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Whole body muscle MRI protocol: Pattern recognition in early onset NM disorders

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Abstract

A paediatric and adult whole-body MRI (WB-MRI) protocol using a 1.5-T MRI system was used to examine 117 individuals (106 patients, 11 asymptomatic relatives). Genetic diagnosis was obtained in 38 subjects (*RYR1*, *LMNA*, *COL6*, *DNM2*, *GAA*, *TPM2*, *SGCA*, *MYH7*, *NEB*, *SMN*, *FKBP14*). T1-TSE WB-MRI sequences were abnormal in 67% of patients and 27% of asymptomatic relatives. Multiple striped signal abnormalities ('tiger-like') were very specific for COLVI-related myopathy. Distinct involvement of muscles in the head, neck, trunk, girdles and limbs was observed in patients with *RYR1*, *SEPN1*, *GAA*, *LMNA* or *TPM2* mutations. Abnormalities and pattern recognition were more frequent in patients studied due to rigid spine syndrome (80% abnormal, recognisable in 75% of cases), hyperlaxity syndrome (75%; 50%) or with confirmed myopathy but absence of these markers (71%; 40%). Pattern was consistent with the molecular diagnosis in 97%. Mild clinical involvement was revealed by muscle testing in three parents with abnormal WB-MRI. The Garches WB-MRI protocol is suitable for a large spectrum of adults and children with early-onset neuromuscular disorders and can be used as an effective screening test in relatives. Recognition of characteristic patterns of abnormalities is improved by whole-body scanning compared with sequential MRI and, therefore, diagnostic impact is greater.

Keywords: Magnetic resonance imaging; Childhood; Genetic or acquired neuromuscular disorders; Muscle; Whole body

1. Introduction

Neuromuscular disorders with onset in childhood are usually inherited. Spinal muscular atrophy (SMA) and muscle disorders such as congenital myopathies (CM) and congenital muscular dystrophies (CMD) are the most frequent entities, presenting early in life with generalised hypotonia, weakness and motor delay. Topography of weakness is variable and often diffuse, and patients may develop orthopaedic complications (scoliosis, joint contractures), cardiac, respiratory or bulbar dysfunction. In contrast, later-onset muscular dystrophies usually show

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primarily a limb-girdle distribution of the muscle weakness (limb-girdle muscular dystrophies or LGMD). There have been extraordinary advances in the last two decades in the identification of the underlying genetic defects of many of these conditions, but diagnosis often remains challenging due to the great clinical and genetic heterogeneity, the lack of specificity of complementary tests (muscle enzymes (CK), electrophysiological studies, muscle biopsy) and the limited availability and complexity of molecular diagnosis of many of these entities. Muscle imaging has recently become a part of the diagnostic work-up of acquired and inherited muscle diseases. While computed tomography (CT) exposes the patient to ionising radiation and ultrasound is not sensitive enough to study deep muscles or differentiate them properly, magnetic resonance imaging (MRI) is free of radiation or side-effects, and has excellent soft tissue contrast and resolution [1]. MRI is therefore the method of choice for muscle imaging and allows detection of changes such as decrease in muscle volume and/or signal changes from fat infiltration into muscle. MRI allows the presence or degree of abnormality to be distinguished for individual muscles, even within the same functional group. In 2002, Mercuri et al. proposed a short protocol for sequential MRI muscle imaging of lower limbs [2]. Soon after, several publications reported distinct patterns of muscle involvement of thighs and legs in various forms of inherited myopathies [3–10]. Due to diffuse involvement in many of these disorders, more extended examinations using sequential studies have been proposed to scan neck, trunk, scapular and pelvic girdles, but only a few slices can be performed to maintain a reasonable study time [11] (six T1 weighted and six STIR slices in this study for a total acquisition time of 25 min). Recent development of whole-body MRI (WB-MRI) techniques bypasses this difficulty and allows true whole-body scanning with broad analysis of muscle involvement by contiguous axial slices extended from head to toe and frontal views from anterior to posterior surface of the body. It has been mainly used in cancer screening and staging [12], and for evaluation of cardiovascular diseases. More recently, a few publications have been reported in musculoskeletal diseases [13–21] suggesting that whole-body MRI may represent a valuable non-invasive, non-irradiating diagnostic tool for neuromuscular disorders.

In the present study we describe a comprehensive, feasible and relatively short WB-MRI protocol especially designed to be used for the diagnosis of different forms of inherited myopathy in young children and adults. Advantages and difficulties of the technique are discussed. Data are presented regarding pattern of muscle involvement that allows muscle cartography and identification of distinct patterns in a large series of patients with different neuromuscular disorders of early onset. WB-MRI has greater diagnostic value than does sequential MRI of lower limbs, particularly in entities with involvement of axial, upper or cephalic muscles, and in patients at the mildest or most severe ends of the clinical spectrum.

2. Patients and methods

During a 5-year period (February 2005 to March 2010), a total of 260 muscular WB-MRIs were performed at Raymond Poincaré University Hospital Medical Imaging Department. A 1.5-T Philips MRI system was used (Achieva Release 11, Philips Medical Systems, Eindhoven, The Netherlands). In order to assess feasibility of WB-MRI in patients with inherited myopathies, to define examination time and detect technical problems to optimise setup parameters, 31 patients were included in a pilot study using a tentative WB-MRI protocol [22]. Examinations were performed for diagnostic purposes, in patients or relatives, searching for signs of muscle involvement following clinical observations or genetic results. Under the supervision of an intensive care physician, a magnetic-resonance-proof ventilator (Servo 900 D Ventilator, Siemens, Forchheim, Germany) was used for patients requiring ventilatory support during the procedure. Patients' ventilatory and hemodynamic condition was assessed using an NMR-compatible monitoring system (Maglife C Plus, Bruker-Schiller, Wissembourg, France). To prevent motion artefacts in young children, sedation (Nembutal, diphenhydramine, chloral hydrate, melatonin) at standard doses was administrated before the examination [23]. Informed consent was obtained before each examination, and the study was approved by the Local Ethic Committee. After the pilot study, parameters were modified to increase spatial resolution and reduce artefacts, without additional total in-room study time. In patients with severe lower limb contractures, transverse section plans were modified proportionally to obtain better muscle images (Fig. 1). Whole-body imaging was performed with a built-in volume transmitter/quadrature detection receiver coil (Q body coil with the Philips machine). The patient laid on a moveable whole body tabletop, which facilitated displacements in the Z-direction. Patient safety was ensured by braces fitted to the table. The system enabled a maximum combined field of view (FOV) of 200 cm (Philips). For each orientation, coronal and axial, data acquisition was completed in 4–7 steps during the patient's head-first passage through the magnet. In coronal orientation, the series of images acquired successively was automatically combined to generate a single coronal composite view, using the constructor's optional software. No manual realignment was needed. The selected imaging sequence was a T1-weighted turbo spin echo (T1-TSE). Stacks of T1-weighted images were acquired, in coronal orientation, with TR/TE of 573/18 ms and in axial orientation with TR/TE 631/16 ms. In-plane resolution was almost millimetric and slice thickness was 5 or 6 mm. Thirty-two composed coronal images were generated, and up to 234 axial slices in the tallest subjects. Total acquisition time for T1 slices was 24.5 min. Whole-body transverse STIR (short tau inversion recovery) sequences were obtained by the same procedure, but the in-plane resolution decreased to 1.6 mm. The maximal 530 mm FOV was large enough to scan all patients, including those with increased body mass.