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MR bone imaging in pediatric craniofacial disorders

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For the past five years, National University Hospital has been utilizing MR bone imaging as an alternative to ionizing radiation modalities for imaging of pediatric craniofacial disorders. We have previously demonstrated the ability of a "black bone" MR sequence to accurately depict a wide range of craniofacial pathologies in the pediatric population.[1] An inherent advantage of MR bone imaging sequences is the ability to evaluate both osseous and soft tissue abnormalities in the head and neck region, obviating the need for CT imaging in many cases.

This is of particular interest for imaging in this radiosensitive region (head and neck) and in this demographic (pediatric). Cases with craniofacial pathologies range from traumatic injuries to craniosynostosis and focal osseous/fibro-osseous lesions, such as fibrous dysplasia and Langerhans cell histiocytosis (LCH). In fact, MR bone imaging has become part of our routine protocol for these cases, often negating the need for any exposure to ionizing radiation.

Recently our hospital has also incorporated 3D printing into the treatment of several of these complex cases, for both patient education as well as for surgical planning. However, 3D printing requires images with the ability for multiplanar reconstruction, necessitating the use of CT in these cases. With the introduction of the new Zero TE (ZTE) sequence, oZTEo, available for multiplanar reconstruction, we are investigating the utility of this sequence for 3D printing and 3D visualization in cases of pediatric craniofacial disorders.

At present, we have performed approximately 12 cases on our hospital's SIGNA™ Premier 3.0T MR system with oZTEo in the prior six months. The cases include cases of craniosynostosis, orbital lesions and imaging of fibro-osseous lesions. The cases have been performed with our routine and validated black bone MR sequence and the new oZTEo sequence for comparison.

SIGNA Premier 3.0T MR			
	oZTEo 0.8 mm	oZTEo 1.0 mm	3D Axial T1 FSPGR
TR (ms):			Minimum
TE (ms):	0	0	Minimum
FOV (cm):	22	22	18
Slice thickness (mm):	0.4	0.5	0.5
Frequency:	275	220	256
Phase:	275	220	256
NEX:	3	4	2
Scan time (min.):	4:57	3:35	6:53
Flip angle:	1	1	4
Spokes per segment:	512	512	
Bandwidth:	62.5	52.5	31.25
Slice resolution:	50	50	50

Case 1

A 4-month-old patient with patent sutures (normal). In Figure 1, the arrows demonstrate the expected, normal appearance of unfused sutures, in a four-month-old patient. This includes the metopic suture anteriorly (solid arrow), the sagittal suture posteriorly (dotted arrow), and the coronal sutures bilaterally (arrow heads).

Case 2

A 4-month-old patient with fused sutures (craniosynostosis). In Figure 2, we can clearly see the asymmetrical shape of the calvarium, often seen in cases of craniosynostosis with early fusion of the sutures. Compared to Figure 1, the calvarium appears continuous, with the arrows indicating the expected locations of the respective sutures: the metopic suture anteriorly (solid arrow), the sagittal suture posteriorly (dotted arrow), and the coronal sutures bilaterally (arrow heads). Note that this is also a four-month-old child, similar to Figure 1.

Discussion

The oZTEo sequence provides excellent contrast-to-noise ratio (CNR) between the soft tissue-bone interface, which is typically a challenge when using standard MR sequences such as T1-weighted or T2-weighted imaging. Compared to CT imaging, oZTEo sequences impressively provides a similar CNR and excellent differentiation of both the cortical and medullary bone (a key feature of CT images).

The cases utilizing oZTEo thus far are satisfactory for the surgical teams in their bony assessment, important for differentiating the soft tissue and bone interface; so far none of the patients have required an additional CT examination for surgical planning. Often, the oZTEo sequences are used in conjunction with standard T1-weighted post-contrast fat-saturated images for surgical planning.

However, based on the current cases, there is difficulty determining suture patency on the oZTEo images, an aspect perhaps seen more clearly in the black bone imaging. Further investigation of the oZTEo sequence for craniosynostosis will require a larger sample with more cases for validation. Thus far, at least anecdotally, oZTEo images have not been able to replace black bone imaging or CT for evaluation of craniosynostosis.

For future use, we feel that the key utility of this sequence is its application for 3D reconstruction and its use in 3D printing, an application we are yet to explore. Thus far, this has been mainly limited by the clinical need where only rare, complex cases requiring surgical intervention are indicated for 3D printing. As

