that are associated with only minimal sensory damage and mortality (27). The major complications reported in the literature—blindness (28), cerebrospinal fistula, carotid-cavernous fistula, permanent cranial nerve deficits (29) did not occur; and no severe disabilities were noted during follow-up after the CT-guided procedure.

It is also more selective than gasserian ganglion and retrogasserian rootlet percutaneous balloon compression, which cannot produce isolated division anesthesia. CT-guided RTPTN can also be used in cases of recurrence after other procedures (30) for both younger and older patients. The low invasiveness of the procedure allows RTPTN to be discontinued at any time and reapplied upon pain recurrence. The procedure is associated with few lasting side effects, and the shorter duration of the procedure and noninvasiveness result in shorter hospital stays. To conclude, in conjunction with careful patient selection and meticulous attention to detail, CT-guided RTPTN holds great potential for the treatment of refractory TN in elderly pa-

tients (31).

### CT with Integrated Neuronavigation for Trigeminal Neuralgia

Neuronavigation guided cannulation of the foramen ovale can be executed both quickly and safely on an outpatient basis. Additionally, the use of CT with integrated neuronavigation technology provides superior visual-spatial information compared to conventional fluoroscopy, the process of CT scanning, object planning, and neuronavigation-guided intervention can be completed in the same locale, and its application is easy to master and has the potential to enhance procedure tolerability of awakened patients.

Haertel's technique has stood the test of time since its original description in 1912. Its three cutaneous reference points—the cheek point, zygomatic point, and mid-pupillary point—guide the cannulation of the foramen ovale. The needle is typically advanced under a fluoroscope utilizing a combination of the anteroposterior, lateral, and oblique submental views (32); however, visualization of the foramen ovale under such circumstances can be inadequate and inadvertent injury to the surrounding neurovascular structures can result in catastrophic complications. Several localization modalities have been explored thus far, including CT guidance, high-speed real-time CT fluoroscopy, neuronavigation and stereotaxy, all of which are intended to avoid multiple needle passes to minimize cannulation related complications and improve procedure tolerability of awakened patients. CT images are by far superior, when combined with neuronavigation, which allows trajectory visualization in three dimensions and multiple planes at the surgeon's choosing, and use of real-time cannulation. Three-dimensional (3D)-CT and electrophysiology Gasser's ganglion locations can raise the success rate of puncture, enhance the safety and reduce the incidence of complication, showing high academic value and its promising future (33).

### Ultrasound-Guidance for Trigeminal Neuralgia

Infraorbital nerve block is a well-recognized regional anesthetic technique which can provide intraoperative and postoperative pain relief in nasal endoscopic surgery and also in some types

of oral and dental surgery (34). The block may also be used to help diagnose neuralgia arising from the second division of the trigeminal nerve. The technique for infraorbital nerve blockade is most commonly performed as it exits the infraorbital foramen just below the inferior orbital rim (35). Several techniques based upon anatomical landmarks have been described, including both percutaneous and intraoral approaches. All techniques involve the placement of the needle in close proximity to the infraorbital foramen which is usually palpated through the skin. These techniques may be associated with the nerve trauma or with hematoma resulting from damage to the infraorbital vessels (36). The use of ultrasound in anesthesia is a rapidly expanding arena and it has long been used by radiologists. Several reports have described detection of a bone defect, disruption or fracture with the use of ultrasound (37). Using similar principles, various bone foramina may also be detected. The infraorbital foramen is visualized under ultrasound as a defect in the maxillary bone. Tsui (39) in 2009 suggested ultrasound-guided technique for the blockade of trigeminal nerve peripheral branches.

### Conclusion

From the available evidence, we can conclude that: 1) Percutaneous glycerol gangliolysis is very effective and applicable to a wide variety of patients with TN. The presence of CSF outflow dur-

ing puncture predicts better immediate and long-term outcomes; 2) It may be quite obvious that the high-speed real-time CT fluoroscopic method enables better imaging compared to X-ray fluoroscopy; 3) CT images are by far superior, when combined with neuronavigation, which allows trajectory visualization in three dimensions and multiple planes at the surgeon's choosing, and use of real-time cannulation. 3D-CT and electrophysiology Gasser's ganglion locations can raise the success rate of puncture, enhance the safety and reduce the incidence of complication, showing high academic value and its promising future; 4) Balloon Compression causes only a mild sensory loss with immediate pain relief in practically all patients; 5) Ultrasound-guided technique for the blockade of trigeminal nerve peripheral branches is very rational.

### Future Prospects

For both treatment methods, the fused CT and MRI scans are used for improved treatment planning in the treatment for the TN. While the MRI scans provides better details on the anatomical situation, CT scans are required for dosimetric assessment. In the future, other imaging methods like spectroscopy and evoked-potential imaging will become available to better shape the target volume and spare critical normal tissue structures.

No potential conflict of interest relevant to this review was reported.

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