RESEARCH ARTICLE

Mandibular canal visibility using a plain volumetric interpolated breath-hold examination sequence in MRI

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Objectives: To evaluate the validity of plain volumetric interpolated breath-hold examinations (VIBE) for detecting the course of the mandibular canal, and to compare the results with contrast-enhanced (CE) VIBE images.

Methods: From our imaging archives, we collected 28 cases taken with a VIBE sequence both before and after intravenous administration of gadolinium hydrate, and then two observers evaluated neurovascular bundle (NVB) visibility in the VIBE images. For the invisible NVB cases, we identified the invisible areas and analysed the causes of invisibility. For cases that also had corresponding CT thin slice images, we obtained a fusion image between MRI and CT, and investigated the relationship between the NVB in VIBE and the mandibular canal in CT images.

Results: The visibility of the NVBs in plain VIBE was 89%, the same as on CE VIBE. There were three invisible cases in each plain and CE VIBE images. The invisible areas were premolar in three cases, and molar in one case, and the causes of the invisibility were a metallic artefact in one case and motion artefacts in the other two cases.

Conclusions: A plain VIBE can depict the NVB at the same rate as CE VIBE, and is suitable for detecting NVBs.

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Introduction

Dental practice sometimes necessitates detecting the mandibular canal (MC) to prevent neurosensory disturbances.¹ It is typical to employ CT examination² for locating the MC course three-dimensionally;³ however, this approach is limited for the identification of the MC, with a maximum identification rate of 82%.⁴ In a previous study, we demonstrated that it is useful to employ MRI examination for undetected MC cases,⁵ because MRI can depict inferior alveolar neurovascular bundles (NVBs) at the higher rate than CT, and fusion images between MRI and CT can help us to identify the course of the MC. In that study, we collected

from image archives cases possessing CT thin slice data or three-dimensional volumetric interpolated breath-hold examination (3D-VIBE) data, and investigated their concordances on fusion images. The fusion image technique has already reached a level suitable clinical use, but it remains unclear whether the use of contrast media is necessary.⁶ The VIBE sequence was originally developed for 3D examinations after gadolinium (Gd) administration, which could deliver an image with high spatial resolution image with isotropic voxels;^{7,8} however, the administration of contrast medium is costly and time-consuming, and could potentially cause allergic side effects or nephrogenic systemic fibrosis in renal failure patients.⁹ If a plain VIBE image could provide similar information to contrast-enhanced (CE) MRI, it

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would be sufficient to perform only the plain examination. The aim of this study was to evaluate the validity of plain VIBEs for detecting the course of the MC, and to compare the results with CE VIBE.

Methods and Materials

Examination image data collection

This was a retrospective study, and we selected from our imaging archives cases taken with a VIBE sequence both before and after an intravenous administration of Gd hydrate. The data set consisted of 18 cases from March 2015 to April 2016; the patients were 11 males and 7 females whose ages ranged from 11 to 84 years (mean, 53.3 years). The patients were examined because they had cystic lesions (10 cases), benign tumours (3 cases) or malignant tumours (5 cases). In this study, the right and left mandibles were evaluated as independent cases, but of the 36 hemi-mandibles, 8 were excluded because the MC passed through a lesion. The remaining 28 hemi-mandibles were included in the study.

All patients were examined with a Magnetom Spectra 3T MRI scanner (Siemens Healthcare, Forchheim, Germany), a 16-channel head and neck array coil and a 3D-VIBE sequence. The scan parameters were those used routinely in clinical practice: repetition time/echo time of 13.7/3.9 msec, flip angle of 20°, field of view of 150 × 150 mm and matrix size of 192 × 192; the scans take 3 min and 35 s. These patients were examined with a VIBE before and after intravenous administration of Gd (0.2 ml kg⁻¹) owing to some clinical necessity.

The study was approved by the institutional review board of Tokyo Medical and Dental University (No. D2015-530), and informed consent was waived owing to the retrospective nature of this study.

Evaluation of the images

The obtained image data sets were observed by two oral and maxillofacial radiologists (CD and HW). Evaluations were performed on a Syngo.via VA20A workstation (Siemens) with a 24.1-inch light-emitting diode monitor (EIZO, Ishikawa, Japan) in a dim room. The observers evaluated whether NVB could be recognized in the 3D-VIBE images. An NVB was defined as visible when one can track the course of continuous high signal intensity, and as invisible NVB when the course was interrupted. The 28 hemi-mandibles were evaluated as independent cases, and the images of plain and CE VIBE were observed independently. The evaluation of NVB visibility was performed twice, at 3-week intervals, and intra- and interobserver reliability was calculated. Disagreement between the two observers was resolved by discussion, and a consensus was reached.

