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Characterization of neurovascular compression in facial neuralgia patients by 3D high-resolution MRI and image fusion technique

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ABSTRACT

Objective: To describe the anatomical characteristics and patterns of neurovascular compression (NVC) in patients suffering trigeminal neuralgia (TN) by 3D high-resolution magnetic resonance imaging (MRI) method and image fusion technique. **Methods:** The anatomic structure of trigeminal nerve, brain stem and blood vessel was observed in 100 consecutive TN patients by 3D high resolution MRI (3D SPGR, contrast-enhanced T1 3D MP-RAGE and T2/T1 3D FIESTA). The 3D image sources were [illegible] and visualized using 3D DOCTOR software. **Results:** One or several NVC sites, which usually appeared [illegible]-9.8 mm away from brain stem, were found on the symptomatic side in [illegible]% of the TN [illegible]. Superior cerebellar artery was involved in 76% (71/93) of these cases. [illegible] other vessels including antero-inferior cerebellar artery, vertebral artery, basilar artery and veins also [illegible]ated to the occurrence of NVC. The NVC sites were found to be located in the proximal segment in 42% of these cases (39/93) and in the distal segment in 45% (42/93). [illegible]e dislocation or distortion was observed in 32% (30/93). **Conclusions:** Various 3D high resolution MRI methods combined with the image fusion technique could provide pathologic anatomic information for the diagnosis and treatment of TN.

1. Introduction

Neurovascular compression (NVC), also known as neurovascular contact or neurovascular conflict, refers to the abnormal compression between blood vessel and trigeminal nerve and it may be the primary cause for typical facial neuralgia. [illegible]nt, the pathological mechanism for the disease remains to be fully understood[1-3].

Magnetic resonance imaging (MRI) scanning for patients with facial neuralgia can provide information on anatomic structure of their nerve, brain stem and blood vessel and has been applied widely in clinical practice[4]. In this study, an attempt was made to retrospectively analyze the anatomic characteristics of trigeminal nerve as well as NVC between blood vessel and brain stem or trigeminal nerve in patients suffering trigeminal neuralgia (TN) using 3D high-resolution MRI. Especially, different NVC patterns and their frequency of occurrence were observed.

2. Materials and methods

2.1. Patients

Between January 1, 2011 to December 1, 2011, 100 typical TN patients were selected, 60 of which underwent surgery using trigeminal ganglion decompression. All patients were examined using a high resolution 3.0 T MRI scanner (Signa, General Electronic Co., USA). The pulse sequences used were SPGR (TOF), T2/T1 3D FIESTA (TrueFisp), and contrast-enhanced T1 3D MP-RAGE (for some cases). Table 1 shows the imaging parameters of each pulse sequence.

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2.2. Image data post–processing and analysis

The 3D image fusion and analysis were done on a PC workstation using 3D DOCTOR software, and multi–plane multi–sequence image data were visualized using Version 12.0. The T2/T1 FIESTA sequence was used to visualize the basic anatomic structure of brain stem, trigeminal nerve and angioid structure at nerve root, while the SPGR (TOF) and contrast–enhanced T1 3D MP–RAGE sequences were used to locate blood vessel. Artery and vein were distinguished according to their anatomic characteristics such as origin, orientation and thickness of vascular walls. After image fusion, the structure of brain stem, trigeminal nerve, artery and vein was acquired and visualized in the T2/T1 FIESTA axial image (Figure 1).

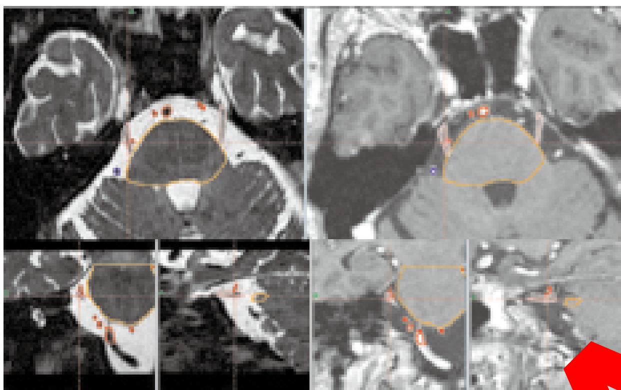

Figure 1. Multi–planar visualization of 3D FIESTA and contr[illegible] enhanced 3D MP–RAGE images by reconstruction [illegible] DOCT[illegible] software after obtaining regions of interest.

NVC sites were identified by visualizing blood vessel that was in contact with trigeminal nerve. According to the report of Masur *et al*, NVC is either simple contact or nerve transfer. The presence of cerebrospinal fluid between nerve root and blood vessel, which is depicted as a high signal in T2/T1 FIESTA, indicates the absence of NVC. However, nerve root is thought to be transferred if the nerve is moved or distorted at horizontal contact site. Multiple NVC occur if nerve root contact with two or more blood vessels. The location of NVC was described at two levels. The NVC site was proximal if it appeared within 3 mm away from brain stem or on brain stem surface, while the NVC site w[illegible]its distance from brain stem was farther tha[illegible] mm. The [illegible]quency of occurrence of NVC was calculated [illegible] case nu[illegible]er.

