

Evaluation of the vascular contacts of the facial nerve on three-dimensional fast imaging employing steady-state acquisition MRI in Bell's palsy

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Abstract

Objective: The purpose of this study was to demonstrate the vascular contact patterns of the facial nerve (FN) on three-dimensional fast imaging employing steady-state acquisition (3D-FIESTA) magnetic resonance imaging (MRI) and evaluate the correlation between these patterns, House-Brackmann (HB) grades and outcomes in Bell's palsy (BP).

Methods: Fifty-two patients with BP and 25 healthy controls were included in the study. Besides, a third group was formed by the asymptomatic sides of 52 patients. The vascular contact patterns of the FN on 3D-FIESTA MRI were classified with regard to the presence, number and anatomic location of the contact.

Results: A significant difference was found between the groups in terms of vascular contact patterns of the FN ($p<0.001$). Multiple vascular contacts were more prominent in the symptomatic sides of the patients. There was a positive statistical correlation between vascular contact patterns and HB grades at presentation and at the 3rd week and 3rd month follow-ups ($r=0.335$; $p=0.015$, $r=0.587$; $p<0.001$ and $r=0.493$; $p<0.001$).

Conclusion: Multiple vascular contacts of the FN on 3D-FIESTA MRI were found to be more common and associated with poor recovery in BP. Thus, 3D-FIESTA MRI may provide prognostic information in BP.

Keywords: 3D-FIESTA MRI, Bell's palsy, facial nerve, vascular contacts.

Özet: Bell felcinde kararlı-durum eldeli MRG ile hızlı üç boyutlu görüntüleme de fasiyal sinire vasküler basının değerlendirilmesi

Amaç: Bu çalışmanın amacı, üç boyutlu kararlı-durum eldeli hızlı manyetik rezonans görüntüleme (3D-FIESTA) fasiyal sinirin vasküler bası kalıplarını göstermek, bunun yanı sıra bu kalıplar, House-Brackmann (HB) derecelendirmeleri ve Bell felcindeki (BP) sonuçlar arasındaki korelasyonu değerlendirmektir.

Yöntem: Çalışmaya 52 BP hastası ve 25 sağlıklı kontrol dahil edildi. Ayrıca 52 hasta da sağlıklı (asemptomatik) taraf üçüncü grubu oluşturdu. Vasküler temasın varlığı, sayısı ve anatomik yerleşimine göre fasiyal sinirin vasküler temas kalıpları 3D-FIESTA MRG'de sınıflandırıldı.

Bulgular: Yüz sinirinin vasküler bası kalıpları bakımından gruplar arasında anlamlı bir farklılık saptandı ($p<0.001$). Hastaların semptomatik taraflarında çoklu vasküler basılar daha belirgindi. Hasta geldiğinde, 3. hafta ve 3. aydaki kontrollerde vasküler bası kalıplarıyla HB dereceleri arasında pozitif istatistiksel korelasyon mevcuttu ($r=0.335$; $p=0.015$, $r=0.587$; $p<0.001$ ve $r=0.493$; $p<0.001$).

Sonuç: 3D-FIESTA MRG'de fasiyal sinirin çoklu vasküler basısının çok daha sık olduğu ve BP'de düşük iyileşme oranlarıyla ilişkili olduğu saptanmıştır. Bu nedenle, 3D-FIESTA MRG BP'de prognostik bilgi sağlayabilir.

Anahtar sözcükler: 3D-FIESTA MRG, Bell felci, vasküler bası, yüz siniri.

Bell's palsy (BP) is a rapid unilateral facial nerve paresis/paralysis with idiopathic etiology. The most common cause of unilateral peripheral facial weakness is BP, and BP leads to the inability of voluntary movements of

the affected side of the face.^[1] Other etiologies of unilateral peripheral facial weakness include trauma, iatrogenic injuries, infections, neoplastic diseases, autoimmune diseases, and otologic diseases.^[2]

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Idiopathic acute facial palsy, known as BP, is primarily hypothesized to occur as an inflammatory response to *Herpes simplex* virus type 1 (HSV-1) infection with subsequent blockage of the neural activity. The underlying mechanism of BP, such as microcirculatory failure of the vasa nervorum and ischemic neuropathy, still remain unknown even if the viral etiology has been discussed by several authors.^[3] Furthermore, it was suggested that causes of secondary facial palsy and BP may coexist, and while patients with BP present with facial paresis/palsy as a primary complaint, not all patients with facial paresis/palsy have BP. Thus, the presence of contributing factors such as coexisting anatomical differences along the course of the facial nerve is an open question.

