The Diagnostic Value of Magnetic Resonance Imaging in Posttraumatic Trigeminal Neuropathic Pain

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Aims: To evaluate the diagnostic value of non–nerve-selective MRI sequences in posttraumatic trigeminal neuropathic pain (PTNP). **Methods:** This study retrospectively analyzed all MRI protocols performed between February 2, 2012 and June 20, 2018 commissioned by the Department of Oral and Maxillofacial Surgery, University Hospitals Leuven. Demographic, clinical, and radiologic data were extracted from the records of patients with an MRI in the context of PTNP. A contingency table was constructed based on the opinions of the treating physician and the radiologist who initially evaluated the MRI. Sensitivity, specificity, positive predictive value, and negative predictive value were calculated. **Results:** The sample consisted of 27 women (65.9%) and 14 men (34.1%). The sensitivity and negative predictive value of MRI in PTNP were 0.18 and 0.77, respectively. Artifacts interfered with visualization of a possible cause of the trigeminal pain in 24.4% of MRIs. Almost all artifacts (90%) were caused by metal debris originating from the causal procedure or posttraumatic surgeries. MRI resulted in changed management for PTNP patients only once. **Conclusion:** The diagnostic value of non–nerve-selective MRI sequences for PTNP is low and has little impact on clinical management. Therefore, there is a need for dedicated sequences with high resolution and low artifact susceptibility for visualizing the posttraumatic injuries of the trigeminal branches. *J Oral Facial Pain Headache 2021;35:35–40. doi: 10.11607/ofph.2732*

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Although neuropathic pain has a low incidence of 8.2 per 1,000 persons a year, it is often considered one of the most difficult pain syndromes to diagnose and manage.[1] In 2020, the International Headache Society (IHS) published the first edition of the International Classification of Orofacial Pain (ICOP).[2] In this classification, posttraumatic trigeminal neuropathic pain (PTNP) is defined as "unilateral or bilateral facial or oral pain following and caused by trauma to the trigeminal nerve(s), with other symptoms and/or clinical signs of trigeminal nerve dysfunction, and persisting or recurring for more than 3 months."[2]

The diagnosis of neuropathic pain in general and PTNP specifically poses a great challenge due to the complex trigeminal nerve system and the variety in clinical symptoms and causes. Therefore, disorders of the trigeminal nerve are often misdiagnosed, which can lead to unnecessary and invasive diagnostic or therapeutic interventions.[3] Until today, there was no gold standard for the diagnosis of PTNP. Therefore, the diagnostic process relies on a history of relevant traumatic events, a clinical examination with positive or negative sensory signs in a plausible neuroanatomical distribution, and other diagnostic tests aiming to confirm a lesion of the peripheral trigeminal branch (eg, electromyography or imaging).[4,5] While CBCT, as well as multislice computed tomography, are used for the 3D evaluation of bony structures, MRI examination is preferred for soft tissue and neurovascular visualization. Therefore, these techniques are often routinely used in the diagnostic process of trigeminal pathologies.[6] Nontraumatic disorders of the trigeminal nerve, such as classical trigeminal neuralgia caused by a neurovascular compression or secondary trigeminal neuralgia caused by inflammation or infections, can be diagnosed based on MRI examination.[7,8] However, the visualization capability of MRI strongly depends on the chosen sequences.[9]

Therefore, it is believed that MRI could have the same impact on PTNP, but its potential has not been able to be realized until presently due to the use of non–nerve-selective sequences.[10] The objective of this retrospective study is to assess the hypothesis that the diagnostic value of current non–nerve-selective MRI sequences used in clinical practice in the context of PTNP is low and has a minor impact on the clinical management of these patients, hereby underlining the need for nerve-selective PTNP MRI sequences.

