Original Article

DOI: 10.7860/IJARS/2025/73807.3036

Radiology Section

Comparison of Fractional Anisotropy Variances in the Trigeminal Nerve at Root Entry and Cisternal Segment Zones in Patients with and without Clinical Features of Trigeminal Neuralgia: A Cross-sectional Study

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ABSTRACT

Introduction: Although vessel impingement on nerves can be detected using High-resolution steady-state free precession sequences, such as Fast Imaging Employing Steady-state Acquisition (FIESTA), it remains uncertain whether the compression is a physiological variation or a pathological cause of symptoms. A non invasive tool is required to confirm the aetiology, as Microvascular Decompression (MVD) can significantly improve prognosis. Diffusion Tensor Imaging (DTI) is commonly utilised to identify white matter tracts in the brain through tractography, providing valuable insights into neural integrity and potential compression.

Aim: To compare the Fractional Anisotropy (FA) value at root entry and cisternal segment zones in patients with and without clinical features of Trigeminal Neuralgia (TN).

Materials and Methods: A cross-sectional study was conducted in the Radiology Department, Dr. Pinnamaneni Siddhartha Institute of Medical Sciences and Research Foundation, Vijayawada, Andhra Pradesh, India, from January 2024 to May 2024. The study included a total of 60 patients, divided into symptomatic (TN) and asymptomatic groups based on clinical diagnostic criteria. FA values were measured bilaterally in the trigeminal nerve zones, including the root entry and cisternal segments. Statistical analysis was used to compare FA values between the symptomatic and asymptomatic groups. Data was analysed using Statistical Package for the Social Sciences (SPSS) software version 21.0.

Results: Sixty patients (25 females, 35 males) with a mean±Standard Deviation (SD) age of 41±14 years participated in the present study. Among them, 47 were asymptomatic and 13 presented with symptoms. The FA values at the Root Entry Zone (REZ) (combined right and left-side) were 0.243, and at the cisternal segment (combined right and left-side) were 0.242 in symptomatic patients, compared to FA values of 0.403 at the REZ (combined right and left-side) and 0.414 at the cisternal segment (combined right and left-side) in asymptomatic patients, with a statistically significant difference (p-value=0.001).

Conclusion: The present study highlights the potential of FA values derived from DTI metrics to improve diagnostic precision for identifying pathological vascular compression in patients with TN.

Keywords: Diagnostic precision, Diffusion tensor imaging, Fractional anisotropy, Neurovascular compression, Trigeminal neuralgia

INTRODUCTION

According to the International Headache Society, the prevalence of TN is reported to be 5.9 per 100,000 among women and 3.4 per 100,000 in men [1]. The pressure exerted on the trigeminal nerve by the blood vessels is a significant contributing factor to TN [2]. This led to the development of MVD, now recognised as the primary treatment for TN [3].

High-resolution steady-state free precession sequences, such as Fast Imaging Employing Steady-state Acquisition (FIESTA), are crucial for visualising the cisternal courses of cranial nerves. These sequences offer exceptional spatial resolution, with cranial nerves appearing as dark structures against the bright Cerebrospinal Fluid (CSF) background [4].

Why is DTI necessary despite this capability?

The DTI is necessary in our investigative paradigm because it can differentiate between pathological and occasional instances of neurovascular compressions. Although high-resolution steady-state free precession sequences, such as FIESTA excel in identification, DTI offers a more refined perspective of the underlying pathology. Introducing metrics such as FA allows for the quantitative assessment of microstructural changes, thereby elevating diagnostic precision [4].

This advanced imaging modality employs various other metrics, including Apparent Diffusion Coefficient (ADC), Mean Diffusivity (MD) and Radial Diffusivity (RD) to quantify microstructural changes. Currently, FA is the most effective technique for measuring diffusion anisotropy. It is widely used for fiber tracking and is highly sensitive to microstructural changes, offering quantitative insights into nerve integrity and pathology, making it ideal for comparison in the present study [5].

Therefore, the present study aimed to compare FA values in patients with and without neurovascular compression at the root entry and cisternal segment zones. By investigating these quantitative measures, the authors aimed to contribute to a deeper understanding of microstructural alterations associated with TN.