The cerebellopontine angle (CPA) cistern or internal auditory canal (IAC) crossed by the facial and vestibulocochlear nerves may be involved in various pathologies, such as neurogenic and glomus tumors, leptomeningeal disease and vascular lesions. Vertebrobasilar dolichoectasia, aneurysm and vascular loops may produce vestibulocochlear symptoms such as sensorineural hearing loss, vertigo or tinnitus, as well as facial palsy.^[4] The branches of the anterior inferior cerebellar artery (AICA) and the posterior inferior cerebral artery (PICA) in the CPA cistern usually run between the facial and vestibulocochlear nerves and may have contact with them. The three-dimensional fast imaging employing steady-state acquisition (3D-FIESTA) magnetic resonance imaging (MRI) technique is valuable for demonstrating the course of the facial nerve from the brain stem to the IAC and provides a clear depiction of these neurovascular contacts.

The purpose of our study was to compare 3D-FIESTA MRI scans between patients with and without a history of facial palsy and to determine whether these vascular contacts may contribute to the risk for this disease. We also analyzed whether there was a correlation between the vascular contact patterns of the facial nerve and House-Brackmann (HB) facial nerve grading scores, outcomes and recovery of the patients or not. To our knowledge, this study is the first to demonstrate the vascular contact patterns of the facial nerve on 3D-FIESTA MRI and evaluate the correlation between these patterns and the grade of facial palsy and outcomes in patients with facial palsy.

Materials and Methods

This single center retrospective study was conducted at the Radiology, Otorhinolaryngology and Neurology departments of our institution. The study protocol was approved

by the institutional ethical committee and written informed consent was waived due to its retrospective nature.

The medical records of 52 patients with unilateral Bell's palsy and 25 healthy controls were retrospectively evaluated. Patients presenting with acute onset of idiopathic unilateral facial palsy and who subsequently underwent temporal bone MRI were included in the study. Patients with any evidence of congenital, autoimmune, neurovascular, traumatic, neoplastic or infectious etiologies and with a history of temporal bone surgery, history of facial palsy on the opposite side or bilateral nerve palsy were excluded. All patients in the study received 10 days of oral prednisone therapy (60 mg oral prednisone for 5 days with 5 days of gradually decreasing doses) initiated within 72 hours of symptom onset and were followed up for at least 3 months. Also, according to the records of topographic test results, the facial nerve was affected proximal to the geniculate ganglion in all patients. The grade of facial nerve palsy was recorded at presentation, at 3rd week and at 3rd month after initial symptom onset, according to the House-Brackmann (HB) facial nerve grading system.^[5]

Patients who were referred for brain MRI with complaint of headache and reported to be otherwise healthy, and those without a history of facial palsy were included in the control group. Both sides of the 25 patients in the control group were evaluated separately, constituting a group of 50 facial nerve sides. Besides the facial palsy and control groups, a third group was formed by the asymptomatic sides of the 52 patients with facial palsy. All subjects were evaluated for vascular contacts of the facial nerve on 3D-FIESTA MRI.

Magnetic resonance imaging was performed on a General Electric (GE) Signa 1.5 T MRI scanner (GE Healthcare, GE Medical Systems, Milwaukee, WI, USA) with an eight-channel head coil. For high-resolution MR images of the IAC, axial 3D-FIESTA sequence was used with the following scanning parameters: repetition time, 5.5 ms; echo time, 2.1 ms; bandwidth, 244 Hz/px; section thickness, 0.8 mm; slice gap, 0.6 mm; matrix size, 256×256; number of excitations, 4; flip angle, 65°; field of view, 220 mm.

All images were interpreted retrospectively based on the consensus of two national board-certified radiologists with five and ten years of experience in head and neck radiology, respectively. The radiologists knew that the patients all had acute facial palsy; however, they were blinded to the original MRI reports and clinical findings. Each study was recruited from the Picture Archiving and Communication System (Centricity PACS; GE Healthcare, Milwaukee, WI, USA) and loaded onto a dedicated workstation with three

3MP high-resolution monitors (Barco, Inc., Kortrijk, Belgium). The vascular contact patterns of the facial nerve were classified with regard to the presence, number and anatomic location of the neurovascular contact (Table 1, Fig. 1). In order to demonstrate the course of the facial nerve from the brain stem to the IAC and to depict the neurovascular contacts, sagittal, semi-sagittal and semi-coronal reconstructions were created on axial 3D-FIESTA images with the scanner console.

