Advances in CNS tumour imaging

Andrea Rossi

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Brain tumours are the second most common group of paediatric malignancies after leukaemia. Unlike those in adults, most paediatric brain tumours are primitive lesions. The most common location is the posterior cranial fossa, where tumours prevail between ages 1 and 11 years. Conversely, tumours occurring in children younger than 1 year and older than 12 years are located more commonly in the supratentorial compartment. Magnetic resonance imaging (MRI) is an invaluable tool for identifying and characterising brain tumours, presurgical planning and evaluating the effectiveness of surgery, chemotherapy and radiotherapy. Advanced MRI modalities, including diffusion-weighted imaging (DWI), perfusion-weighted imaging (PWI) and spectroscopy, provide significant additional information regarding quantities, such as tumour cellularity, haemodynamics and metabolism.

DWI provides information regarding diffusion of water molecules from which quantitative values, the apparent diffusion coefficient (ADC), can be calculated. The most important application of DWI in the field of brain tumour imaging is in estimation of cellularity, which correlates grossly with tumour grade. Diffusion tensor imaging (DTI) and fibre tractography are important tools for preoperative mapping of brain tumours, including the identification of the anatomical relationship between tumour and functional areas, such as major fibre tracts.

PWI measures cerebral haemodynamics at the microcirculation level. The cerebral blood volume (CBV), defined as the volume of blood per unit of brain tissue and expressed in ml/100 g, is the parameter most commonly evaluated in the field of brain tumour imaging. The average relative CBV of high-grade lesions is significantly higher than that of low-grade neoplasms—a direct function of neovascularity, regardless of the integrity of the blood-brain barrier. There are several techniques for performing PWI. The most widely available is T2*-weighted dynamic susceptibility contrast (DSC) imaging, which requires intravenous administration of a bolus of paramagnetic contrast material and rapid acquisition of images over time during the first pass of contrast material through the capillary bed. DSC-PWI poses a number of technical challenges in the paediatric age group, including the need for constant, high-flow contrast material injection by power injectors, and stable, sufficiently sized intravenous access catheters, which may be problematic in the newborn and infant age groups. Arterial spin labelling (ASL), a perfusion technique that does not use an intravenous tracer, while promising, is less widely available in the clinical arena. Its use is currently limited to a few centres where high field-strength (i.e. 3 T and higher) magnets are available.

Magnetic resonance spectroscopy (MRS) allows non-invasive detection and measurement of normal and abnormal metabolites and plays an important role in the diagnostic work-up of brain tumours in children. Available 1H-MRS techniques include single-voxel and multi-voxel (chemical shift imaging) methods. Acquisition is possible at short (20–30 ms), intermediate (135–144 ms), and long (270–280 ms) echo times, yielding different possibilities for metabolite identification and peak analysis. In most instances of brain tumours, a pathological spectrum (non-specific for tumour type) consisting of increased choline (Cho)/creatine (Cr) and

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A. Rossi (✉)
Pediatric Neuroradiology,
G. Gaslini Children's Research Hospital,
Largo G. Gaslini 5,
Genova 16147, Italy
e-mail: andrearossi@ospedale-gaslini.ge.it

decreased N-acetylaspartate (NAA)/Cr ratios is detected. It is noteworthy that Cr, usually considered a stable peak and therefore used as an internal standard, can be markedly reduced in brain tumours because of energy impairment; thus, an increased Cho/Cr ratio can be due to elevated Cho, reduced Cr or a combination of both. The Cho/NAA ratio, indicating a combination of increased myelin turnover and loss of neuroaxonal integrity, can be used to overcome this shortcoming and is believed to be linked more closely to tumour grade as well as treatment response. Lipid resonances, indicative of necrosis, are frequently found in rapidly proliferating malignant tumours. Lactate indicates impaired energy metabolism and is usually found in high-grade tumours. However, it is also elevated in pilocytic astrocytomas, low-grade tumours typical of the paediatric population, yielding a paradoxically malignant spectrum in these. Multi-voxel MRS can be used to identify higher grade regions within large, heterogeneous neoplasms, and this can be useful for directing biopsy.

In conclusion, quantitative MRI techniques, including DWI (augmented by diffusion tensor imaging/fibre tractography), PWI and MRS, have contributed significantly to the pre- and postoperative assessment of brain tumours in the paediatric age group. These techniques are complementary to conventional MRI as they provide additional information about physiological, metabolic and other biological features of brain tumours that is not available in conventional MRI. On the other hand, these techniques increase MRI scan-time significantly, introducing new challenges in work organisation and patient safety. Therefore, it is important that the scan protocol is tailored individually to avoid unnecessary scanning while maximising the output of clinically relevant information, both anatomical and functional. The advent of higher field-strength magnets is expected to improve the speed and yield of these techniques, leading to increased use both for presurgical imaging and for monitoring of treatment response.