For each NVB invisible case, the hemi-mandible was divided in three areas premolar (PM), molar (M) and retromolar (RM) as previously described,⁵ and the locations of invisible area were specifically identified.

Table 1 Visibility of neurovascular bundle in plain VIBE and CE VIBE images

Sequences	Visible (%)	Invisible (%)	Total
Plain VIBE	25 (89)	3 (11)	28
CE VIBE	25 (89)	3 (11)	28

CE, contrast-enhanced; VIBE, volumetric interpolated breath-hold examination.

Fusion volumetric images

Because we collected cases possessing either plain or CE VIBE in this study, the number of cases with corresponding CT thin slice images was limited to 17. The presence of corresponding images was necessary for creation of fusion volumetric images between MRI and CT. The CT images had been taken by multislice CT using a Somatom Sensation 64 (Siemens) with settings of 120-kV tube voltage, 140-mA effective tube current or 190-mA quality effective current, 64 × 0.6 mm collimation and a pitch of 0.6, and the thin slice images were reconstructed with thickness of 0.6 mm in 0.3-mm increments. For patients under 12 years old, reduced-quality effective tube currents of 45–70 reference mA were applied. We could obtain a fusion image on the Syngo.via workstation, as described in the previous study, for 17 cases,⁵ in which we investigated the relationship between the MC and NVB.

Statistical analysis

Intraclass correlation analysis was used to evaluate intra- and interobserver variabilities, and Cohen's κ coefficients were also calculated; $p < 0.01$ was considered to be statistically significant.

Results

The visibility of the NVBs on plain and CE VIBE was evaluated for 28 hemi-mandibles, and the results after reaching a consensus are summarized in Table 1. The visibility in plain VIBE was 89%, the same as in CE VIBE. The data were obtained from two evaluations from both of the observers; the intraobserver reliabilities (the κ -values) were 1.000 (1.000) and 1.000 (1.000) in plain VIBE observations, and 0.787 (0.781) and 0.841 (0.711) in CE VIBE. Interobserver reliability was 0.751 (0.627) and 0.780 (0.741) for plain and CE VIBE, respectively. These values indicated there was

Table 2 Location of the invisible neurovascular bundle area in plain VIBE and CE VIBE images

Sequence	PM	M	RM
Plain VIBE	3	1	0
CE VIBE	3	1	0

CE, contrast-enhanced; M, molar; PM, premolar; RM, retromolar areas; VIBE, volumetric interpolated breath-hold examination.

Figure 1 Cases of invisible neurovascular bundles. (a) One case (51-year-old male) showing a metallic artefact. The artefact was observed in the right mandible, which influenced the premolar and molar area and interrupted the course of the right NVB. There was a high-signal intensity area in the left mandible on coronal view caused by invasion of a malignancy. (b) These figures depict one typical case (84-year-old female) showing a motion artefact. The anatomical structures are depicted as blurred, and the NVB is also depicted as a broad blurred band. CE, contrast-enhanced; NVB, neurovascular bundle; VIBE, volumetric interpolated breath-hold examination.

substantial or almost perfect agreement within each observer, as well as between the two observers.

There were three invisible cases in each plain and CE VIBE images, and the invisible areas were defined, as summarized in Table 2. The areas were PM in three cases, and M in one case. Furthermore, the causes of invisibility were analysed. One case was owing to a metallic artefact, which influenced the PM and M areas, and was common to plain and CE VIBE (Figure 1a). The other two cases were owing to motion artefacts, a typical example of which is shown in Figure 1b.

All the other cases were visible NVBs, and representative useful VIBE images are shown in Figures 2–4. Figure 2 shows typical plain and CE VIBE images, Figure 3 the bifid MC case and Figure 4 a comparison of a useful CT/plain-VIBE fusion image with a difficult case, highlighting the superior border of the MC on CT images.