2.3. Statistical analysis

The data obtai[illegible] were [illegible]yzed u[illegible]g two tailed Fisher´s test. A P valu[illegible]05 was con[illegible]statically significant.

3. R[illegible]

3[illegible] Frequency [illegible] occurrence of NVC

As [illegible]y 3D high resolution MRI, NVC was observed [illegible] the symptomatic side in 93% (93/100) of the TN cases and [illegible]symptomatic side in 55% (55/100), and the frequency of occurrence between these two sides was significantly different (P<0.0001).

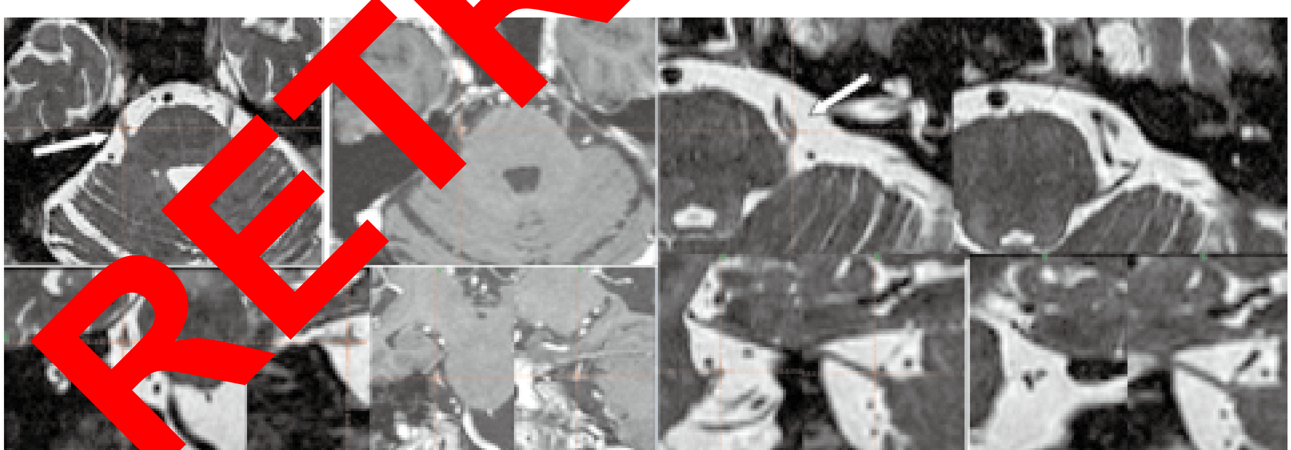

Figure 2. Neurovascular compression (NVC) resulted from SCA. Arrow reveals the NVC site.

Table 1

Pulse sequences and imaging parameters used in 3D high resolution MRI scanning.

Pulse sequence	TE/TR (ms)	Flip angle	Inversion recovery	Band width (kHz)	Field of view (mm^2)	Slice thickness (mm)	Scanning matrix size	Resolution (mm)
3D MP–RAGE	3.4/8.9	35	450	16	180×180	1.2	256×256	0.7×0.7
3D FIESTA	3.7/7.6	60	a	50	180×180	1.2	256×256	0.7×0.7
3D SPGR (TOF)	2.0/17	15	a	62.5	180×180	1.2	256×256	0.7×0.7

a: No data.

3.2. Characteristics of NVC on symptomatic side

The average distance between nerve origin in brain stem and NVC site was (3.8±2.9) mm (a range of 0-9.8 mm). Additionally, vascular compression could be found at any site of trigeminal nerve, leading to nervous distortion. Of the 93 TN cases having NVC on the symptomatic side, 39 (41.9%) had proximal NVC sites and 42 (45.2%) had distal ones. Multiple NVC sites were also found in seven cases (7.5%) including four caused by compression from SCA and AICA and three caused by cooperative compression from vein and artery. Moreover, five cases (5.3%) had obvious contact between blood vessels and brain stem at the origin of trigeminal nerve rather than at the nerve itself. Such contact was also recognized as proximal NVC. For example, the vertebral artery (VA) groove compressed the brain stem without contact with the trigeminal nerve (Figure 4b). NVC was observed on superior cerebellar artery (SCA) of two TN cases, antero-inferior cerebellar artery (AICA) of one case, and vein of one TN case. Nerve transfer or distortion was detected on the symptomatic side of 32.3% (30/93) of the TN cases having NVC on this side, but only simple contact was detected on the contralateral asymptomatic side. The frequency of nerve transfer or distortion was significantly different between these two sides ($P<0.0001$).

