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the same compartments computed from the physical sections. The in-vivo study was performed for five healthy young females after obtaining fully informed written consent. The 3D SPGR sequence does not allow optimum visualization of the grey/white matter boundary throughout the cerebral hemispheres. Consequently, a novel protocol comprising acquisition in two stages of nine coronal T2 maps and nine inversion recovery images at identical locations was employed to produce a series of composite images. In addition, in-vivo data were obtained using Magnetisation Prepared Gradient Echo (MPRAGE) and Double Inversion Recovery (DIR) protocols.
*Results:* Volumes of the whole hemisphere and grey and white matter compartments are most efficiently obtained from coronal sections in which case 5, 10 and 7 sections are respectively required in order that the CE on the estimates is less than 5%. On average, compared to physical sectioning, the volume of the whole cerebral hemisphere was overestimated by only 1.1% from the MR images obtained for the formalin fixed brains. However, taken individually the total volume of cortical grey matter was overestimated by 22.8% and that of white matter underestimated by 21.5%. The mean ratio of grey to white matter obtained from the physical sections of the formalin fixed brains was 1.3 compared to a value of 1.9 obtained from the MR images and 1.5, 2.4 and 3.1 obtained from the in-vivo studies using MPRAGE, T2/IR and DIR sequences respectively.
*Discussion:* Further work is required to understand the source of the discrepancy between the volumes of the grey and white matter compartments obtained from the MR images and the physical sections. The answer undoubtedly lies in a better understanding of the effect of partial voluming and of the mechanisms by which these tissues provide contrast on T1 and T2-weighted MR images.

## 36 Development and trial of a segmentation software for quantitative analysis of multiple sclerosis MR images

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*Introduction.* Brain MR studies are considered mandatory in multiple sclerosis (MS) in order to obtain quantitative indexes of disease progression. This work deals with a PC-DOS software package that randomly presents the patient images, uses a semi-automated growing region method to segment the lesions identified by the operator and transfers the area measurements into a database. Subsequently these data are elaborated using statistical methods.
The purpose of this work is to present the software package and the measurement errors evaluation.
*Subjects and Methods.* The PC-DOS used as elaboration environment is equipped with a frame grabber card (PCVISION*plus*) and an external monitor used only to display the clinical image; the software was developed using MS C-compiler (ver. 7.00) and linking the ITEX Pcplus frame grabber library.
The segmentation method is based on a growing region beginning from a seed that is identified by the operator clicking a point inside the lesion; the region grows including pixels spatially connected and having signal level between two thresholds that derived from the analysis of the signal levels histogram of the lesion ROI. The operator can further arrange the thresholds to best cover the lesion.
The mean operator time required to localize and segment the lesion is about 20 s.
In order to test the area measurements reliability we made a plexiglas phantom to simulate a clinical image. The phantom presents 6 circular and 6 elliptical cross-section blind milling filled-in with water, having cross areas in the range of most multiple sclerosis lesions ($10 \div 40$ mm$^2$); the image contrast can be adjusted making the scan slice to cross the blind end of the millings and varying the water-plexiglas percentage in the slice. The phantom image used to test the segmentation software presents a signal contrast equal to the mean one measured on 20 reference clinical images.
Subsequently a test on the variability of the lesion burden evaluated on the same set of clinical images by three different operator and by the same operator in three different times, was done.
*Results.* The semi-automated segmentation program gives phantom cross-sections area measures consistent with the known values; the measures are affected by error less than 15%.
The within-observer variation is 17%, the between-observer variation is not significantly different.
*Conclusion.* Different clinical applications of this package are planned: long-term studies of natural history of the disease comparing clinical disability evaluations (standard scales and neuropsychological tests) with number, area, location, and enhancement of the lesions; clinical trials for evaluating the efficacy of new treatments of the disease.

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## 37 MR, 3D segmentation analysis of white matter lesions

