European Journal of Radiology 97 (2017) 65–70

Contents lists available at ScienceDirect

European Journal of Radiology

journal homepage: www.elsevier.com/locate/ejrad

Original article

Retrospective comparison of three-dimensional imaging sequences in the visualization of posterior fossa cranial nerves

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ARTICLE INFO

Keywords:
Magnetic resonance imaging
Cranial nerves
Cisternography
Heavily T2-weighted imaging

ABSTRACT

Purpose: To compare efficancy of three-dimentional SPACE (sampling perfection with application-optimized contrasts using different flip-angle evolutions) and CISS (constructive interference in steady state) sequences in the imaging of the cisternal segments of cranial nerves V–XII.

Methods: Temporal MRI scans from 50 patients (F:M ratio, 27:23; mean age, 44.5 ± 15.9 years) admitted to our hospital with vertigo, tinnitus, and hearing loss were retrospectively analyzed. All patients had both CISS and SPACE sequences. Quantitative analysis of SPACE and CISS sequences was performed by measuring the ventricle-to-parenchyma contrast-to-noise ratio (CNR). Qualitative analysis of differences in visualization capability, image quality, and severity of artifacts was also conducted. A score ranging 'no artefact' to 'severe artefacts and unreadable' was used for the assessment of artifacts and from 'not visualized' to 'completely visualized' for the assesment of image quality, respectively. The distribution of variables was controlled by the Kolmogorov–Smirnov test. Samples *t*-test and McNemar's test were used to determine statistical significance.

Results: Rates of visualization of posterior fossa cranial nerves in cases of complete visualization were as follows: nerve V (100% for both sequences), nerve VI (94% in SPACE, 86% in CISS sequences), nerves VII–VIII (100% for both sequences), IX–XI nerve complex (96%, 88%); nerve XII (58%, 46%) ($p < 0.05$). SPACE sequences showed fewer artifacts than CISS sequences ($p < 0.002$).

1. Introduction

Magnetic resonance imaging (MRI) provides a significantly superior method of assessing neurovascular structures of the posterior fossa when compared to other radiological techniques. Moreover, modern MR cisternography now enables clinicians to treat previously unidentifiable neuralgias due to vascular compression. However, the success of the operation is dependent on the ability of the clinical team to determine the relationship of the mass lesion to adjacent neurovascular structures, and further advancements in microsurgical techniques necessitate knowledge of small vessels and nerve branches in the affected region. Similarly, the diagnosis of conditions such as hemifacial spasm and trigeminal/glossopharyngeal neuralgia requires the determination of vascular structures in close proximity to these nerves. In conventional T1A and T2A sequences, assessment of neurovascular structures is suboptimal due to cross-sectional thickness [1]. MR cisternography techniques, in contrast, are significantly superior to other radiological methods in assessing the anatomy of the posterior fossa and its relationship to adjacent neurovascular structures because of their high spatial and contrast resolution. MR cisternography techniques, including SPACE (sampling perfection with application-optimized contrasts using different flip-angle evolutions) and CISS (constructive interference in steady state) sequences, make it possible to distinguish facial, superior/inferior vestibular, and cochlear nerves, applicable to patients who will receive cochlear implant treatment [1]. It is further possible to use 3D sequences to show the relationship between the trigeminal nerve and its surrounding structures both pre- and post-operatively [1].

Modern heavily T2-weighted (T2W) MRI sequences are highly sensitive, allowing for precise determination of cranial nerve anatomy and associated pathologies [2]. With the development of new MR cisternography sequences that more clearly differentiate cranial nerves from cerebrovascular fluid [3], clinicians are better able to determine the postoperative relationships between cranial nerves and posterior fossa tumors, tinnitus, and vascular neuralgias, providing superior direction for the treatment of patients. A variety of cisternography techniques have been developed for the assessment of cranial nerves, and each sequence presents specific advantages and disadvantages with

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http://dx.doi.org/10.1016/j.ejrad.2017.10.012
Received 9 May 2017; Received in revised form 9 September 2017; Accepted 17 October 2017

respect to other methods [3,4].

During the past decade, 3D CISS–a heavily T2W steady-state gradient echo sequence capable of producing high-resolution 3D images by focusing residual transverse magnetization–has been the most commonly used diagnostic technique for such applications [3]. However, without a high rate of homogeneity in the magnetic field, routine steady-state free precision images (SSFP) tend to exhibit dark banding artifacts [4]. To improve homogeneity and reduce these types of artifacts, shim coils are often used, though the sensitivity difference between air and bone in the internal auditory canal leads to an additional decrease in homogeneity and renders the minimization of band artifacts somewhat difficult.