Analysis of the results was performed using the IBM SPSS Statistics Version 21.0 software for Windows (Armonk, New York, NY, USA). Data were tested for normal distribution using the Kolmogorov-Smirnov test. Data were described using mean and standard deviation for continuous normal distributions and frequency for categorical variables. Comparisons between groups were performed using Kruskal-Wallis test for nonparametric variables with more than two groups. Chi-square test was performed for categorical variables. Spearman's correlation analysis was used for the analysis of the correlations among parameters. Statistical significance was defined as $p < 0.05$.

Table 1. Vascular contact patterns of the facial nerve.

Type I	Absence of a vascular contact
Type II	Presence of a single vascular contact in any of the three anatomical locations of the facial nerve including the root entry/exit zone (REZ), the cisternal and the intracanalicular segments
Type III	Presence of multiple vascular contacts (contacts with more than one vessel in the same anatomic location and/or contacts in more than one anatomic location)

Results

Subjects

After patients with a history of facial palsy on the opposite side ($n=1$), history of bilateral facial palsy ($n=1$), vestibular schwannoma ($n=3$), stroke ($n=2$), middle ear and mastoid inflammation ($n=4$), and Ramsay Hunt syndrome ($n=3$) were excluded, 52 patients [29 (55.8%) women; mean age 45.7 ± 18] with acute onset of idiopathic unilateral facial palsy and 25 controls with 50 facial nerves [27 (54%) women; mean age 44.8 ± 18.5] without a history of facial palsy were included in the study. There was no significant difference between