Materials and Methods

Patient and Radiologic Characteristics

This study was approved by the Ethics Committee of the University Hospitals Leuven (S62823) and conducted in compliance with Good Clinical Practice standards and the Declaration of Helsinki. All protocols of MRI scans that were performed between February 1, 2012 and June 20, 2018 commissioned by the Department of Oral and Maxillofacial Surgery of the University Hospitals Leuven were retrospectively analyzed. The medical records of patients with PTNP were retrospectively evaluated for demographic, clinical, and radiologic characteristics. Demographic data consisted of age and sex of the patients. Information about the causal trauma and the affected trigeminal nerve branch was extracted from the medical file of the first consultation in the context of trigeminal pain. Findings of the physical examination were classified as positive sensory signs (eg, hyperalgesia, allodynia), negative sensory signs (eg, hypoesthesia, anesthesia), or a combination of positive and negative sensory signs. Based on these findings, patients were divided into two subgroups: painful neuropathy and nonpainful neuropathy. The initial management of the trigeminal pain problem was categorized into watchful waiting, pharmacologic treatment, or surgery. Medical records after the MRI were searched for information about the impact of the MRI findings on the initial management. If the MRI results changed the initial management, details about the treatment decisions were collected. The following MRI parameters were extracted from the radiologic reports: used MRI sequences; the use of a gadolinium-based contrast agent; the total nerve of interest visualized on MRI; the ability to visualize the most plausible cause of the trigeminal pain on MRI; and the presence of artifacts on the MRI that possibly limited the reporting of a lesion of the trigeminal nerve; and the type of artifact, categorized into movement artifact or metal artifact.

Contingency Table

A contingency table was constructed based on clinical and radiologic opinions on the trigeminal pain problem found in the medical records of the patients. The clinical opinion was considered positive when there was a relevant history of a neurologic lesion with sensory signs and/or pain in a neuroanatomically plausible region or when confirmed by exploratory surgery in accordance with the suggested grading system by Finnerup et al.[5]

The radiologic opinion was based on the report of the performed MRI in the context of a possible PTNP case. The MRI was considered positive when the initial radiology report mentioned the visualization of a lesion of a peripheral trigeminal nerve branch.

Statistical Analysis

Statistical analysis was conducted in GraphPad Prism 8 software. Univariate analyses (eg, mean and mode) were used for different variables in the total dataset to summarize the patient characteristics in this sample. A contingency table was constructed for the total dataset, and sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were calculated. Since there were cells with an expected cell count of less than five, Fisher exact test was conducted between the clinical and radiologic opinions to determine if there was an association between these two dichotomous variables. Further statistical tests to assess the correlation between clinical and radiologic variables were not performed due to the low number of subjects per group.

Results

Patient Characteristics

This sample consisted of 41 patients who underwent MRI examination in the context of PTNP, comprising 27 women (65.9%) and 14 (34.1%) men. Their mean age was 42.59 ± 14.20 years, with a range between 4 and 70 years (Table 1). The majority of patients had a possible cause in their medical history, most frequently being tooth extraction or orthognathic surgery. Nearly 75% of all patients were assigned to the subgroup for painful neuropathy on the basis of physical examination. More than half of the patients (51.2%) presented with positive sensory signs, 11 patients (26.8%) with negative sensory signs, and 9 patients (21.9%) with a combination of positive and negative sensory signs. In the diagnostic work-up, a dental panoramic radiography and CBCT were almost always added to the MRI examination (Table 2).

Table 1 Patient and Clinical Characteristics of All 41 Patients with an MRI in the Context of PTNP

Mean (SD) age, y	42.59 (14.20)
Gender	
Men	14 (34.1)
Women	27 (65.9)
Evaluated nerve	
Lingual nerve	13 (31.7)
Inferior alveolar nerve	11 (26.8)
Mandibular nerve	7 (17.1)
Total trigeminal nerve	6 (14.6)
Maxillary nerve	4 (9.7)
Cause of injury	
Non–wisdom tooth extraction	10 (24.4)
Third molar surgery	9 (21.9)
Orthognathic surgery	5 (12.2)
Local anesthesia	4 (9.8)
Noniatrogenic trauma	4 (9.8)
Implant placement	3 (7.3)
Other iatrogenic trauma	6 (14.6)
Clinical symptoms	
Positive sensory signs	21 (51.2)
Negative sensory signs	11 (26.8)
Positive and negative sensory signs	9 (21.9)
Subgroups based on clinical findings	
Painful neuropathy	30 (73.2)
Nonpainful neuropathy	11 (26.8)
Initial management, n (%)	
Watchful waiting	3 (7.3)
Medication	28 (68.3)
Surgery	10 (24.4)

All data are reported as n (%) unless otherwise indicated.

Table 2 Radiologic Characteristics of All 41 Patients with an MRI in the Context of PTNP

Additional imaging	
PANO	35 (85.4)
CBCT	26 (63.4)
Second MRI	1 (2.4)
Artifacts on MRI	10 (24.4)
Use of gadolinium-based contrast agents in MRI	39 (95.1)

All data are reported as n (%). PANO = dental panoramic radiography.

