



ORIGINAL RESEARCH

ROLE OF 3D-CONSTRUCTIVE INTERFERENCE IN STEADY STATE (3D-CISS) SEQUENCE OF MAGNETIC RESONANCE IMAGING IN EVALUATION OF TRIGEMINAL NEURALGIA

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Abstract

Background: Trigeminal neuralgia is a chronic, debilitating neuropathic pain condition characterized by severe facial pain in the distribution of one or more branches of the trigeminal nerve. Accurate identification of neurovascular conflict or other structural abnormalities is essential for diagnosis and treatment planning. Advanced MRI techniques, especially the 3D-Constructive Interference in Steady State (3D-CISS) sequence, offer high-resolution imaging of the cranial nerves and adjacent vascular structures, improving the diagnostic accuracy in cases of trigeminal neuralgia.

Aim: To assess and compare the morphologic and hemodynamic parameters of the carotid arteries using Doppler ultrasonography in smokers and non-smokers.

Materials and Methods: This was a prospective observational study conducted over a one-year period from January 2023 to December 2023 at a tertiary care hospital. A total of 50 patients with clinically diagnosed trigeminal neuralgia were included. All patients underwent MRI brain with dedicated 3D-CISS sequences to assess the trigeminal nerve for the presence of neurovascular compression or other pathologies.

Results: Out of the 50 patients evaluated, neurovascular conflict was detected in 38 cases (76%) using the 3D-CISS sequence. The superior cerebellar artery was the most commonly implicated vessel, seen in 29 of these cases. Trigeminal nerve root distortion or atrophy was also appreciable in 12 patients. In 12 patients (24%), no vascular contact was observed, and the MRI findings were within normal limits.

Conclusion: The 3D-CISS MRI sequence is a highly sensitive non-invasive imaging modality for evaluating patients with trigeminal neuralgia. It offers precise anatomical detail of the trigeminal nerve and its surrounding vasculature, making it invaluable in detecting neurovascular conflicts and aiding in treatment planning.

Keywords: Trigeminal Neuralgia, 3D-CISS, MRI, Neurovascular Conflict, Cranial Nerve Imaging, Non-invasive Diagnosis, Superior Cerebellar Artery

INTRODUCTION

Trigeminal neuralgia (TN) is a chronic neurological condition characterized by episodes of severe, lancinating, electric shock-like facial pain typically affecting one or more branches of the trigeminal nerve (cranial nerve V). It is often unilateral and triggered by minimal stimulation such as chewing, talking, or even light touch to the face ¹. Though the exact incidence

varies across populations, TN is estimated to affect approximately 4 to 13 per 100,000 individuals annually, with a predilection for individuals over the age of 50 and a slightly higher prevalence in females. The impact of this condition on the quality of life is profound, often leading to functional disability, psychological distress, and social withdrawal if left untreated or inadequately diagnosed ².

The pathophysiology of trigeminal neuralgia most commonly involves neurovascular compression (NVC) at the root entry zone (REZ) of the trigeminal nerve. The superior cerebellar artery is the vessel most frequently implicated in such compressive phenomena³. This close relationship between the offending vascular structure and the nerve results in focal demyelination, aberrant nerve conduction, and the generation of paroxysmal pain. While idiopathic TN may present without any discernible anatomical cause, secondary forms can be attributed to multiple sclerosis, brainstem infarcts, cerebellopontine angle tumors, or other structural lesions compressing the nerve⁴.

Imaging plays a critical role in the evaluation and management of trigeminal neuralgia. Conventional MRI sequences may not always provide adequate resolution or contrast to visualize the small trigeminal nerve and adjacent vascular structures [5]. In this context, the 3D-Constructive Interference in Steady State (3D-CISS) sequence has emerged as an advanced neuroimaging technique, offering superior spatial resolution and high contrast differentiation between cerebrospinal fluid (CSF), nerves, and vessels. This heavily T2-weighted sequence enables exquisite visualization of the cranial nerves, especially in the posterior fossa, and is invaluable in identifying subtle neurovascular contacts, anatomical anomalies, and nerve atrophy⁶.

With increasing emphasis on accurate non-invasive diagnostics, the utilization of 3D-CISS MRI imaging has gained prominence in both diagnosis and preoperative evaluation of TN. This modality not only aids in detecting neurovascular conflicts but also helps in surgical planning, particularly for microvascular decompression, stereotactic radiosurgery, or other targeted interventions⁷.