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*Purpose/Introduction.* The aim of this work was to improve the characterization of MS lesions and differentiated them from other white matter abnormalities found in the elderly population.
*Subjects and Methods.* The results of 3D, MRI segmentation of ten patients with known multiple sclerosis MS were compared with the results of 3D segmentation of ten elderly patients with leukoaraiosis and 10 patients with lacunar infarctions. The MRI studies were performed on the GE 1.5 Signa MRI unit. Three sets of MRI data were obtained using proton density, T2 fast spin echo, and T1 weighted spin echo sequences. Segmentation was performed using Sun Sparc Station 2. RF inhomogeneity was minimized by the technique divised by Mohamed [1]. Then, nonlinear "diffusion type" filters [2] were applied to remove spikes. The qualified observer "seeded" tissue samples (40–50 samples/tissue); k-Nearest Neighborhood segmentation was utilized for both 2D and 3D feature map calculations. Up to eight tissues were classified. A connectivity algorithm [3] along with a dividing cube algorithm constructs a surface of selected tissue.
*Results.* The contribution of a third MRI input (T1 weighted spin echo) into the segmentation produced a dramatic improvement in tissue identification allowing the differentiation of two areas of different within the same MS plaque. These changes were not found in the patients with leukoaraiosis where the lesions were homogeneous, without T1 intensity contribution. Patients with lacunar infarcts revealed a central gliotic area with intensities close to cerebrospinal fluid (CSF) surrounded by areas of demyelination.
*Discussion/Conclusion.* We presumed that the changes found in the MS plaques represent either gliosis, or edema and acute demyelination reflecting either more chronic or more acute changes within the lesion. In contrast changes seen in the patients with leukoaraiosis represent only demyelination, while in lacunar infarcts there is both an atrophic core with CSF like fluid in the cavity, surrounded by a ring of demyelination.

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## 38 Automatic analysis of the deformation of the cerebral ventricles

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*Purpose:* The aim of the study was to use 3D MR data obtained for a group of healthy control subjects to build an atlas describing the morphology of the cerebral ventricles. The atlas comprises a set of landmark features which are common (i.e. present in all items in the data base) and a small set of statistical parameters describing the inherent variability in the size and position of these features amongst individuals. Subsequently, the atlas is used to automatically analyze the deformation of the cerebral ventricles observed in patients with focal aphasia.
*Subjects and Methods:* The database comprises ten T1-weighted 3D SPGR data sets obtained for the brains of volunteers who had given fully informed written consent. In addition, comparable data were available for several patients with focal aphasia.
The atlas of the cerebral ventricles is built in four stages. First, a set of features that are unambiguously definable and anatomically relevant needed to be computed for each item in the database. The chosen features are crest lines whose points are defined by; i.e. the principal curvature is zero. Second, a non-rigid registration algorithm is used to determine the common crest lines amongst the sibjects in the database. These features form the structure of the atlas. Third, a set of crest lines is taken as a reference set and a modal analysis is performed in order to determine the fundamental deformations that are necessary to bring the individual data in line with the reference set. The deformations are averaged and the set of mean lines becomes the atlas. Finally, the standard deviation of the deformations between the atlas and the items in the database defines the

range of 'normal' deformations that the atlas is expected to accommodate. The crest lines obtained for the cerebral ventricles in the patients with focal aphasia were computed and compared to the atlas. When the amplitude of the displacements necessary to register the crest lines obtained for the patient with the atlas are greater than three standard deviations beyond the variability inherent in the atlas, the deformation is considered significant.
*Results:* Three of the five main deformation modes were consistently, significantly different in the patients with focal aphasia compared to the atlas. In particular, in the patients the cerebral ventricles are asymetrically enlarged and elongated in the anterio/posterior direction.
*Discussion:* Ultimately, the approach may provide a useful screening technique for brain diseases involving cerebral atrophy. Serial studies of particular patients may provide insights into the processes controlling or affected by the disease. Work is in progress to incorporate several tens of new cases in the database and to compute further sets of robust features for the cerebral ventricles in addition to the crest lines.

## 39 Cervical syringomyelia: MRI and neuroendoscopy

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*Purpose:* To evaluate the diagnostic reliability of high-resolution MRI and relevance of CSF flow measurements in planning endoscopic exploration and surgery of cervical syrinx cavities.
*Subjects and Methods:* In 10 patients, high-resolution MR imaging using a 3D CISS sequence in axial or sagittal orientation (TR/TE/flip angle of 12.3/5.9/70° slice thickness of 1–2 mm) was performed on 1.5 T system (Siemens Vision) to show the complete CSF space. In addition to qualitatively assess a CSF motion a 3D PSIF sequence (TR/TE/flip angle of 18/7/60°) in the same position and the same resolution was also performed. A single-slice phase-contrast (PC) velocity-coded FLASH 2D (TR/TE/flip angle of 46/15/15°, slice thickness of 4 mm, velocity coding of 5–10 cm/s) was used for quantitative evaluation of CSF pulsation within syrinx cavities and extramedullary space. The PC sequence was measured in sagittal and in some cases also in axial orientation. A 3D high-resolution data set was segmented using a dedicated medical workstation (Prominence, Siemens-ISG) and spinal cord was reconstructed as a 3D object. A flow evaluation was performed using in-house software on a Sun Spark 20.