Table 3 Contingency Table for PTNP

	Clinical +	Clinical –	Total	
MRI +	2	0	2	PPV = 1
MRI –	9	30	39	NPV = 0.77
Total	**11**	**30**	**41**	
	Sensitivity = 0.18	**Specificity = 1**		

MRI + = positive MRI; MRI – = negative MRI; Clinical + = positive clinical findings; Clinical – = negative clinical findings; PPV = positive predictive value; NPV = negative predictive value.

A positive MRI was based on the opinion of the initial radiologist found in the report of the MRI in the context of a possible PTNP. The clinical opinion was considered positive when there was a relevant history of a neurologic lesion with sensory signs and/or pain in a neuroanatomically plausible region or when confirmed by exploratory surgery in accordance with the suggested grading system by Finnerup et al.[5]

Contingency Table

Specificity and PPV were 1 (Table 3). Sensitivity and NPV were 0.18 and 0.77, respectively. Fisher exact test showed no significant association ($P = .067$) between clinical and radiologic opinions.

MRI sequences and artifacts

All 41 MRIs were taken on an Ingenia 3.0T scanner (Philips Healthcare). A total of 10 different MRI sequences were used. A T1-TSE sequence was present in 98% of cases (Fig 1). No metal artifact reduction pulse sequences were applied.

A gadolinium-based contrast agent was used in 95% of MRIs taken in the context of PTNP.

An artifact that possibly limited the visualization of a cause of the trigeminal pain was present in 24.4% of the MRIs (Table 2). Nine out of 10 artifacts were metal artifacts caused by metal debris originating from the causal procedure (eg, orthognathic surgery) (Fig 2).

Changed management

MRI acquisition resulted only once (2.4%) in changed management for the PTNP patient. This patient suf-

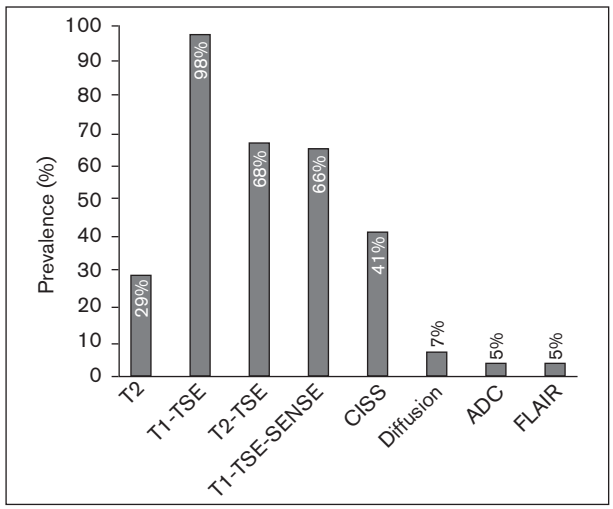
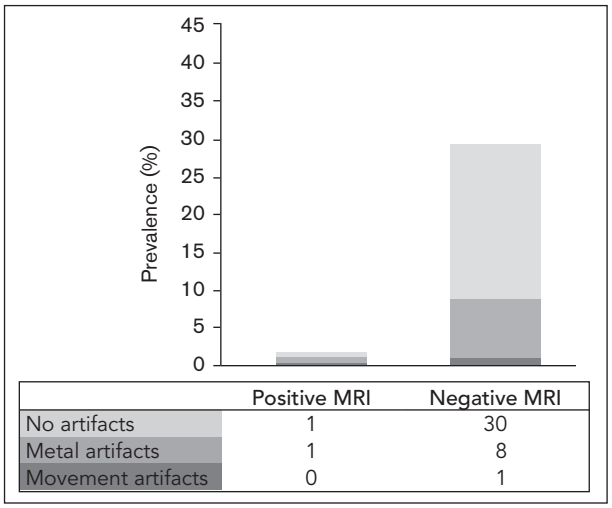


Fig 1 MRI sequences used in the study population (N = 41 patients). Only MRI sequences used in > 5% of patients are shown. T2 = T2-weighted sequence; T1-TSE = weighted turbo spin echo; T2-TSE = T2-weighted turbo spin echo; T1-TSE-SENSE = T1-weighted turbo spin echo sensitivity encoding; CISS = constructive interference steady state; ADC = apparent diffusion coefficient; FLAIR = fluid-attenuated inversion recovery.



	Positive MRI	Negative MRI
No artifacts	1	30
Metal artifacts	1	8
Movement artifacts	0	1

Fig 2 The presence of artifacts on MRIs. The MRI was considered positive if the cause of PTNP could be identified by the consulting radiologist.

