Perfusion Imaging in Pediatric Brain Tumors: Pseudo-continuous Arterial Spin Labeling at Work

Giovanna Stefania Colafati[1]; Chiara Carducci[1]; Ioan Paul Voicu[1,2]; Antonio Napolitano[3]

[1]Department of Imaging, Neuroradiology Unit, Bambino Gesù Children's Hospital, Rome, Italy
[2]Department of Hematology/Oncology and Stem Cell Transplantation, Bambino Gesù Children's Hospital, IRCCS, Rome, Italy
[3]Medical Physics Unit, Risk Management Enterprise, Bambino Gesù Children's Hospital, Rome, Italy

Patient history

A 2-year-old male patient[1] with a history of gait and balance problems, associated with nausea, was admitted to our Emergency Department. A brain CT scan revealed a posterior fossa mass.

Patient underwent brain and spine MRI with MAGNETOM Skyra 3T (Siemens Healthcare, Erlangen, Germany) to characterize the lesion. The protocol in use in our institution includes conventional 2D and 3D sequences as well as advanced sequences acquired before and after endovenous injection of contrast medium, including the Pseudo-Continuous Arterial Spin Labeling (PCASL) sequence[2] (Fig. 1).

PCASL sequence details

Pseudo-continuous labeling was performed with a prototype sequence[2] using a labeling period of 1500 ms, followed by a 1500-ms post-label delay (inversion time 3000 ms). Whole-brain images were obtained with a 3D background-suppressed Gradient and Spin-Echo (GRASE) sequence, with a TR of 4.6 s, turbo factor = 14 and EPI

[1]MR scanning has not been established as safe for imaging fetuses and infants less than two years of age. The responsible physician must evaluate the benefits of the MR examination compared to those of other imaging procedures.

[2]WIP, the product is currently under development and is not for sale in the US and in other countries. Its future availability cannot be ensured.

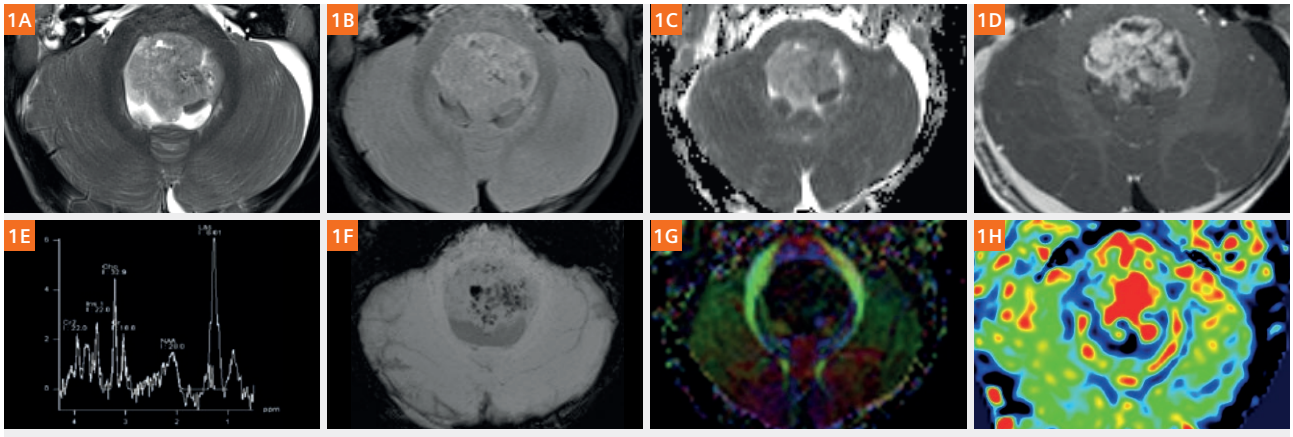

Figure 1:
Multiparametric MR imaging of the lesion (**1A** axial T2-weighted; **1B** axial FLAIR; **1C** ADC map; **1D** axial high-resolution 3D T1-weighted Gradient Echo Sequence (MPRAGE) reconstruction; **1E** Spectroscopy; **1F** axial Susceptibility-Weighted Imaging (SWI); **1G** Fractional Anisotropy color map from Diffusion Tensor Imaging (DTI); **1H** Pseudo-continuous Arterial Spin Labeling (PCASL)[2] with a 3D background-suppressed Gradient and Spin-Echo (GRASE)). An intraventricular posterior fossa mass is seen (1A–D, 1F–H). The lesion presents a heterogeneous appearance due to solid-enhancing components (1A, B, D), necrotic portions (1D), regions with restricted diffusivity (1C) and low-signal foci consistent with calcifications (1F). Spectroscopy reveals increase of Choline, decrease in N-acetylaspartate, and a peak of lactate and lipids (1E). Low FA values are seen within the lesion (1G). PCASL cerebral blood flow (CBF) color maps (1H) show high CBF values within the lesion.

