Pushing back the frontiers in pediatric neuroradiology

Brussels University Hospital uses new software for quantitative MRI examinations with shorter scan times

The University Hospital of Brussels (UZB) combines not only the treatment of patients in routine clinical care but also R&D activities aimed at developing, evaluating and implementing the latest leading-edge technologies.

The MRI department in particular has recently been applying a new software package, SyMRI, which enables quantitative MRI examinations to be carried out with short acquisition times of typically six minutes. The pediatric neuroradiology section has been using the new software in the diagnosis and follow-up of certain pediatric neurological cases, especially neonates.

We wanted to find out more about UZB's MRI department in general and their experience of SyMRI in pediatric radiology in particular so we spoke to Prof. Hubert Raeymaekers, Head of MRI, Dr. Tim Vanderhasselt, pediatric neuroradiologist and Maarten Naeyaert, Ph.D. student in MRI physics.

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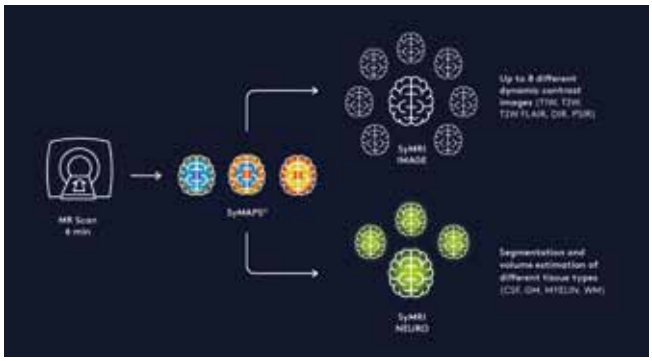
Q *Let's start with some background to UZB and the MRI department*

In Belgium, the Universitair Ziekenhuis Brussel is one of a total of seven teaching hospitals attached to a university or medical school. We are affiliated with the Vrije Universiteit Brussel (VUB) which is the Dutch language university in Brussels. Located in the north west part of the city, we have approximately 750 beds and receive patients principally from the western suburbs and the surrounding areas. As an integral part of the hospital we have a specialised Children's Hospital, so all our hospital departments also have a pediatric unit. For example, in our radiology department, headed by Prof. J. De Mey, we have a section devoted to pediatrics.

In the MRI section of the radiology department, we actually have four MRI systems: one is a 1.5T Ingenia from Philips, and then there are three 3 Tesla systems, namely a 3.0T Skyra from Siemens, a 3.0T Discovery system from GE and a 3.0T Ingenia from Philips.
We know that such a mixture of different vendors of systems for the same modality is relatively unusual, but this was a deliberate policy choice taken to conform to the role of the UZB as a teaching hospital, and so to be able to provide resident radiologists who are carrying out their specialization here at UZB with as broad an experience of different MRI systems as possible. Such a set-up with MRIs from different vendors can sometimes pose logistic problems but can also be extremely interesting from a scientific point of view in enabling the comparison of the various systems.

Q *And what about the SyMRI software that you have recently installed?*

SyMRI is a software package developed and marketed by the Swedish company SyntheticMR. We were attracted to it since it provides an efficient way of integrating quantitative MRI into the clinical work flow. The principle of the system is based on the absolute quantification of the physical parameters of the patient that govern the MRI image signal intensity, namely R1 and R2 relaxation, and proton density. From these values it is possible to differentiate tissue and synthetically recreate contrast-weighted images that are independent



The principle of operation of SyMRI. By using a multi-delay, multi-echo sequence to estimate the R1, R2 and proton density maps, any contrast-weighted image can be synthesized, with a free choice of echo time TE, repetition time TR and inversion delay TI. Hence, standard contrasts such as T1W, T2W and FLAIR images, but also Double Inversion Recovery (DIR), Phase Sensitive Inversion Recovery (PSIR) and Short Tau Inversion Recovery (STIR) can be synthesized using the same scan data. Thus a single acquisition sequence of approx 6 minutes can be used to generate contrasts which otherwise in standard MRI would require several acquisition sequences and a much longer total scan time

of scanner settings. One additional advantage is that the SyMRI method provides maps that are independent of the magnetic resonance scanner and hence provides the same result on all major platforms.