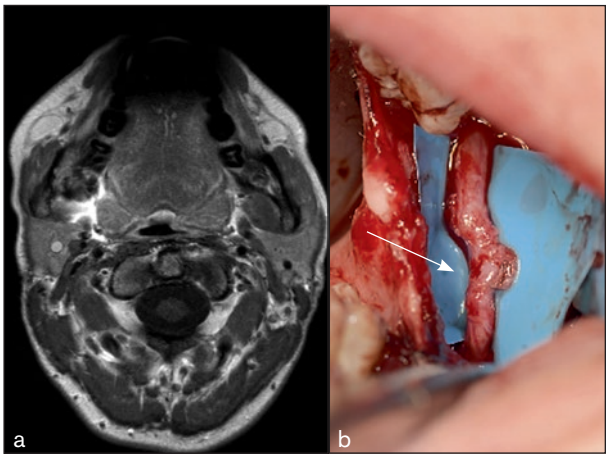


Fig 3 **(a)** MRI and **(b)** surgical images of a patient exhibiting trauma due to crushing of the lingual nerve (third division of the trigeminal nerve) caused by third molar extraction. This lesion could not be visualized on MRI (T1-TSE sequence) due to metal artifacts, but a surgery was performed due to a clinical indication. During the surgery, a neuroma-in-continuity of the lingual nerve was found (arrow).

fered from PTNP caused by third molar extraction. Subsequent nerve damage was visualized on T2-TSE. Therefore, a microsurgical repair was performed.

Discussion

This study provides real-world information from a tertiary referral center about the diagnostic value of non–nerve-selective MRI sequences in the context of PTNP. The demographic results and age and sex ratios for PTNP patients were in line with the findings of Zuniga et al.[11]

Although MRI has good results for the diagnosis of classical and secondary trigeminal neuralgia and is even included in the guidelines for these two pathologies, the question remains as to whether it can be an asset in the diagnosis and treatment of PTNP.[12–14]

Currently, MRI is not part of the guidelines for the diagnosis of PTNP and therefore not used for every patient consulting with a history suggestive of PTNP.[2] It is only used in specific cases to provide important information when differentiating between diagnoses or when surgical repair is a therapeutic option. However, the contingency table (Table 3) of this study shows that the sensitivity and NPV of MRI for the causal injury of the trigeminal nerve are 0.18 and 0.77, respectively. This means that an MRI examination with non–nerve-selective sequences is not designated for diagnosis of posttraumatic trigeminal injuries; otherwise, too many false negative results will be obtained (Figs 3 to 5). Non–nerve-selective MRI sequences are therefore not able to provide an important added value to the diagnostic work-up of PTNP patients. Moreover, MRI resulted in changed management for these PTNP patients only once (2.4%).

A possible explanation for the low diagnostic value of the current non–nerve-selective MRI sequences for PTNP is the frequent presence of a metal artifact, which possibly limits the visualization of a lesion. In this study, artifacts possibly interfered with visualization of a cause of the trigeminal pain in 24.4% of MRIs.

However, artifacts alone cannot completely explain the low diagnostic value of MRI in PTNP. There was no artifact present in 5 out of 9 false negative MRIs (Fig 2). The remaining cause is most probably inherent to non–nerve-selective MRI sequences.

Although MRI is often used to image larger nerves, Cassetta et al demonstrated that evaluation of the inferior alveolar nerve (IAN) is possible by means of a 3T MRI and that early assessment of relative signal intensity values can be considered as a valid predictor for the prognosis of sensory disorders.[15] Recent findings have shown the potential of nerve-selective magnetic resonance techniques in the visualization of the peripheral trigeminal nerve system and injuries of the small trigeminal branches.[10,11,16,17] The capacity to visualize the trigeminal nerve depends on the used sequences, and therefore a nerve-selective MRI protocol needs to be composed of sequences with high resolution and low artifact susceptibility. Specific magnetic resonance neurography (MRN) sequences in previous research articles were most often executed on 3T scanners with T2-weighted gradient echo imaging.[18] To clearly visualize the peripheral trigeminal nerve system, a uniform fat suppression sequence—for example, an adiabatic inversion pulse or a chemical