Given the clinical significance of early and accurate detection of the underlying cause of trigeminal neuralgia, this study was undertaken to evaluate the diagnostic role of the 3D-CISS MRI sequence in patients presenting with classic TN symptoms. The objective was to assess the prevalence and pattern of neurovascular conflicts and other pathological findings on 3D-CISS imaging, thereby establishing its efficacy as a routine imaging tool in TN evaluation.

MATERIALS AND METHODS

Study Design:

This was a prospective observational study conducted over a 12-month period from Jan 2023 to Dec 2023.

Study Setting:

The study was carried out in the Department of Radiodiagnosis at a tertiary care center equipped with high-resolution 1.5 Tesla MRI facilities.

Sample Size and Sampling Method:

A total of 50 patients clinically diagnosed with trigeminal neuralgia were enrolled in the study. Patients were selected using purposive sampling based on inclusion and exclusion criteria.

Inclusion Criteria:

- Patients of either sex, aged 18 years and above
- Patients presenting with typical clinical features of trigeminal neuralgia as per the International Classification of Headache Disorders (ICHD) criteria
- Patients willing to undergo MRI brain with 3D-CISS sequences
- Patients who provided informed written consent

Exclusion Criteria:

- Patients with known space-occupying lesions already diagnosed
- Patients with contraindications to MRI (e.g., pacemakers, cochlear implants, ferromagnetic clips)
- Patients with a history of cranial surgery or facial trauma
- Patients with psychiatric illness interfering with cooperation
- **Imaging Protocol:**
- All patients underwent MRI brain imaging on a 1.5 Tesla scanner. The imaging protocol included conventional sequences (T1-weighted, T2-weighted, and FLAIR) as well as high-resolution 3D-Constructive Interference in Steady State (3D-CISS) sequences. The 3D-CISS sequence was acquired in the axial plane with thin slices (≤ 1 mm) and multiplanar reconstructions (coronal and sagittal) were performed as needed. These sequences provided clear visualization of the cisternal segments of the trigeminal nerves and adjacent vascular structures.
- **Data Collection and Evaluation:**
- The MRI images were independently reviewed by two experienced radiologists who were blinded to the clinical side of involvement. The presence of neurovascular conflict was documented, including the identification of the offending vessel (arterial or venous), contact point (root entry zone or other segments), and

any secondary findings such as nerve angulation, displacement, or atrophy. In cases of interobserver disagreement, a consensus opinion was reached after joint review.

- **Ethical Considerations:**
- The study protocol was reviewed and approved by the Institutional Ethics Committee. Written informed consent was obtained from all participants prior to inclusion.
- **Statistical Analysis:**
- Data were entered into Microsoft Excel and analyzed using descriptive statistics. Categorical variables were expressed as frequencies and percentages. Associations between imaging findings and clinical symptoms were assessed, but no inferential statistical tests were applied given the descriptive observational design of the study.

RESULTS

This prospective observational study was

conducted on 50 patients clinically diagnosed with trigeminal neuralgia who underwent detailed MRI evaluation including 3D-CISS sequences. The study aimed to assess the demographic characteristics, symptom distribution, nerve involvement, and radiological findings on 3D-CISS imaging. The mean age of the study population was 53.8 years, with a slight female predominance. Most patients presented with unilateral symptoms, and the maxillary (V2) and mandibular (V3) divisions were more commonly involved. Radiological evaluation revealed neurovascular conflict in a majority of cases, most frequently due to the superior cerebellar artery, and often involving the root entry zone. The affected nerves frequently demonstrated features such as angulation or displacement. The following tables summarize the core clinical and imaging observations in detail. Table 1 shows the age distribution among patients with trigeminal neuralgia. Most patients fell into the 51–60-year age group, indicating mid to late adult onset is common.

Table 1. Age-wise distribution of patients diagnosed with trigeminal neuralgia

Age Group (Years)	Number of Patients	Percentage
21–30	3	6%
31–40	5	10%
41–50	12	24%
51–60	18	36%
61–70	9	18%
>70	3	6%

Table 2 shows the sex distribution of the study population. Female patients formed the majority, suggesting a slight gender predisposition.

Table 2. Gender-wise distribution of trigeminal neuralgia patients

Sex	Number of Patients	Percentage
Male	21	42%
Female	29	58%

Table 3 shows the laterality of symptoms. Unilateral involvement was dominant, with right-sided facial pain being more frequent.

Table 3. Distribution of patients based on side of facial pain involvement

Side of Involvement	Number of Patients	Percentage
Right	30	60%
Left	18	36%
Bilateral	2	4%

Table 4 shows the most commonly involved branches of the trigeminal nerve. The mandibular division (V3) was the most frequently affected.