Discussion

In our previous study, we demonstrated that CE 3D-VIBE images are useful for identifying the course of MC, even for cases that could not be detected by CT.⁵ Detectability was up to 98% in MRI, but was limited to 68% when only CT was used. However, there is one concern remaining regarding the necessity of injecting a contrast medium (Gd). Gd injection is certainly useful for examining cases of cyst, benign or malignant tumours or inflammation because it can depict the interiority and the extents of the lesions;^{8,10} however, it remains controversial whether to identify the course of

Figure 2 Comparative observation between plain and CE VIBE images (47-year-old female). The same sagittal and coronal sections are shown, and the corresponding CT images are also lined up as a reference. The neurovascular NVB was depicted on both plain and CE VIBE images in the same manner, but the contrast on CE VIBE is higher than that of plain VIBE, and the branches as nutrient canals from NVB were better observed on CE VIBE. CE, contrast-enhanced; NVB, neurovascular bundle; VIBE, volumetric interpolated breath-hold examination.

the MC on the assumption of a dental implant operation or an extraction of an impacted tooth. Mensel *et al*⁶ reported that plain VIBE is sufficient to measure the diameter of the thoracic and abdominal aorta, yielding reliable results in comparison with CE MR angiography. This study was conducted to determine whether plain VIBE is inferior to CE VIBE. We found that the visibility of NVBs in plain VIBE was 89%, the same as in CE VIBE. In addition, the intra- and interobserver correlations exhibited substantial and almost complete agreements, indicating that NVBs can be identified with great confidence. Although visibility was lower than in the previous study, the difference was within sampling variation. Incidentally, we selected from the imaging archive another 60 cases taken with only plain VIBE without CE VIBE; their

Figure 3 A case of bifid mandibular canal (35-year-old male). The figures are plain VIBE, CE VIBE, CT and CT/plain-VIBE fusion images. The dotted lines (A and B) represent the section locations of the coronal views. On CT images, the mandibular canal is clearly observed, but there was a junction in the retromolar area (the arrow). The bifid NVB was well observed in both plain and CE VIBE images, and the contrast on CE VIBE was relatively higher than that on plain VIBE. The inferior secondary canal could not be identified in CT coronal view (coronal B), but could be identified in plain and CE VIBE images, and it is especially easy to identify the location in the CT/plain-VIBE fusion image (coronal B). CE, contrast-enhanced; VIBE, volumetric interpolated breath-hold examination.

Figure 4 A useful case of a CT/plain-VIBE fusion image. The patient was an 11-year-old female, and reduced-quality effective tube currents of 45–70 reference mAs were applied. In children, it is sometimes difficult to identify the MCs, and in this case it is difficult to see the superior border of the MC on CT images. However, it is easy to identify the neurovascular location in the CT/plain-VIBE image. CE, contrast-enhanced; MC, mandibular canal; VIBE, volumetric interpolated breath-hold examination.

rate of NVB visibility was the almost the same, 88% (53/60). Hence, we believe that plain VIBE can provide NVB visibility that is not inferior to that of CE VIBE.

The analysis of the three invisible cases revealed that two of them were owing to motion artefacts, and the other case was from a metallic artefact. Patients are not allowed to move during the examination because such movement could cause motion artefacts. One potential reason for movement is that our 3D-VIBE sequence is routinely performed as the last session of an MRI examination after conventional T_1 and T_2 weighted sequences; hence, patients are apt to move involuntarily owing to fatigue from the long examination, which lasts approximately 50 min. By contrast, the VIBE sequence is sufficiently optimized to obtain a high-quality image within a short examination time (3 min and 35 s), which could not be shortened further. If the purpose of the examination was limited to identification of NVBs, it would be sufficient to perform the plain VIBE protocol independently. Alternatively, if we must consider employing another sequence, one candidate is StarVIBE, which would be effective for moving patients and enable us to obtain 3D volume data with movement compensation using the radial sampling method.¹¹ For a metallic artefact, the VIBE belongs to the gradient echo sequences, which is relatively weak to a metallic artefact in exchange for a shorter acquisition time. In most studies, a VIBE sequence has been used to depict NVBs.^{12–14} Several studies employed spin echo sequences,^{15,16} but they have not more effectively depicted NVBs. Hence, in some cases, a clinician must potentially remove the metals causing a metallic artefact owing to the clinical requirements for identifying the MC.

In this study, we revealed that plain VIBE can depict NVBs as the same rate as CE VIBE. This is

advantageous to patients for whom it is necessary to identify the course of the MC not detected by CT, because a plain VIBE never requires Gd injection, leading to shorter examination time, lower examination cost and avoidance of any side effects from Gd. Although there are some contraindications for MRI examinations, such as electronic and/or metallic medical devices, metallic implants such as tattoos, and claustrophobia, we can recommend that clinicians perform a plain VIBE MRI examination for the purpose of identifying the course of the MC.

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Conclusions

Plain VIBE can depict the NVB at the same rate as CE VIBE. Hence, plain VIBE would be a sufficient examination for patients whose MC cannot be detected using CT.

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