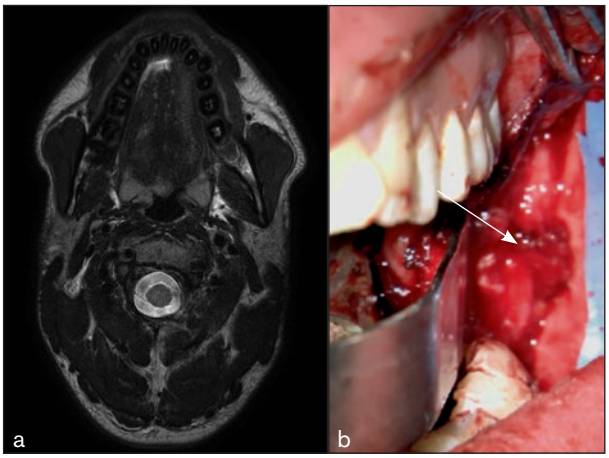


Fig 4 **(a)** MRI and **(b)** surgical images of a patient reporting trigeminal pain after third molar extraction. The treating physician suspected PTNP of the lingual nerve, and an MRI (T2-weighted sequence) was performed. There were no artifacts that limited the reporting of a possible lesion, but the lingual nerve could not be visualized on the MRI. During surgery, complete transection of the lingual nerve was found (arrow).

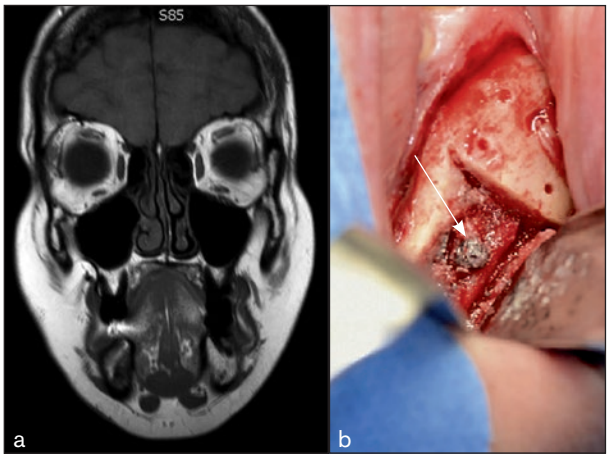


Fig 5 **(a)** MRI and **(b)** surgical images of a patient reporting neuropathic pain after a dental implant placement procedure. There was no clear visualization of the trauma on MRI (T1-TSE sequence), but during surgery, contact between the implant screw and the inferior alveolar nerve was seen (arrow).

shift selective pulse—must be added to this combination.[18–20] Since the presence of a metal artifact often hinders the visualization of a possible lesion in this population, sequences with low artifact susceptibility based on spin echo imaging should be preferred. Newer techniques such as slice encoding for metal artifact correction and view angle tilting sequences could provide added value in a standardized combination of MRI sequences in the context of PTNP.[21]

The present study has limitations, including its retrospective nature and the subsequent introduction of selection bias. The retrospective design also implies a large amount of different MRI sequences, depending on the choice of the consulting radiologist. Therefore, this study did not have the purpose of evaluating the diagnostic value of each individual MRI sequence, but rather of illustrating the real-world value of non–nerve-selective MRI sequences. In the future, a single- or multicenter prospective study should be performed to evaluate and compare the diagnostic value of different MRI sequences. Quantitative sensory testing was not executed in a standardized way in the diagnostic process of these patients, and therefore clinical opinion was based on basic neurosensory testing and thorough history-taking. An association between the MRI results and clinical symptoms could not be determined due to the low sample size.

Due to the lack of a golden standard reference test, it was decided to create the contingency table based on the opinions of the clinician and radiologist. Therefore, this table demonstrates the agreement between MRI and clinical evaluation. Subsequently, the definitions of sensitivity, specificity, PPV, and NPV are not aligned with their usual definitions.

Conclusions

This study showed that the diagnostic value of non–nerve-selective MRI sequences for PTNP patients is low and has little impact on the clinical management of these patients. Currently, the diagnosis of PTNP should rely on a combination of thorough history-taking, clinical examination, and other radiologic modalities, sometimes supplemented with a surgical exploration.[22] However, it is unethical to perform a surgical exploration for every suspected PTNP, and MRI has the potential to provide a clear indication for surgery with its ability to directly visualize the nerve. Consequently, there is a need for dedicated MRI sequences with high resolution and low artifact susceptibility for visualizing the posttraumatic injuries of the peripheral trigeminal branches in the maxillofacial area.

Highlights

- MRI has the potential to become a strong diagnostic tool for PTNP.
- Non–nerve-selective MRI sequences have low diagnostic value and have little impact on the clinical management of PTNP.
- Dedicated MRI sequences with high resolution and low artifact susceptibility are needed.

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