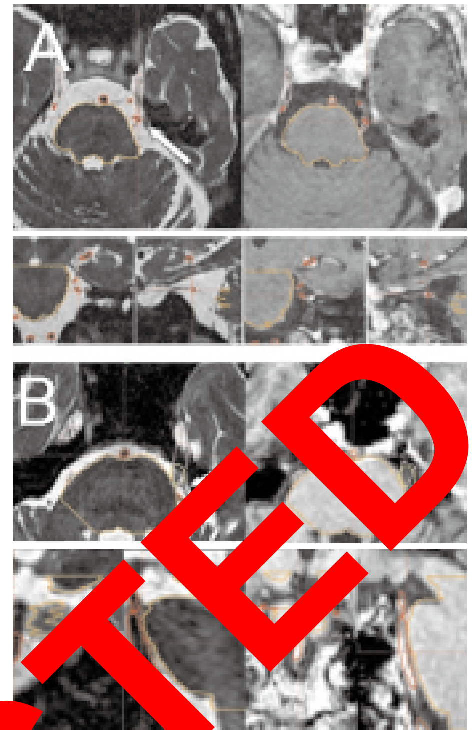

Figure 3. Neurovascular compression (NVC) resulted from basilar artery (a) and vertebral artery (b).
Arrow reveals the NVC site. Neurovascular compression (NVC) resulted from A[illegible] reveals the NVC site.

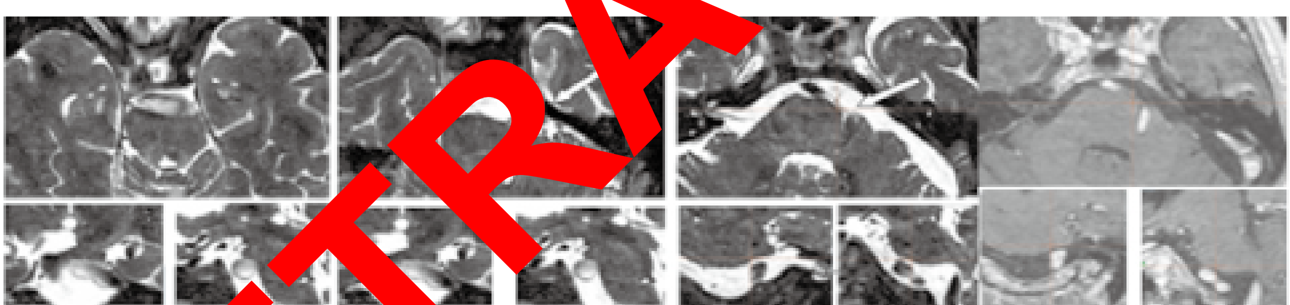

Figure 4. Neurovascular compression (NVC) resulted from AICA.
Arrow reveals the NVC site.

3.3. Patterns of blood vessels in patients with NVC

3.3.1. SCA

Generally, SCA is located at the proximal end of nervous descending part, coils and then rises up towards the distal end. The size of its vascular wing varies largely, which accounts for a high frequency in NVC patients. The contact between nerve and SCA had three patterns: (a) compression on the main SCA, which was the most frequent (60.6%, 43/71) (Figure 2); (b) horizontal crotch of SCA (21.1%, 15/71); and (c) one or two arteries contacting with nerve after branching (18.3%, 13/71).

3.3.2. AICA

Vascular compression appeared on the main AICA in 11 TN cases. The AICA rose up in the proximal part followed by vascular rings and then went down in the distal part. The contact sites were usually located horizontally against vascular ring (Figure 3a and 3b). This phenomenon was observed in seven cases (63.6%, 7/11), in four of which SCA compressed nerve root.

3.3.3. Basilar artery (BA)

BA caused NVC in two TN cases. One patient had extended and expanded BA, which resulted in nerve transfer and deformation of brain stem (Figure 4a), and the other had distorted BA.

3.3.4. VA

VA caused NVC in two TN cases. Both showed distortion of VA groove which was inferior to the origin of nerve root but did not contact with nerve root.

3.3.5. Vein

NVC resulted from veins was more uncertain because veins have multiple origins and largely varying anatomic structure. The contact between nerve and vein had six patterns: (a) superior petrolsal vein (Four cases); (b) transverse pontine vein vertically compressing nerve (Four cases) (Figure 5a); (c) cerebellar bridging vein (Three cases); (d) vein surrounding nerve along the long axis (One case) (Figure 5b); (e) veniplex surrounding nerve (One case).