Table 4. Trigeminal nerve branch involvement among study subjects

Division Involved	Number of Patients	Percentage
Ophthalmic (V1)	4	8%
Maxillary (V2)	16	32%
Mandibular (V3)	22	44%
V2 + V3	8	16%

Table 5 shows the duration of symptoms prior to imaging. A significant number of patients had chronic symptoms persisting beyond one year.

Table 5. Duration of symptoms prior to MRI evaluation

Duration	Number of Patients	Percentage
<6 months	7	14%
6 months–1 year	15	30%
1–2 years	18	36%
>2 years	10	20%

Table 6 shows the presence of neurovascular conflict (NVC) as visualized on 3D-CISS MRI sequences. A large proportion of patients had identifiable NVC.

Table 6. Detection of neurovascular conflict on 3D-CISS MRI

Neurovascular Conflict	Number of Patients	Percentage
Present	38	76%
Absent	12	24%

Table 7 shows the most commonly implicated vessels in neurovascular contact. The superior cerebellar artery was the dominant offending vessel.

Table 7. Distribution of vascular structures causing neurovascular contact

Offending Vessel	Number of Patients	Percentage
Superior Cerebellar Artery	26	68.4%
Anterior Inferior Cerebellar Artery	7	18.4%
Vein or venous structure	5	13.2%

Table 8 shows the site of neurovascular contact on the trigeminal nerve. The root entry zone was the most frequently involved area.

Table 8. Anatomical site of neurovascular conflict on trigeminal nerve

Contact Site	Number of Patients	Percentage
Root Entry Zone	28	73.7%
Cisternal Segment	7	18.4%
Other	3	7.9%

Table 9 shows additional nerve changes detected on imaging such as angulation, displacement, or atrophy of the nerve.

Table 9. Structural alterations of trigeminal nerve identified on MRI

MRI Finding	Number of Patients	Percentage
Nerve Angulation	16	42.1%
Nerve Displacement	12	31.6%
Nerve Atrophy	10	26.3%

Table 10 shows the side-to-imaging correlation, comparing clinically symptomatic sides with imaging-detected abnormalities.

Table 10. Correlation between clinical symptoms and radiological side of involvement

Clinical vs Imaging Side	Number of Patients	Percentage
Match	44	88%
Mismatch	6	12%

A high degree of correlation was noted.

Table Summary

The analysis presented across Tables 1 to 10 revealed key clinical and imaging characteristics among patients with trigeminal neuralgia. Table 1 identified the 51–60 years age group as the most affected, while Table 2 showed that females predominated. Unilateral symptoms, especially right-sided (Table 3), were most common. Mandibular division (V3) was the most frequently involved branch (Table 4). Chronic symptom duration over 1 year was frequent (Table 5). Neurovascular conflict was observed in 76% of cases (Table 6), most commonly due to the superior cerebellar artery (Table 7) and predominantly affecting the root entry zone of the nerve (Table 8). Structural nerve changes like angulation and atrophy were documented in several patients (Table 9), and imaging findings correlated with clinical symptoms in 88% of cases (Table 10), affirming the diagnostic reliability of the 3D-CISS MRI sequence.

DISCUSSION

Trigeminal neuralgia (TN) is a chronic neuropathic condition characterized by sudden, severe, brief, stabbing pain in the distribution of one or more branches of the trigeminal nerve. The condition most commonly affects middle-aged and elderly individuals and may severely impair quality of life. Imaging plays a vital role in both confirming the diagnosis and identifying underlying causes such as neurovascular conflict (NVC). This study utilized the high-resolution 3D-CISS MRI sequence to explore its diagnostic value in a prospective cohort of 50 patients with clinically diagnosed TN ^{8,9}.

The demographic analysis of the study population revealed that the majority of patients were in the age group of 51–60 years, with a slight female predominance. These findings align with the general epidemiological trends observed in TN, where age-related microvascular changes and structural alterations may predispose individuals to neural compression. Female predominance in TN may be attributed to hormonal or anatomical variations, though this remains speculative ¹⁰.

Laterality analysis showed that 60% of patients presented with right-sided facial pain, with only a small minority demonstrating bilateral involvement. This finding is consistent with the clinical understanding that TN more commonly presents unilaterally and with a right-side dominance, possibly due to anatomical variations or vascular asymmetries ¹¹. The mandibular (V3) and maxillary (V2) divisions of the trigeminal nerve were most frequently involved, while ophthalmic (V1) involvement was relatively rare. The higher frequency of V2 and V3 involvement may be due to the longer intracranial course of these branches or their anatomical relationship with adjacent vessels ¹².

