3D visualization of pathological forms from MRI data obtained with simultaneous water and fat signal suppression

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ABSTRACT

For enhancement of visualization and 3D image reconstruction of intracranial pathological forms, it is suggested to use MR images obtained with simultaneous water and fat signal suppression. In this case one can more distinctly reveal pathological forms which are hidden ordinarily under powerful signals of fat tissue (orbits and hypodermic fat) and free water (brain ventricles). To realize simultaneous suppression of strong water and fat signals, we use modified sequence “inversion - recovery” supplemented by second inversion pulse. The signal/noise ratio degrades insignificantly in comparison with common “inversion – recovery ” technique. Yet due to suppression of intensive background signals the dynamic range of the receiver extends and its responsiveness to weak signals improves. Herewith the graphical data processing and construction of 3D images are significantly simplified as tissue contrast picture is maximally refined. The method is illustrated by 3D images in the cases of subdural haematomas and intracranial tumors. Drawing of 3D images for pathological forms was carried out by the standard software of MR scanner TOMIKON S50 (Bruker) which was used in MRI investigations.

Keywords: magnetic resonance imaging, 3D visualization, MIP reconstruction, volume rendering, subdural haematoma, brain tumor

1. INTRODUCTION

At present time new methods for the construction of realistic 3D images of internal parts of a body based upon MRT data are in active development. Normally this problem reduces to the identification of structures through pre-analysis of the image contrasts on 2D slices. Generally the processing of the image is effected manually though there is an active search after new methods of automation of this procedure [1-2]. Construction of 3D images for pathological cerebral formations (e.g. haematomas, tumors, zones of gliosis transformations) is complicated by the fact that one could hardly allocate on normally generated T1- and T2-weighed images pathological deformations vis-à-vis normal brain structures with sufficient reliability. Similar problem arises if the diseased area extends to a fat tissue boundary and/or covers areas which contain a large amount of free water (e.g. brain ventricles). The areas of fat tissue and free water generate an excessively intensive signal on the T2-weighed images (T2WI) and therefore the identification of pathologies is embarrassed. Commonly available researcher’s set of image modes which are based on the alternate water and fat signal suppression could simplify this problem only in part [3].

2. MATERIALS AND METHODS

2.1 Simultaneous water and fat signal suppression

We could have the maximally simplified MR contrast image when both signals (of free water and that of fat) are suppressed simultaneously at scanning. In this case the zone of pathology is more distinct and its 3D image could be adequately composed with standard software for 3D data processing, MIP reconstruction and rendering included.

The simultaneous free water and fat suppression could be realized in different ways [4-5]. We prefer to use for the given purpose a “doubly inverted” impulse sequence, which doesn’t necessarily imply a discriminatory frequency range adjustment: 180°, T1w - 180°, T1f - 90°, FID, where T1w, T1f - relaxation time of longitudinal magnetization for water and fat correspondingly; in the field of 0.5 Tesla they make about 1-2 s for water and 0.1 s for fat.
Using this sequence initially we obtain the inversion of magnetization both for water and fat, and when they cross the zero point during the relaxation period the visualizing part of the sequence is launched. At the moment of launching the visualizing 90° pulse the longitudinal magnetization of fat is equal to zero and that of water is partially restored up to the value of the T1f/T1w. As T1f/T1w<<1, the contribution of a signal of free water on the MR image is small enough. Highest visualization quality is appropriate to the tissue, whose time of longitudinal relaxation is in the interval T1f<<T1<<T1w. Such temporal values of relaxation are common for intracranial pathological forms, subdural haematomas and brain tumor inter alia. The signal/noise ratio decreases insignificantly while using double inversion, compared to that of the FLAIR mode, but owing to the suppression of the over-intensive water and fat signals the dynamic range of a receiver expands and its sensitivity to weak signals increases.

It turned out to be very productive to use the mode with simultaneous suppression of water and fat signal while plotting 3D images of certain pathological forms, subdural haematomas and brain tumor included. Common modes of MR analysis (with separate suppression of water or fat signals inter alia), don’t provide sufficiently simple image even for manually executed image processing. Simultaneous suppression of water and fat signal permits not to visualize those brain structures, which generate intensive signal on common T2WI: hypodermic fat, cerebral ventricles and eye bulb’s content inter alia. As a result of this operation we have a considerable simplification both for MIP reconstruction and for 3D rendering of MR images.