MATERIALS AND METHODS

A cross-sectional study was carried out in the Radiology Department, of Dr. Pinnamaneni Siddhartha Institute of Medical Sciences and

Research Foundation, Vijayawada, Andhra Pradesh, India, from January 2024 to May 2024. Prior clearance was obtained from the Institutional Ethics Committee (IEC) (certificate number: PG/1194/24).

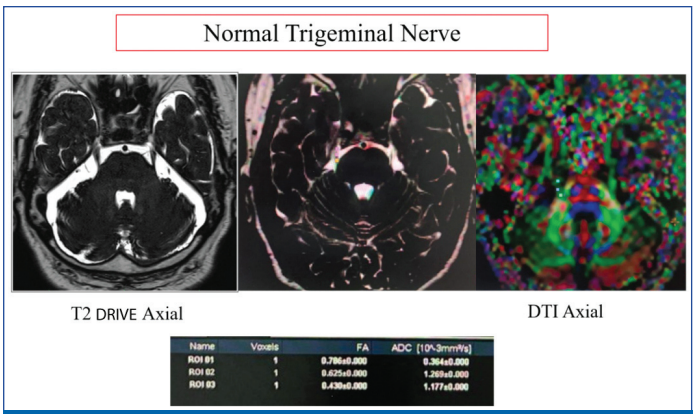
Inclusion criteria: Patients who satisfied the diagnostic criteria for TN as per the International Society of Headache [6] were included in the study.

Exclusion criteria: Patients with secondary causes, such as tumours, vertebrobasilar dolichoectasia and multiple sclerosis, were excluded to maintain specificity.

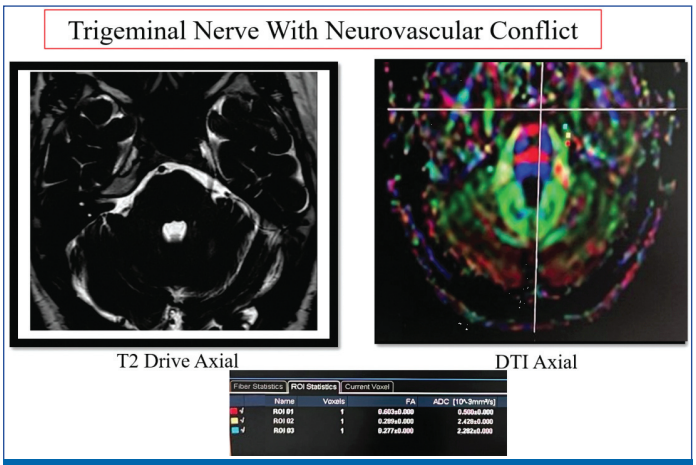
Sample size: The study included a total of 60 patients, divided into symptomatic (TN) and asymptomatic groups based on clinical diagnostic criteria.

Study Procedure

The primary parameters studied were the FA values at the REZ and cisternal segment of the trigeminal nerve in both symptomatic and asymptomatic groups. Data was collected through advanced MRI scanning techniques, specifically focusing on DTI metrics [Table/Fig-1,2]. A single experienced radiologist, blinded to the patients' clinical status, performed all measurements to ensure consistency and minimise interobserver variability. Each parameter was measured three times, and the mean value was used for analysis to reduce random errors. Standardised measurement protocols and automated software tools were employed to minimise intraobserver variability, ensuring precise and reproducible FA value assessments across the study. FA values were obtained using 16-channel head coil integrated into a Philips 1.5-Tesla MRI machine. The imaging parameters used to acquire DTI sequences are provided in [Table/Fig-3], along with a comprehensive overview of the key parameters of DTI sequence acquisition. Critical factors, such as the b-value and diffusion directions (marked with a black star), as mentioned by Van Hecke W et al., in their study [7].



[Table/Fig-1]: Illustrations demonstrating procedural clarity in image acquisition T2 Driven Equilibrium (DRIVE) are overlaid on DTI with Region of Interest (ROI) placement at the root entry, cisternal segment and Meckel's cave.



[Table/Fig-2]: Image showing a 45-year-old male patient with complaints of facial pain for the past three months. ROI is placed at the root entry, cisternal segment and Meckel's cave, with FA values noted to be low.