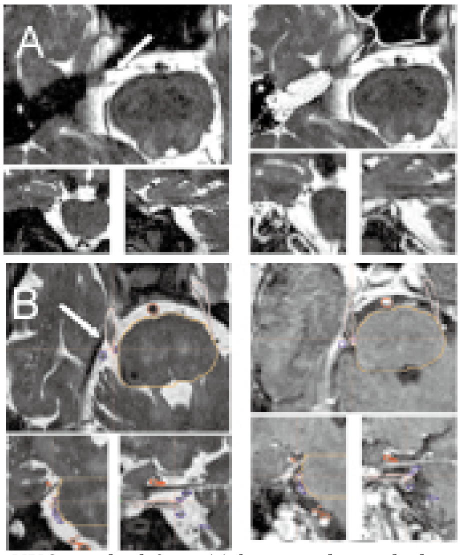

Figure 5. NVC resulted from (a) horizontal petrolsal vein and (b) veniplex around trigeminal nerve. Arrows reveals the NVC site.

4. Discussion

In the present study, the positive rate of NVC sign co[illegible] up to 93% as examined by 3D high resolution MRI sca[illegible]ng technique. Through image fusion and reconstructio[illegible]f 3D image sources, pathologic anatomic basis for NVC s[illegible] could be efficiently obtained. Anderson *et* [illegible]ared t[illegible] intraoperative observations in microvasc[illegible] dec[illegible]pressio[illegible] surgery with the pre-operative exami[illegible]on re[illegible] of high resolution 3D MRTA (TOF) image a[illegible]d ga[illegible] enhanced SPGR image in TN patients. Th[illegible]ound t[illegible]91% of NVC signs could be detected by [illegible] and the p[illegible]ve rate of responsible vessels was 76[illegible]. Hence, th[illegible]ensitivity and specificity of MRI were thoug[illegible] be 76% and 75%, respectively[4], which [illegible]n line with o[illegible]sults.

To determine the[illegible]sponsible vessel[illegible]s also important for the treatment [illegible]TN. A[illegible]nfirmed by surgical practice in 1 204 TN patie[illegible] SC[illegible] was co[illegible]idered to be the major responsible [illegible]el fo[illegible] (75.5[illegible] the cases). The positive rates of N[illegible]ed by [illegible]A as well as BA and PICA (poste[illegible]-infe[illegible]r cere[illegible]ar artery) compression were 9.6[illegible]% a[illegible]7% respectively. Additionally, veins were involve[illegible] in up to 68.2% of the TN cases[1]. However, [illegible]ur study, NVC resulted from vein compression was found o[illegible]n 14 cases, 10 of which just showed simple contact and th[illegible] of which showed cooperative compression from SCA and vein. This difference may be mainly attributed to the low sensitivity of MRI to veinlet. In fact, vessel will be concealed due to volume effect if its diameter is smaller than voxel size. The other reason is that the limited venous enhancement can also lead to the omission or unclearness of image, although the low-signal-density vascular mass in T2/T1 FIESTA image can be enhanced by fusion with high-signal-density mass in SPGR (TOF) image to a certain extent.

In this study, we found that the NVC sites could be detected at any site of whole trigeminal nerve running through subarachnoid space. The proximal and distal NVC sites accounted for 42% and 45% of the cases having NVC on the symptomatic side, respectively. The nerve part within 3 mm away from brain stem was defined as the proximal segment, because lemnocytes in this part originate from oligodendrocytes and can generate stronger algesthesia at the time of vascular compression[5,6]. The relationships between the blood vessel and trigeminal motor or sensory root reveal that the frequency of NVC between the trigeminal sensory root and SCA, AICA or vein was 45.5%, 4.5% and 54.5%, respectively, but the trigeminal motor root only touched with SCA with a frequency of occurrence of 48.5%. Therefore, the dislocation and distortion of nerve root caused by compression from responsible vessel were very specific signs for the diagnosis of TN.

For some TN patients, to fully und[illegible] the anatomic structure before operation is parti[illegible]rly i[illegible]ant for the development of surgical strate[illegible]he detai[illegible] anatomic structure of TN patients can help [illegible]ect prop[illegible]reatment strategy. For example, if ga[illegible] knife [illegible]apy i[illegible]ed to treat those TN patients with g[illegible] vessels (BA[illegible]) contacting with nerve or their co[illegible]ession [illegible] proxima[illegible]erve, pain will be exacerbated rather t[illegible] bei[illegible] relieved. The high resolution MRI can provid[illegible]taile[illegible] clea[illegible]atomic information of typical TN [illegible]ents, which [illegible] doctors to choose the best surger[illegible]. This is a[illegible]mportant for preoperative planning o[illegible] micro[illegible]ular decompression surgery. Hence, the application of 3[illegible]h resolution MRI and image fusion tec[illegible]s valuable fo[illegible]vestigating the complex pathologic a[illegible]omic mechanism of TN.

Co[illegible]t of in[illegible]est statement

[illegible]e declare that we have no conflict of interest.

Acknowledgments

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