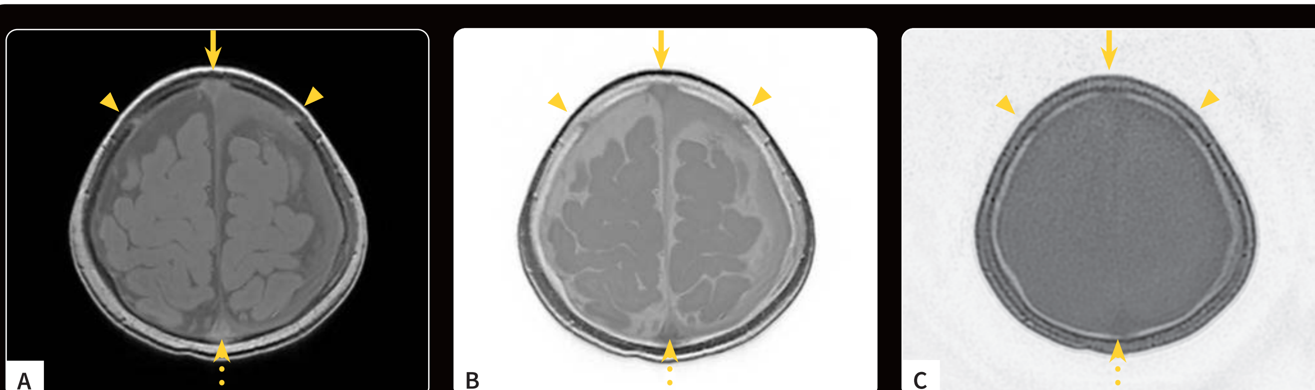

Figure 1. (A) Black bone MR, (B) black bone MR inverted and (C) oZTEo sequence.

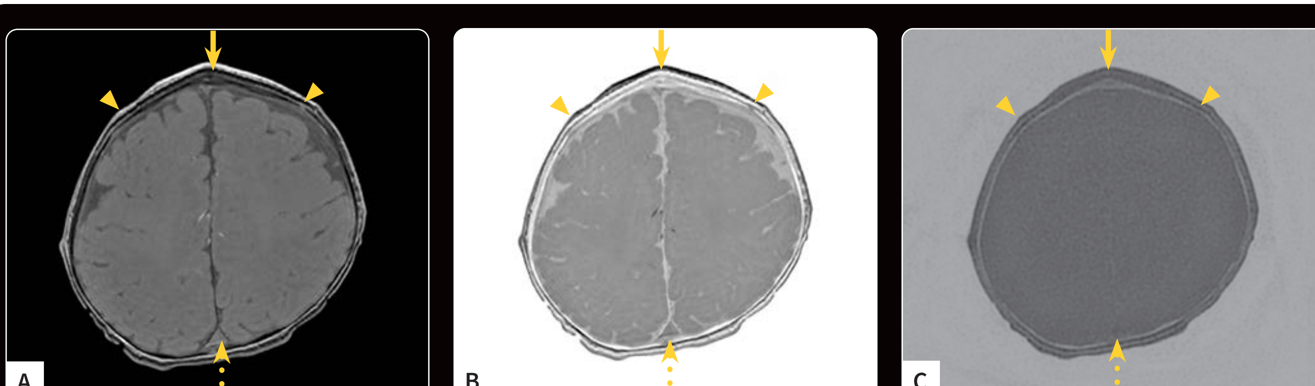

Figure 2. (A) Black bone MR, (B) black bone MR inverted and (C) oZTEo sequence.

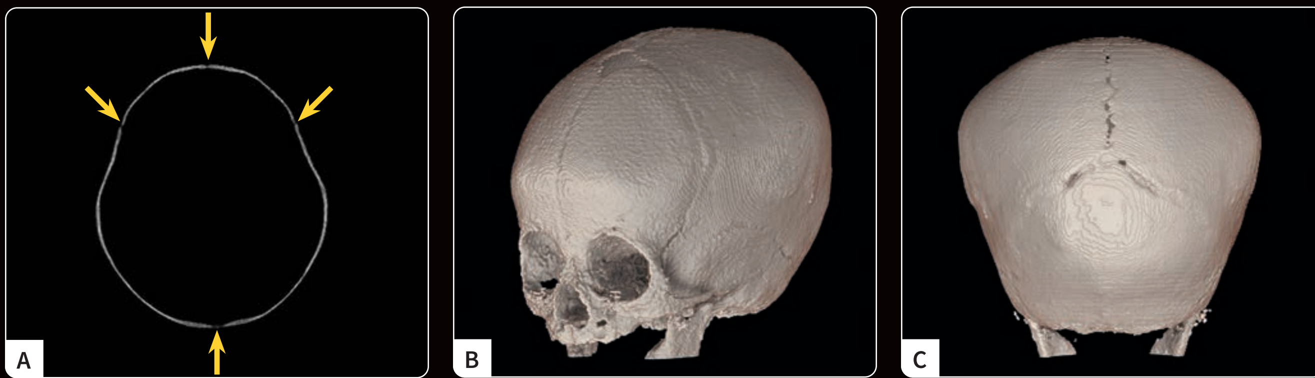

Figure 3. (A) The subtraction maps from SNUH's automated segmentation protocol. (B, C) 3D rendering of the oZTEo sequences, demonstrating good delineation of the calvarium and craniofacial structures.

part of a collaboration, we have sent anonymized images to our counterparts at Seoul National University Hospital (SNUH), who also have a SIGNA Premier, and have developed an automated process for 3D reconstruction (Figure 3).

Previous attempts to perform 3D reconstruction with black bone images have often been suboptimal due to the relatively thin calvarium in pediatric patients, resulting in artifactual defects. The oZTEo sequence provides excellent CNR of the bone relative to the soft tissue and is adequate for automated 3D reconstruction of the facial structures in our preliminary studies.

In previous experiences with black bone sequences, additional CT imaging was required in order to acquire 3D reconstructions for surgical planning and 3D printing. We believe the oZTEo sequence may provide the opportunity to bridge this gap. Prior studies have also demonstrated the technical feasibility of this application, with prior studies showing robust comparisons between ZTE sequences and the gold standard of CT imaging.[2,3]

References

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