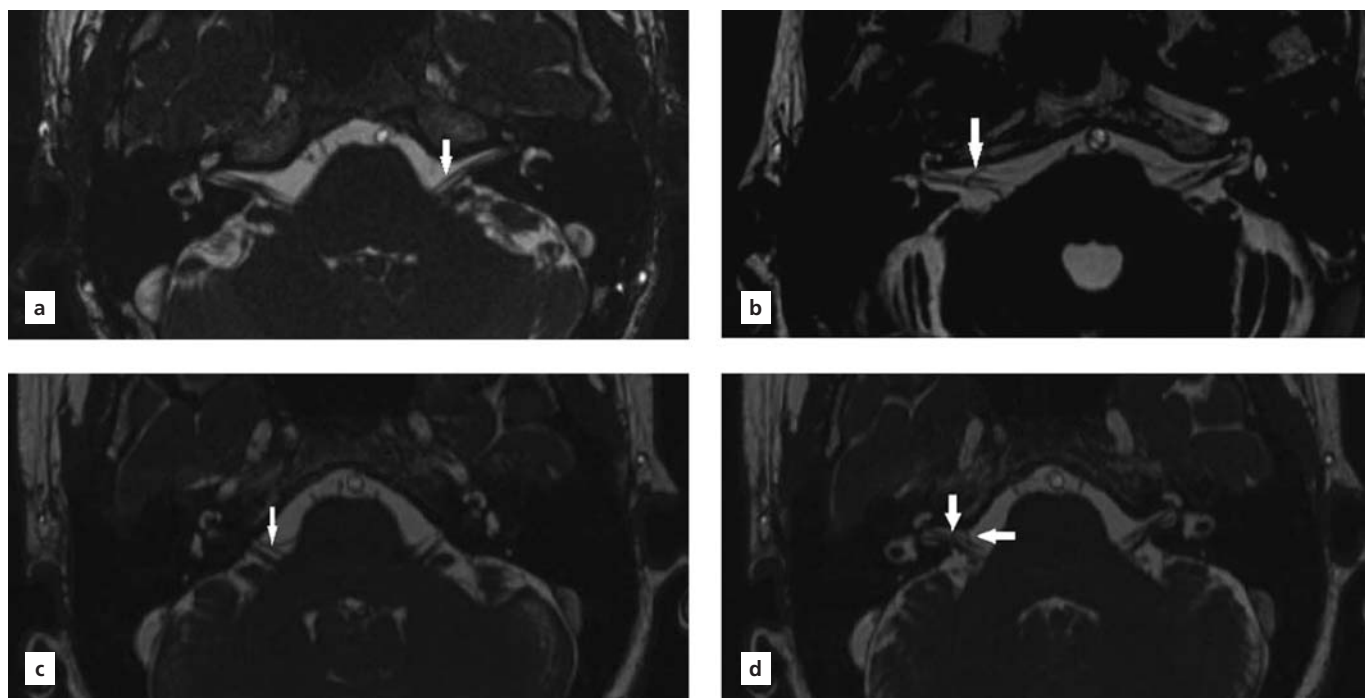


Fig. 1. Examples of vascular contact patterns on axial 3D-FIESTA images. (a) Type I, absence of a vascular contact of the left facial nerve is seen (arrow). (b) Type II, presence of a single vascular contact in the proximal intracanalicular segment of right facial nerve is seen (arrow). (c, d) Type III, presence of multiple vascular contacts in more than one anatomic location (cisternal and intracanalicular segments) of the right facial nerve is seen (arrows).

the study and the control group in terms of gender and age ($p=0.97$ and $p=0.95$, respectively). Besides the facial palsy and control groups, a third group was formed by the asymptomatic sides of the patients with facial palsy. A total of 154 sides including 52 symptomatic sides and 52 asymptomatic sides of the patients with facial palsy and 50 (both sides of 25 patients) sides in the control group were evaluated on 3D-FIESTA MRI.

MRI results

The vascular contact patterns of the facial nerve in the symptomatic sides of the study group, asymptomatic sides of the study group and in the control group were as follows, respectively: 5 (9.6%), 28 (53.8%) and 29 (58%) were classified as type I; 13 (25%), 14 (26.9%) and 16 (32%) were classified as type II; and 34 (65.4 %), 10 (19.2 %) and 5 (10 %) were classified as type III. A significant difference was found between groups in terms of vascular contact patterns of the facial nerve ($p<0.001$). Presence of multiple vascular contacts (contacts with more than one vessel in the same anatomic location and/or contacts in more than one anatomic location) (type III vascular contact pattern) was more prominent in the symptomatic sides of the study group, while absence of a vascular contact (type I vascular contact pattern) was more prominent in the asymptomatic sides of the study group and in the control group.

HB facial nerve grading score results

According to the HB facial nerve grading system, 12 patients were grade V, 23 patients were grade IV, 11 patients were grade III, and 6 patients were grade II at presentation. Two patients were grade V, 9 patients were grade IV, 21 patients were grade III, 13 patients were grade II, and 7 patients were grade I at the 3rd week from the initial symptom onset. Complete recovery was achieved in 29

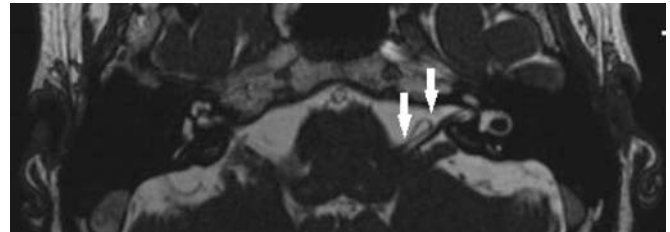


Fig. 2. A 52-year-old woman with recurrent left facial palsy (recurrent case no. 2). Axial 3D-FIESTA image shows multiple vascular contacts (arrows) in cisternal segment of the left facial nerve (Type III contact pattern).

patients after 3 months of treatment with corticosteroids. Regarding the remainder of the patients, 16 were grade II, 6 were grade III and one was grade V. There was a positive statistical correlation between vascular contact patterns of the facial nerve and HB grades of the patients at presentation, at the 3rd week and at the 3rd month follow-up ($r=0.335$; $p=0.015$, $r=0.587$; $p<0.001$ and $r=0.493$; $p<0.001$). Therefore, patients who had vascular contacts of the facial nerve on the symptomatic sides had higher HB grades both at presentation and in the follow-up period in comparison to patients who had no vascular contacts.