*Fig. 1.*

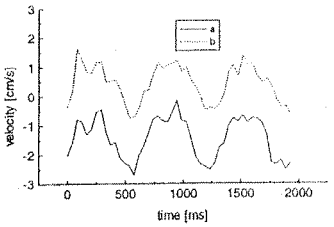


*Fig. 2.*

*Results:* Intracavitary septa of thickness 2 mm and more could be identified and reconstructed in detail showing the usually incomplete perforated formation and oblique orientation of the septa within the syrinx (fig. 1). Floating septa below a thickness of 2 mm could not be demonstrated reliably even in cases of complete interruption of the CSF pathway which made endoscopic perforation necessary. A comparison of CISS and PSIF images allowed us to differentiate places with relative small and high amplitude of CSF pulsation which can also have consequences to find flow communications within the syrinx as well as with the extramedullary space. In all cases pulsation of CSF was present within the cavities with a maximum in central part and no flow at the cranial and caudal ends. Obvious interruptions of flow by transverse septa could be also seen. In two cases we could demonstrate an opposite direction of CSF flow in a two parallel subchannels within a syrinx (fig. 2) which indicated the possible complete septation in one of them. This fact was also proved by neurosurgical endoscopy where this "blind" channel was found.
*Conclusion:* Although MRI and CSF flow measurements can show most septa and flow profile with syrinx cavities, reliable exclusion of occluding membranes which have to be perforated is not possible at the moment. Extramedullary disturbance of flow which may have an impact on syrinx formation can also be demonstrated.

## 40 Fluoroscopic MRI of eye movement with EOG monitoring

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*Purpose and introduction:* Imaging of eye movement disorders has so far been restricted to the semifunctional cine mode of computed tomography (CT) and magnetic resonance imaging (MRI). Since real time imaging of eye movement is necessary to investigate dynamic disorders, the aim of our study was to implement an ultrafast MRI technique to investigate eye movement in a real time mode.
*Materials and methods:* Six healthy volunteers and five patients suffering from different motility disorders were examined with ultrafast MRI sequences while performing the following eye movements: holding different gaze positions, reading a defined text to demonstrate saccadic movements, and holding a primary gaze position and maximal endpoint position to cause nystagmus when present.
MRI was performed on a 1.5 T whole body imager ("Vision", Siemens Medical Systems, Erlangen, Germany) using a circular polarized head coil. Imaging was performed in axial and coronal planes. Spin-density weighted 2D-FLASH (fast low angle shot) sequences were obtained with an in-plane resolution of 2.5 × 1.95 mm and a temporal resolution of five images per second. During MRI an EOG (elctro-oculogram) was performed.
*Results:* In all cases we were able to delineate eye movement with ultrafast MRI. Anatomic and functional information could be obtained simultaneously with MRI and EOG for the first time in observation of saccadic and pursuit eye movements.
During right to left horizontal movement, the rotation of the globe, change in muscle thickness and the mobility of the optic nerve could be easily visualized. The optic nerve was restricted in lateral movements by its fixation to the globe and optic foramen. The occurrence of reading saccades and backward nystagmus at the end of each text line could be observed in all subjects.
*Discussion and conclusion:* Eye movement in ocular disorders has been described previously using the cine mode technique in CT [1,2] and MRI [3,4]. However, a disadvantage of the cine mode is it reconstructs motion from images taken during static preassigned gaze positions. This procedure, therefore does not allow for the detection of involuntary eye movements. Using fast MRI-techniques and an EOG-system, designed for MRI, it was possible to delineate eye movement in real time mode with MRI under EOG monitoring. This imaging ability has the potential to be a significant contribution in the planning of eye surgery and in the selection and implementation of therapy for eye movement disorders.

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## 41 Evaluation of the movements of oro-farynx cavity during the phonation by using MRI

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*Purpose:* The more recent MRI units offer the Turbo-Flash sequences that allow to obtain images in less than 5 seconds. Purpose of this study was to evaluate the movement of oro-farynx cavity during the phonation.
*Materials and Methods:* We have evaluated 15 volunteers (using a 0.5 Tesla unit (Gyroscan T5 III, Philips Medical System). We have acquired Turbo-Field echo sequences (acquisition parameters: TR: 12 msec; TE: 6 msec; TI: 900 msec; N. Ex.: 4; Acq. T.: 6) with coronal, sagittal and axial scans (slice thickness: 5 mm) using a specifically designed volume coil for head and neck. The volunteers were invited to emit an high and low frequency sound and the vowels A, E and U during the different acquisitions at two different vocal levels (high: 70 dB; low: 50 dB).
*Results and Conclusion:* In all the patients we have evaluated the movement and the activity of farynx, soft palate and tongue with the sagittal scans. By