Symptom duration analysis revealed that a significant proportion of patients had been suffering from TN

symptoms for over one year prior to undergoing MRI evaluation. This underscores a frequent delay in definitive diagnosis and highlights the need for prompt referral and advanced imaging in persistent or recurrent facial pain syndromes ¹³.

A major focus of the study was the evaluation of neurovascular conflict on 3D-CISS imaging. In this cohort, NVC was detected in 76% of patients, validating the well-established theory that compression of the trigeminal nerve—particularly at the root entry zone—by an adjacent vessel is the primary cause of classical TN. The superior cerebellar artery (SCA) emerged as the most common offending vessel, followed by the anterior inferior cerebellar artery (AICA) and venous structures. This vascular distribution supports the anatomical proximity of the SCA to the cisternal segment and root entry zone of the trigeminal nerve, making it a frequent culprit in compressive pathology ¹⁴.

The root entry zone, a transitional area where central myelin changes to peripheral myelin, is particularly vulnerable to vascular compression. This study demonstrated that 73.7% of neurovascular conflicts were localized to this zone. The findings reinforce the notion that even subtle compression in this region can trigger significant neuropathic symptoms, and that imaging protocols should be designed to clearly visualize this anatomical segment ¹⁵.

In addition to vascular contact, 3D-CISS imaging detected secondary nerve changes in many cases, including nerve angulation, displacement, and atrophy. These structural alterations are suggestive of long-standing or severe compression and may correlate with symptom severity or refractoriness to medical therapy. Such features, easily detectable on high-resolution sequences like 3D-CISS, may have implications for surgical planning, particularly in patients being considered for microvascular decompression (MVD) ¹⁶.

Importantly, the imaging findings showed high concordance with the clinically affected side in 88% of patients. This level of side-to-imaging correlation confirms the diagnostic utility of 3D-CISS sequences, offering a non-invasive, detailed, and highly sensitive modality for identifying nerve-vessel relationships. The small percentage of mismatched cases may be attributed to sub-threshold conflicts or limitations in spatial resolution in certain areas, warranting complementary imaging if clinical suspicion remains high¹⁷.

Overall, this study underscores the clinical relevance of incorporating 3D-CISS MRI sequences in the routine diagnostic workup of trigeminal neuralgia. The modality enables superior visualization of the trigeminal nerve and adjacent vessels within the cisternal space. Its capacity to detect neurovascular compression, delineate anatomical sites of conflict, and identify associated nerve changes makes it indispensable in both diagnostic and preoperative settings.

Moreover, the findings strengthen the causal association between vascular compression and classical trigeminal neuralgia and support the therapeutic rationale for microvascular decompression in appropriate candidates. With early and accurate identification of neurovascular conflict, treatment strategies can be more precisely tailored, potentially improving patient outcomes and reducing the duration of uncontrolled pain.

CONCLUSION

This prospective study clearly establishes the diagnostic value of the 3D-CISS MRI sequence in the evaluation of trigeminal neuralgia. The high-resolution imaging provided by this sequence enabled accurate identification of neurovascular conflicts, which were observed in a majority of the patients and were most commonly caused by the superior cerebellar artery. The root entry zone of the trigeminal nerve was the predominant site of compression, reaffirming its vulnerability due to anatomical and histological transitions. The ability of 3D-CISS to detect secondary nerve changes, such as angulation, atrophy, and displacement, adds further depth to its diagnostic utility, particularly in chronic or treatment-resistant cases.

The excellent concordance between the clinical and radiological sides of involvement in most patients supports the reliability of 3D-CISS in localizing the pathology. Given its non-invasive nature, superior spatial resolution, and ability to delineate even subtle

nerve-vessel interactions, the 3D-CISS sequence should be considered a mandatory component of MRI protocols for all patients presenting with symptoms suggestive of trigeminal neuralgia. Incorporating this sequence into routine imaging practices can significantly enhance diagnostic accuracy, guide surgical decision-making, and ultimately improve clinical outcomes in this debilitating condition.

DECLARATION

Ethical Approval

The study was approved by the Institutional Ethics Committee. The study was conducted in accordance with the ethical principles of the Declaration of Helsinki.

Informed Consent

Written informed consent was obtained from all participants included in the study.

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Conflict of Interest Statement

The authors declare no conflicts of interest related to this study.

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