Four patients had recurrent disease on the same side and all of them had type III vascular contact patterns of the facial nerve on the symptomatic side, while 2 patients had type I, and 2 patients had type III pattern on the asymptomatic side. One of these patients, who was HB grade V at the 3rd month follow-up, did not recover after 4 months of standard treatment and reconstructive procedures were performed to improve the appearance of the paralyzed facial side (Fig. 2). The vascular contact patterns, HB grades and outcomes of these recurrent cases are shown in Table 2. Three of the patients in the study group (one of them had recurrent disease) had higher HB grades at the 3rd week than at presentation and all of them had type III vascular contact patterns of the facial nerve on

Table 2. Vascular contact patterns on the affected sides, House-Brackmann grades and outcomes of the recurrent cases.

Case	Vascular contact pattern	House-Brackmann grade			Outcome
		Presentation	3rd week	3rd month	
No. 1	Type III	IV	II	I	Complete recovery at 5th month
No. 2	Type III	III	V	V	Progression during follow-up, reconstructive procedure at 4th month
No. 3	Type III	V	III	II	Complete recovery at 5th month
No. 4	Type III	V	IV	II	Complete recovery at 5th month

the symptomatic side. Complete recovery was achieved after 6 months of standard treatment in two of them, while in one who had recurrent disease the recovery was not achieved after 4 months of standard treatment and reconstructive procedures were performed. One patient with a history of bilateral facial palsy who was excluded from the study also had type III vascular contact patterns on both sides (Fig. 3).

Discussion

BP is an acute unilateral facial nerve paresis or paralysis that appears in less than 72 hours without any identifiable cause.^[1] Although the precise cause remains unclear, numerous etiologies have been proposed, such as ischemic neuropathy, autoimmune diseases and viral inflammation of the facial nerve.^[6,7] The most commonly accepted etiology, however, is HSV-1 infection that induces edema within the facial nerve as an inflammatory response.^[8] Some risk factors for the development of BP have been identified, including pregnancy, severe preeclampsia, diabetes, hypertension, obesity, and upper respiratory tract infections.^[1,9] On the other hand, HSV-1 infection is relatively common in comparison to BP, thus, the presence of contributing factors such as vascular contacts along the course of the facial nerve is a factor to explain why some patients develop palsy and others do not.

In this study, we have demonstrated that vascular contact patterns of the facial nerve on 3D-FIESTA MRI differ in patients with facial palsy. The type III contact pattern was found to be more common on the affected side in patients with facial palsy. Furthermore, it was shown that patients with multiple vascular contacts had higher HB grades both at presentation and at control in comparison to patients with no vascular contacts of the facial nerve.

Hemifacial spasm is a neurovascular compression syndrome (NVCS) of the facial nerve that is characterized by unilateral, intermittent contractions of the muscles of facial expression. NVCS refers to direct contact of cranial nerves by blood vessels that results in mechanical irritation.^[10,11] This mechanical irritation has been proposed to cause demyelination, compression-induced conduction block, edema, and gliosis.^[11,12] In idiopathic peripheral facial palsy, inflammation and edema associated with HSV-1 infection have been implicated as the cause of the entrapment of the facial nerve that initiates the ischemic neuropathy. Nevertheless, the exact cause of inflammation, the location of entrapment and anatomical differences or contributing factors in peripheral facial palsy still

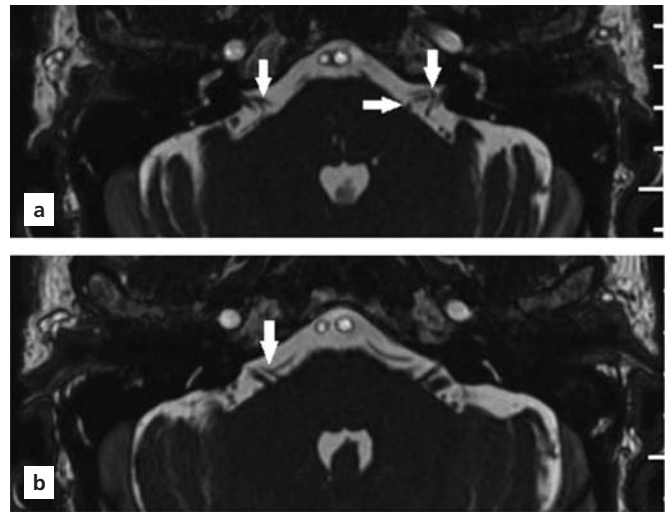


Fig. 3. A 43-year-old man with bilateral facial palsy. (a, b) Axial 3D-FIESTA images show multiple vascular contacts (arrows) in cisternal segments of the left and right facial nerves (Type III contact pattern on both sides).