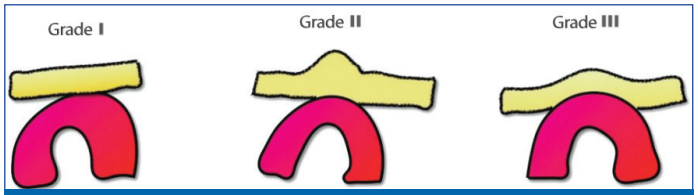
Parameters	Values
b-value	0 and 800 s/mm^2
Diffusion directions	32
Slice thickness	2.5 mm
Field of view (FOV)	224×224 mm
Matrix	92×90
Repetition Time (TR)	2935 mS
Echo Time (TE)	84 mS
Acquisition time	6 min 33 sec

[Table/Fig-3]: The imaging parameters used to acquire DTI sequence in the present study.

Leal PR et al., proposed a classification of neurovascular compression in classical TN. The authors found that FA values can enhance the precision of diagnosis, especially in cases of grade 1 neurovascular conflict [8]. The grading system utilised by Leal PR et al., categorising nerve-vessel contact into three levels have been presented in [Table/Fig-4] [8]. A visual depiction of the grading system is shown in [Table/Fig-5].

Grading	Distribution of neurovascular compression
Grade I	Simple contact
Grade II	Distortion
Grade III	Groove on the nerve

[Table/Fig-4]: Grading system for neurovascular compression proposed by Leal PR et al., [8].



[Table/Fig-5]: Diagrammatic representation of grading system for neurovascular compression proposed by Leal PR et al., [8].

STATISTICAL ANALYSIS

The data was analysed using SPSS software version 21.0. Statistical tests, such as the unpaired t-test, were applied to compare FA values between groups. A p-value of <0.05 was considered statistically significant.

RESULTS

The mean±SD age of the overall population was 41±14 years, with a broad age range of 10-72 years. Sixty patients (25 females and 35 males) participated in the present study. Among them, 47 were asymptomatic, while 13 presented with symptoms related to the study parameters. Among the symptomatic patients, eight were males and five were females.

The mean±SD of the FA values in symptomatic and asymptomatic patients are shown in [Table/Fig-6].

In the present study, the distribution of neurovascular compression according to Leal PR et al., was as follows [8]:

- Grade I (Simple contact): 5 (38%) patients
- Grade II (Distortion): 4 (31%) patients
- Grade III (Groove on the Nerve): 4 (31%) patients

These results highlight that FA values were especially useful in diagnosing patients with Grade I neurovascular compression, when other imaging techniques might not clearly depict the nerve vessel interaction.

Values of FA (mean±SD)	Symptomatic	Asymptomatic	p-value
Root Entry Zone (REZ) (Right)	0.248±0.0064	0.4141±0.1028	0.001
Root Entry Zone (REZ) (left)	0.239±0.104	0.3923±0.1053	0.001
The combined left and right values of FA for REZ	0.243±0.073	0.403±0.104	0.001
Cisternal segment (Right)	0.244±0.0132	0.3893±0.1072	0.001
Cisternal segment (left)	0.241±0.0025	0.4405±0.1066	0.001
The combined left and right values of FA for cisternal segment	0.242±0.009	0.414±0.1069	0.001

[Table/Fig-6]: Mean and standard deviation of the FA values in symptomatic and asymptomatic patients.
Unpaired t-test was used

DISCUSSION

The present study investigated the intricate interplay among high-resolution steady-state free precession sequences, such as T2 DRIVE, DTI and FA, to identify and characterise neurovascular compression. The FA, which is a key metric in DTI, is a crucial indicator of white matter integrity. By quantifying the degree of directionality and revealing how much diffusion is restricted along the dominant axis within the white matter, FA provides valuable insights into microstructural organisation. In the realm of neurovascular compression, FA is instrumental in discerning subtle alterations in white matter integrity that may elude on other imaging techniques. The quantitative nature of FA enhances our ability to objectively assess the severity and nature of microstructural changes associated with neurovascular compression [7].