As for the practical implementation of the system in UZB it was clear that the only efficient way to do this was to have it installed at the level of the PACS system rather than at the level of the acquisition console on each individual MRI machine. Apart from this configuration being suitable for our park of multi-vendor MRI machines, having the SyMRI system in the PACS is more convenient for the radiologists for whom it is often time-consuming to physically go to each MRI machine to decide which contrasts are needed. This is even more important in UZB, since our MRI scanners are located in different parts of the hospital so it's more efficient that SyMRI post-processing is carried out on the PACS. Thus, the use of the PACS plugin means that the SyMRI post-processing is closely integrated with the radiologist's workflow.

Q *And in what particular applications are you using the software ?*

The technique of SyMRI is being applied elsewhere to many adult pathologies, mainly in the brain but also in different areas such as the spine and the knee but here at UZB we are focussed on pediatric/neonatal neuroradiology applications principally because we already have experience in this field and we feel that the technology has a lot of potential in the area.

In UZB our standard protocol for babies born extremely preterm is to carry out an MRI examination at the term-equivalent age. Despite significant progress in therapeutic management over the last decades, these children are still at risk of developing cognitive and motor deficits later in life, such as cerebral palsy, cognitive impairment and autism spectrum disorders. High quality MRI can help identify children at high risk and so guide early intervention therapies and parent counseling, especially for children with major motor deficits. However, there is still some work to do in terms of predicting issues such as mild cognitive impairment or autism spectrum disorders. This is where we believe quantitative data could make the difference.

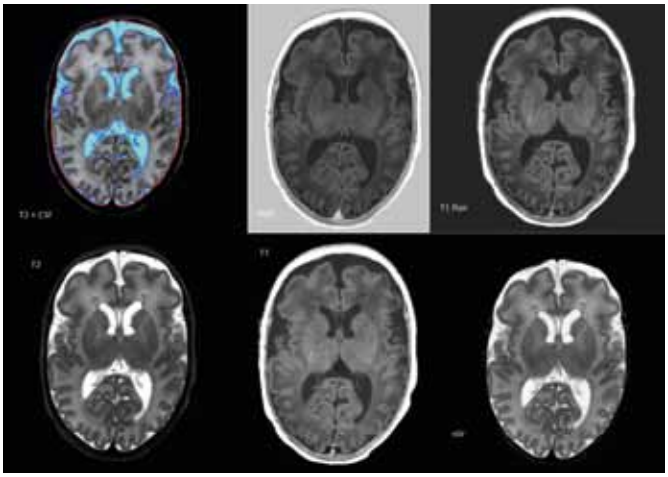
Retrospective selection of contrast.

We find SyMRI to be extremely useful in cases where according to the initial clinical indications we have already specified the acquisitions but then in retrospect we realize that it would have been good to have a different contrast. Sometimes e.g. in meningitis we need a FLAIR image which is not a routine contrast. Using SyMRI we can select that FLAIR contrast at the post-processing stage without having to recall the patient.

In longitudinal studies of course we are familiar with the patients' characteristics so we can already select the optimal contrasts. We use a mixture of SyMRI and routine MRI; the choice between whichever of these approaches we use depends on the clinical indications. For example for the MRI examinations of premature babies at term who are under sedation we will routinely use SyMRI, principally because of the reduced scan time which is a big advantage when dealing with such patients. In other cases, for example if we know that a 3D T1 weighted image or 3D T2w images could be useful, we will go for that directly using standard MRI Protocols since 3D T1 or 3D T2 are not (yet) available on SyMRI.