factor = 21. The sequence required a 6-minute acquisition time, including M0 used for Cerebral Blood Flow (CBF) quantification. Other ASL parameters were TE 15.6 ms; FOV 192 x 192 mm; matrix 64 x 64; measurements 6, and segments 6. For CBF quantification T1 blood and T1 tissue of 1650 ms and 1330 ms respectively was used. Circular 2D regions of interest (ROIs) with a mean area of 50 mm^2 were manually positioned in the most perfused area of the lesion. In addition to CBF, an rCBF was computed normalizing it with the mean value within another ROI in the normal-appearing gray matter of a cerebellar hemisphere.

Quantitative analysis revealed CBF and rCBF values of 58 mL/min/100 g and 1.9 respectively. The child underwent surgical resection of the lesion. Histology revealed an ependymoma grade 2, according to the 2016 World Health Organization classification.

Conclusion

MRI has a key role in examining pediatric brain tumors noninvasively. Both conventional and advanced sequences allow to obtain useful information at diagnosis for surgical planning, after surgery, for monitoring treatment response, and at further follow-up. In the pediatric population, among Perfusion-Weighted Imaging (PWI) techniques, a growing interest is currently emerging in arterial spin labeling (ASL) [1–3], a completely noninvasive and repeatable perfusion technique, that generates an image by magnetically "labeling" water molecules in arterial blood as an endogenous tracer. ASL can be generated using three main techniques of proton labeling: continuous labeling (CASL), pulsed labeling (PASL) and pseudo-continuous labeling (PCASL) [4]. A consensus paper from the ISMRM Perfusion Study Group and the European Consortium for ASL in Dementia recommends pseudo-continuous labeling, background suppression, a segmented three-dimensional readout without vascular crushing gradients, and calculation and presentation of both label/control difference images and cerebral blood flow in absolute units using a simplified model [5].

The evaluation of brain tumor perfusion with ASL may have a different impact in children compared to the adult population, due to their distinct clinical characteristics. Specifically, because of the advantage of higher CBF signal with a better signal-to-noise ratio in children compared to adults, it is possible to obtain robust quantitative perfusion data in this population without endovenous gadolinium administration. This could potentially avoid recently emerging concerns regarding gadolinium tissue accumulation [3]. Another potential advantage of ASL is that the sequence can be repeated in cases of failed sedation or patient motion [1].

Quantitative ASL-derived CBF and rCBF values have been proven useful in pediatric tumor evaluation and grading and quantitative CBF values have shown similar diagnostic accuracy to the most commonly used contrast-based cerebral blood volume, in differentiating between tumoral subtypes [3]. It has also been reported that ASL CBF values correlate significantly with microvascular density [1]. The quantitative CBF values we obtained in our patient are in line with literature.

ASL imaging is proving to be a useful tool from diagnosis to follow-up. It should be considered for implementation in the routine workup of pediatric patients with brain tumors.

References

1 Yeom KW, Mitchell LA, Lober RM et al. Arterial spin-labeled perfusion of pediatric brain tumors. AJNR Am J Neuroradiol 2014;35(2):395-401. doi: 10.3174/ajnr.A3670.

2 Dangouloff-Ros V, Deroulers C, Foissac F, et al. Arterial Spin Labeling to predict brain tumor grading in children: correlations between histopathologic vascular density and perfusion MR imaging. Radiology.2016 Nov;281(2):553-566. Epub 2016 Jun 3.

3 Morana G, Tortora D, Staglianò S et al. Pediatric astrocytic tumor grading: comparison between arterial spin labeling and dynamic susceptibility contrast MRI perfusion. Neuroradiology. 2018 Apr;60(4):437-446. doi: 10.1007/s00234-018-1992-6. Epub 2018 Feb 16.J.-C.

4 Ferré, E. Bannier, H. Raoult et al. Arterial spin labeling (ASL) perfusion: techniques and clinical use. Diagn Interv Imaging. 2013 Dec;94(12):1211-23. doi: 10.1016/j.diii.2013.06.010. Epub 2013 Jul 11.

5 Alsop DC, Detre JA, Golay X et al. Recommended implementation of arterial spin-labeled perfusion MRI for clinical applications: A consensus of the ISMRM perfusion study group and the European consortium for ASL in dementia. MagnReson Med. 2015 Jan;73(1):102-16. doi: 10.1002/mrm.25197. Epub 2014 Apr 8.

Contact

Dr. Giovanna Stefania Colafati
Bambino Gesù Children's Hospital
Department of Imaging
Neuroradiology Unit
Largo S. Onofrio 4
Rome, Italy (00165)
gstefania.colafati@opbg.net