To combat these difficulties, a variant of the T2W turbo spin echo (TSE) technique named "sampling perfection with application-optimized contrast using different flip-angle evolutions" (SPACE, Siemens Healthcare, Erlangen, Germany) has been recently proposed [1,3,5]. The high-speed SPACE sequence is a section selector, single-slice 3D TSE sequence with variable excitation pulse. It allows for the acquisition of high resolution 3D datasets with a degree of contrast similar to those observed in 2D T2W, T1-weighted (T1W), proton weighted, and "dark fluid" protocols in a clinically acceptable timeframe, without specific absorption rate (SAR) limitations [3]. High resolution is achieved through real-time isotropic data registration and voxel sizes less than or equal to 1 mm^3. This 3D isotropic data set allows for retrospective re-formatting of images to examine multiple anatomical regions from different angles. By using 3D SPACE sequences, it is possible to obtain heavily T2W images as well as T1W, T2W, or FLAIR (fluid attenuation inversion recovery) images without gradient-based artifacts [1,3,5]. In addition to providing excellent spatial resolution without interslice gaps and with reduced flow sensitivity, SPACE sequences allow for the reconstruction of images in any desired plane, while the use of a variable flip angle further decreases the acquisition time and reduces specific absorption rate (SAR). Although research has demonstrated the superiority of MR cisternography techniques with respect to 2D T1-T2 weighed sequences in routine temporal imaging studies [6], few studies focus on the comparison of SPACE and CISS sequences [3]. It is important to use the right sequence for tailored examination when evaluating specific cranial nerve deficits in every day routine imaging, in particular, using both SPACE and CISS sequences yields a long examination time. This decision is important especially due to limited time resources and variable patients cooperation. The present study aims to investigate and compare the abilities of SPACE and CISS sequences to assess cranial nerves of the posterior fossa by retrospectively analyzing cisternographic images obtained using 3T MRI.

2. Materials and methods

2.1. Participants

The present study was approved by the institutional review board (IRB) of our training and research hospital ethics committee. We retrospectively analyzed the temporal MRI scans of 52 patients admitted to our radiology department with vertigo, tinnitus, and hearing loss between February and June of 2015. One patient presenting with an epidermoid tumor and one patient who had undergone previous operation of the posterior fossa were excluded from the study, resulting in a total of 50 participants (F:M ratio, 27:23; mean age, 44.5 ± 15.9 years). Specific evaluation of the bilateral cisternal segments of cranial nerves V–XII was conducted across the patient population.

2.2. MRI techniques

All MRI procedures were performed using a 3T MR unit (Verio; Siemens Medical Solutions, Erlangen, Germany) with a 32-channel head-array coil and parallel imaging techniques. The following sequences were used as part of the protocol for temporal MRI: axial T2W, axial T1W, post-contrast axial and coronal T1W and axial heavily T2W sequences (CISS and SPACE). All patients had both CISS and SPACE sequences (it is not routine, 3T MRI unit was new in the department and we used to perform both sequences for the first patients to decide which sequence should be included to protocol). Gadolinium (0.2 ml/kg) was used as a contrast agent. Sequence parameters for SPACE and CISS sequences are presented in Table 1.

Table 1
Sequence parameters for 3D-SPACE and 3D-CISS.

	3D SPACE	3D CISS
Repetition time (ms)	1000	7.82
Echo time (ms)	132	3,58
Flip angle (deg)	*	50
Bandwidth (Hz/Pixel)	287	454
Echo space (ms)	3.88	–
Average	2	1
Field of view (mm)	200	170
In-plane voxel size (mm)	0.5 × 0.5 × 0.5	0.5 × 0.5 × 0.5
Acquisition time (min)	3.48	3.10

*Flip angles of the refocusing pulses in SPACE-using sequences are T2 constant. SPACE: Sampling Perfection with Application-optimized Contrasts using different flip-angle Evolutions; CISS: constructive interference in steady state.

2.3. Quantitative analysis of images

All images were transferred to a commercially available workstation. Image quality was quantified by measuring the CSF-to-pons contrast-to-noise ratio (CNR). Operator-defined regions of interest (ROIs) were identified by an always same radiologist with at least 5 years' experience (not one of the radiologist performing qualitative analysis) and the signal intensity (SI) of the CSF was then measured. ROIs for the SI of the CSF were at least 5 mm^2 and were chosen in homogeneous, artifact-free areas of the third ventricle. To measure the SI of the pons, a single ROI was drawn as large as possible in a homogeneous portion of the pons and set in an area devoid of vessels and prominent artifacts. The CNR was measured as the difference between the signal intensity of the CSF and the signal intensity of the pons divided by the standard deviation (SD) of the background noise, which was determined using a single-acquisition method.

2.4. Qualitative analysis of images

All T2 SPACE and CISS sequences were retrospectively evaluated by two radiologists, each with at least 5 years of experience. The readers could not be blinded to the imaging parameters, because SPACE and CISS images have some visual differences so it is easy to distinguish the sequences for a radiologist. Image analysis occurred over the course of two sessions separated by a one-week interval. Each session focused on the evaluation of one particular sequence, and differences in interpretation were resolved by consensus. Images obtained from both sequences were divided into four groups according to the level of visibility of the cisternal segments of cranial nerves V–XII: (1) not visualized (if no part of the nerve could be seen); (2) partially visualized (if less than%50 of the nerve could be seen); (3) mostly visualized (if more than%50 of the nerve could be seen); (4) completely visualized (if all parts of the nerve could be seen). We did not analyze the nerve root bundles of cranial nerve XI, because in some patients lower bundles were not included the examination. We analysed the cirternal part of the cranial nerve XI. CNRs were calculated, and data were similarly divided into three groups according to the severity of artifacts observed based on visualization: (A) no artifact or minor artefacts, (B) moderate artifacts, and (C) severe artifacts. Fig. 1 compares 3D axial T2-weighted SPACE and CISS MR images in the visualization of cranial nerve V.