Quantitation of brain volume

However we use SyMRI not just for the image contrast aspect, but also for the possibility of quantification, for example in the determination of the brain volume. This



Examples of synthetic MR images of a term scanned preterm neonate of 24w gestational age at birth (GAB.) Upper row, from left to right: A CSF segmentation map overlaid on a synthetic T2w image, a PSIR image, and a T1 flair image. Bottom row, from left to right: A T2w image (TE=200ms, TR=15000 ms), a T1 image (TE=5ms, TR=100ms) and a T2 PSIR contrast image. For the CSF segmentation, the improved algorithm, specifically designed for neonates, was used.

is a particularly useful parameter in the term-equivalent scan which, as we mentioned, serves as a reference point. Quantitative pediatric brain volume determinations are available in research environments but not in routine clinical use. Up till now clinically we have had to rely on indirect indications, for example by measurement of dilated ventricles. Now in a routine clinical setting we can have direct quantitative segmentation of the brain.

Validation

We have looked at the correlation of segmentation data of the brain that are generated by SyMRI with measurements of brain volume that are currently only available via research tools. So in fact what we are doing is validating the SyMRI method in the estimation of the brain volume in pediatric and neonate cases against values generated by standard methods. We think this is a good example of what the role of an academic teaching hospital like UZB should be in addition to routine clinical examinations using standard methodology.

We started this work about two years ago. In the beginning we noted that when applied to pediatric as opposed to adult brains, the SyMRI algorithm was not optimal, for example in the differentiation of CSF.
Through an efficient and successful collaboration, Synthetic MR managed to correct and upgrade the SyMRI software. This modified software is what we are now using regularly in our validation studies.

"... the correlation with the standard methods was very good, a finding that is all the more striking since the SyMRI results are obtained in a six-minute acquisition..."

Our study, involving 80 neonatal patients, shows excellent correlation of the automatic segmentation with that obtained in standard methods, a finding that is all the more striking since the SyMRI results are obtained in 6 minutes (acquisition, reconstruction and post-processing), compared to approximately 20 minutes for the standard methods. Such short examination times are especially advantageous since we are dealing with very young patients. The results of our study will be presented at this year's ISMRM meeting. Given the encouraging results of our validation study, we are very keen to continue with this work, to eventually look at how brain volume measurements correlate with clinical outcomes in the development of such pediatric cases, of which we see some 200 per year.

It should be noted that these studies are carried out with the currently available software from SyMRI, based on 2D-acquisitions. Currently most neuroradiologists are used to work with 3D-acquisitions in the clinic, enabling thinner slices and better spatial resolution A new version of the software, which will shortly be made available by Synthetic MR to us, will enable 3D-acquisition and we will initiate a new validation study of this. Again, we consider this work as part and parcel of our role as a teaching hospital.
We look forward to working with the 3D software since we anticipate that it will provide several advantages such as enabling the neuroradiologist to obtain not only quantitative volumetric data but also to use the reconstructed images for visual diagnosis.
The advantage of having such quantitative data is that the scoring of brain conditions can be much more objective. In neonatal imaging, we use the Kidokoro brain abnormality score, which is calculated from a range of individual parameters and provides a comprehensive characterization not just of brain development but also of regional and global brain injury. The ease of use and value of scoring systems could be greatly enhanced through use of quantitative data. Yet another advantage of hard quantitative data is that comparison of datasets between collaborating hospitals will be greatly facilitated

Neonates and children are scanned on our pediatric scanner (Philips Ingenia 3T) equipped with SyMRI. The scanner is also equipped with an 'In-bore experience', enabling children to watch via a mirror a short animated movie (even a video of their of their own choice) which is shown on a large TV-screen on the wall behind the scanner. With this and new SyMRI developments including 3D acquisitions, our goal of providing a fast and quantitative comprehensive pediatric neuro-MRI protocol will be attained, while also reducing the need for anesthesia or sedation in older children, and shortening the sedation time for younger patients.

Q *And so how do you see the future?*

We hope that it is clear from our conversation so far that we are strong believers in the potential of quantitative MRI and in the way SyMRI enables it. We may even think of future MRI exams resulting in a report similar to a comprehensive blood test today: a procedure that generates a list of objective, quantitative parameters, biomarkers, to be evaluated against appropriate reference standards.
In this brave new world, the neuroradiologist will be freed up from routine to be able to consider the interpretation and significance of the data, for the greater good of the patient.