We have used standard software for MR scanner TOMIKON S50 (ParaVision ™ V1.0, provided by BRUKER company) to process 3D images. The 3D-processing activity was carried out in three steps: formation of 3D package from 2D slices through interpolation, selection of lower threshold of brightness for noise bursts, projection manipulations (rotation, spotlighting, animation etc.). Thus the manual processing of the image that eliminates both structures undesirable for visualization as well as noise while reconstructing 3D object was minimized.

3. RESULTS

3.1 3D-rendering of intracranial tumors

We were working on a problem of 3D image reconstruction of a tumor while processing data extracted from successive MR scanned slices. The 3D images data set, that we have obtained through standard processing of a series of 2D slices, the thickness of each is 6 mm (total number of slices is 22 items), is represented on fig. 1. Without any graphic pre-processing the MR data extracted from the set of common T2-weighted images fit only to outline an area that maps the distribution of hypodermic fat (see upper row of fig. 1). Similar picture represents those data that were gathered with FLAIR method for water signal suppression. The exclusive suppression of fat tissue allows merely to “peer” under the layer of hypodermic fat. Only while processing the data gathered with simultaneous suppression of water and fat signals we could get MR-images free of water and fat inclusions, and pick out the affected (diseased) zone of a brain without any graphic pre-processing (see lower row on figure 1).

The upper row: in the left section – representation of an axial T2WI slice that was taken for constructing the referential 3D image; in the right section – reconstruction of a referential image based upon the standard 3D method, as represented from several perspective angles. The images actually represent allocation of hypodermic fat.

Lower and middle rows represent corresponding reconstruction based on MR-images taken with the simultaneous suppression of water and fat signal mode. In this case the hypodermic fat and cerebral ventricles that generate intense signal on common T2WI images are not visualized and the construction of 3D image for affected zone is much easier. Both for MIP reconstruction (in the middle row) and for 3D rendering (the lower row) the same aspects as for the referential image are represented.

The represented 3D images of hypodermic fat (taken as a control object that has distinguishable geometry), as well as those of the diseased zone were reconstructed from equally directed axial slices. Such orientation simplified the construction of 3D images at identical sight angle. The MIP reconstruction has an auxiliary function – it is useful to make evident the correlation of 3D visualization of intracranial pathology with the exterior anatomy of a head.

Using the data, gathered through the simultaneous suppression of water and fat signal, we have measured by now the size of an area of pathological structures at 12 patients. The most detailed research of tumor dimension’s evolution (6
measurements in 1.5 years) was done for a patient V., 33 years old, whose diagnosis was astrocytoma. This patient has refused to be treated with chemotherapy. Initially measured volume of the patient’s tumor was 52 cm$^3$, then its increment relatively to the initial value in 3, 5, 11, 14, 17 months was 23.8, 26.0, 28.1, 66.5 and 79.4%.

3.2 Visualization of subdural haematomas’ surface
The same principle of MR data processing was applied for reconstruction of an image of surface distribution for bilateral subdural haematomas at another patient (figure 2). There were common T2WI procedures that were used as a source for reconstruction of a basic 3D image, and MR images gathered under the simultaneous water and fat signal suppression mode were used to reconstruct 3D images, where one could very easily distinguish surface geometry of haematomas. It should also be stated that these 3D images better visualize the penetration of a haematoma into hemispheric fissure, as compared to 2D slices.

The upper row: in the left section – representation of an axial T2WI slice that was taken for reconstruction of the referential 3D image. In the right section – reconstruction of referential image based on common 3D method, as represented from several perspective angles. The lower row represents the corresponding visualization data that was gathered using T2WI slices, taken under the simultaneous water and fat signal suppression mode. The same aspects as for the referential image are represented for 3D rendering of haematomas.

It’s necessary to notice that some areas in the nasal zone represent the same degree of a contrast as those typical to the pathology, but they are located in a lower region and don’t prevent the visualization of the haematomas. The similar situation is observed for 3D processing of local blood-vessels’ bright trackways, as they are easily detected on the MIP reconstruction, and the 3D processing program successfully recognizes their linear topology and disregards this
information while reconstructing both surface and 3D structures.

Using data gathered with the simultaneous water and fat signal suppression model one could also easily retrace dynamics of haematomas’ evolution. For example, for the patient O. we’ve observed the decrease of the haematoma’s area from 35.6 cm$^3$ to 17.2 cm$^3$ in 9 weeks.

4. CONCLUSIONS

We could make the 3D image processing more effective if the whole picture of its contrast distribution would be simplified through scanning mode matching. Very useful for this purpose might be those MR images which were produced under simultaneous suppression water and fat signal mode. This procedure enables the diagnosis of pathological structures for their subsequent 3D visualization and quantitative measurements.

5. REFERENCES