remains unknown. On the other hand, vascular pathologies of the cisternal and intracanalicular segments of the facial nerve, such as vertebrobasilar dolichoectasia, vertebrobasilar and PICA or AICA aneurysms and loops are considered in the etiology of facial nerve palsy.^[13,14] Given that multiple vascular contacts were found to be more common on the affected sides in facial palsy cases versus the unaffected sides and controls in our study, we propose that these vascular contacts, though unlikely to be the main predisposing factor in the development of BP, may nevertheless contribute to the risk. The underlying mechanism may be similar to that in NVCS. Vascular contacts that lead to mechanical irritation of the facial nerve and microcirculatory failure of the vasa nervorum may promote the edema associated with HSV-1 infection.

MRI provides optimal soft tissue resolution and has greater accuracy for detecting nervous system lesions compared to other imaging modalities. However, some controversy exists in the literature regarding the value of MRI in cases of idiopathic facial palsy. While MRI, particularly obtained after intravenous administration of gadolinium-chelate, was considered to be of limited value in some studies, others reported that facial nerve enhancement on MRI is valuable in the diagnosis and is associated with a poor prognosis.^[13,15-17] Furthermore, clinicians are discouraged from routinely performing diagnostic imaging for patients with new onset Bell's palsy.^[1] On the other hand, 3D-FIESTA MRI provides much higher spatial resolution than rou-

tine MRI sequences and accurate visualization of the cisternal portion of the cranial nerves without the need for intravenous administration of gadolinium-chelate. In the previous studies, direct contact of cranial nerves by blood vessels depicted on MRI has been proposed as a cause of trigeminal neuralgia, hemifacial spasm, vestibulocochlear paroxysmia, and glossopharyngeal neuralgia.^[11,18-20] In our study, we found that multiple vascular contacts of the facial nerve were more common in patients with Bell's palsy and the presence of these vascular contacts was associated with poor recovery after standard treatment. While most patients with Bell's palsy show complete recovery within 3 to 4 months, 30% of patients do not recover completely and have poor outcomes.^[1] These patients may experience dramatic effects of the facial palsy on their appearance, quality of life and psychological status. Thus, we may assume that 3D-FIESTA MRI may be valuable in predicting the prognosis in patients with Bell's palsy, particularly in those with recurrent disease and/or progression in HB grades during follow-up. In this way, patients who will require emergency facial nerve surgical decompression and appropriate rehabilitation can be determined beforehand.

In our study, we have demonstrated and classified the vascular contact patterns of the facial nerve on 3D-FIESTA MRI in patients with Bell's palsy. The classification system used in the current study is primarily based on the presence of neurovascular contacts. As loop formation of a vessel is not essential to cause neurovascular contact, using the "vascular loops" definition was consciously avoided in order to determine the actual contacts that have the highest possibility to contribute to neurovascular compression. Second, we have considered the number of contacts. We classified multiple contacts (contacts with more than one vessel or contacts within more than one anatomic location) as a separate group. We believe that this classification may help in standardization of MRI reports in the relationship between the branches of AICA/PICA and cranial nerves along their courses from the brain stem to the IAC in future studies.

Our study has several limitations. The study design was single center and retrospective. The classification system used to define vascular contacts of the facial nerve on 3D-FIESTA MRI was based on the consensus of two radiologists. However, this classification system needs to be validated in future studies. Some risk factors for the development of Bell's palsy including diabetes, hypertension and obesity could be excluded; however, only four patients had these risk factors and this did not change the results of the study

significantly. Also we did not determine whether the contact vessel is an artery or vein. Probably contact of an artery may cause more microcirculatory failure of the vasa nervorum than a vein. However, this initial study on this subject may serve as a starting point for conducting a prospective study involving a larger patient cohort where clinical variables could be controlled in order to draw useful conclusions.

Conclusion

We have demonstrated that multiple vascular contacts of the facial nerve on 3D-FIESTA MRI were more common in patients with Bell's palsy. The mechanical irritation associated with these vascular contacts may contribute to the risk by promoting edema associated with HSV-1 infection. Furthermore, presence of these vascular contacts was associated with poor recovery after standard treatment. Thus, 3D-FIESTA MRI may provide valuable prognostic information in patients with Bell's palsy and would be most beneficial in those with recurrent disease and/or progression in HB grades during follow-up.

Conflict of Interest: No conflicts declared.

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