Decoding FA values in neurovascular compression: High FA values (closer to 1) indicate intact, well-organised tissue similar to healthy white matter tracts. In neurovascular compression, closerto-1 FA values highlight minimal impact, helping to precisely identify the unaffected neural pathways [7]. Imagine a group of people walking in a line in the same direction; it shows their integrity, indicating a high FA value.

Low FA values (closer to 0) suggest damaged or disorganised tissue potentially affected by compression. FA values closer to 0 indicate significant alterations, aiding in locating regions where neurovascular compression may affect the microstructural integrity. An observed disarray in directional coherence, with individuals moving in various directions, may signify a state of disorganisation and suggest diminished FA values. Recognising these FA variations enhance our ability to assess the extent of neural tissue involvement and refine diagnostic precision [7].

The present study findings align with those of Kumaran SP et al., who demonstrated a significant decrease in FA values in the affected nerve in TN compared to the unaffected nerve [9]. In their study, among 30 patients, the mean FA on the unaffected side was 0.391, while the mean FA on the affected side was 0.302, with a difference of 0.089 at the REZ. In the control group, the FA difference between both sides of the V nerve at the REZ was only 0.007. These results support the use of FA as a reliable marker for detecting nerve compression in TN [9].

In the study conducted by Wu M et al., the mean FA on the affected side was significantly lower compared to the mean FA on both sides of the control group (0.26±0.09, CI: 0.23-0.30 vs 0.54±0.06, CI: 0.51-0.57) [10]. This suggests the potential utility of FA in detecting nerve alterations even in the absence of apparent neurovascular compression. Wu M et al., further hypothesised that decreased mean FA could reflect microstructural changes in the trigeminal nerve, which may not be visible on conventional imaging. This supports the use of DTI as a valuable tool in diagnosing and assessing TN, even in complex cases where no clear neurovascular involvement is observed.

Although the utility of DTI and FA in elucidating neurovascular compression has been extensively discussed, challenges persist. DTI encounters obstacles such as low spatial resolution, susceptibility artifacts, partial volume effects and variability in acquisition and analysis methods. These challenges introduce potential inaccuracies, which can affect the precision and reliability of DTI measurements. Although insightful, FA in DTI remains an indirect measure that lacks the direct delineation of microstructural characteristics. It is crucial to acknowledge this limitation, emphasising that FA values alone may not fully reveal the intricate microarchitecture that is implicated in neurovascular compression.

Limitation(s)

The FA value inaccuracies may arise from CSF image voxels, prompting the consideration of higher-resolution DTI to mitigate this issue, albeit with a trade-off of extended scan times. Combining fluid suppression Fluid-attenuated Inversion Recovery (FLAIR) with high-resolution nerve-specific DTI is a potential solution for this problem. Although an increased diffusion direction improves the accuracy of FA values, it also contributes to prolonged scanning time. Understanding how DTI measures quantitatively depict TN pathophysiology requires additional research, as does evaluating the potential therapeutic use of DTI in the treatment of this disease.

CONCLUSION(S)

Diminished FA values signify microstructural changes in the trigeminal nerves that may be overlooked on other MRI sequences. FA values play a crucial role in the early detection, precise localisation and reaffirmation of neurovascular compression within the trigeminal nerve, with the possibility of being used as a preoperative prognostic marker in MVD. The authors would like to ensure the transparency and reproducibility of the present study. All relevant data supporting the findings of the present study are included within the paper.

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PLAGIARISM CHECKING METHODS: [Jain H et al.]
- Plagiarism X-checker: Jun 28, 2024
- Manual Googling: Oct 29, 2024
- iThenticate Software: Nov 04, 2024 (9%)

ETYMOLOGY: Author Origin

EMENDATIONS: 8

AUTHOR DECLARATION:
- Financial or Other Competing Interests: None
- Was Ethics Committee Approval obtained for this study? Yes
- Was informed consent obtained from the subjects involved in the study? Yes
- For any images presented appropriate consent has been obtained from the subjects. Yes

Date of Submission: **Jun 27, 2024**
Date of Peer Review: **Sep 09, 2024**
Date of Acceptance: **Nov 05, 2024**
Date of Publishing: **Jan 01, 2025**