Clinical feasibility of a magnetic resonance tracking system to guide the position of the scan plane during physiologic joint motion

Applicabilità clinica di un sistema di guida di posizionamento del piano di scansionie durante il movimento articolare fisiologico in risonanza magnetica

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Received: 24 April 2009 / Accepted: 26 June 2009 / Published online: 28 December 2009
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Abstract

Purpose. Unrestricted physiologic joint motion results in multidirectional displacement of the anatomic structures. When performing real-time magnetic resonance (MR) imaging of such a joint motion, continuous adjustment of the scan plane position may be required. The purpose of this study was to evaluate the clinical feasibility of a method to guide the scan plane position during dynamic-motion MR imaging of freely moving joints.

Materials and methods. The location of a small tracker device (dedicated hardware) placed on the patient’s skin overlying a joint was determined by an ultrashort MR sequence and used to automatically adjust the scan plane position prior to each dynamic-motion MR image. Using a vertically open MR unit, this MR tracking system was applied in ten dynamic-motion MR examinations to evaluate flexion/extension manoeuvres in the weight-bearing knee joint, and in ten dynamic-motion MR examinations of the shoulder joint to evaluate manoeuvres such as internal/external rotation of the humerus, stress testing of the glenohumeral joint and abduction/adduction manoeuvres. Average number of manoeuvre repetitions, total number of images and percentage of useful images per manoeuvre were calculated. Imaging time per scan plane for each manoeuvre was recorded.

Results. Average repetition of manoeuvres varied between 1.6 and 5.8, with an average number of 7 to 18 images per
manoeuvre. Average percentage of useful images varied between 61% and 89%. Total imaging time per scan plane ranged between 1 min 10 s and 4 min 51 s.

Conclusions. The MR tracking system to guide the slice position for each consecutive dynamic-motion MR image of the freely but slowly moving shoulder or knee joint was feasible for clinical use, providing a high percentage of useful images for each manoeuvre within a clinically acceptable time frame.

Keywords Magnetic resonance imaging · Kinematic musculoskeletal imaging · Patellofemoral joint imaging · Glenohumeral joint imaging · MR tracking

Introduction

Real-time dynamic-motion magnetic resonance (MR) imaging refers to acquiring images of an anatomic region of interest (ROI) within a joint that is in motion. It is distinct from a video display of a series of MR images acquired while the joint is held static in different positions [1–4]. Open-configuration MR units provide the opportunity to image joints in motion: patients may move joints in an unrestricted physiologic way within the wide gantry space. Additionally, easy patient access allows physicians to perform stress testing of joints within the MR unit [5, 6]. Moreover, vertically open MR units providing the option to place the patient in upright (standing) position have the added value of evaluating the spine and the joints of the lower limb in physiologically weight-bearing conditions [7, 8].

The unrestricted multidirectional motion of a joint, limb or entire body during MR imaging results in a technical challenge: how to continually adjust the position of the scan plane for imaging the ‘moving’ anatomy of interest. MR tracking using dedicated hardware to guide the scan plane position during dynamic-motion imaging of phantoms has been described previously [9]. The purpose of our study was to evaluate the clinical feasibility of this MR tracking system to maintain the scan plane position at a constant anatomic location within a joint or limb that is freely moving in a slow fashion.

Materials and methods

MR tracking system

The MR tracking system was developed from a real-time position-monitoring system used for localising the tip of invasive devices within patients’ bodies, such as MR-compatible intravascular catheters [10]. The development, specific technical details and preclinical tests of this MR tracking system have been previously reported [9]. Relevant hardware components and function are explained hereafter.

The MR tracking system or MR position-monitoring system uses a configuration of four hardware parts: a miniature radiofrequency coil immersed in a reservoir of dilute gadolinium diethylenetriamine pentaacetic acid (DTPA) (Cordis Corporation, Europe N.V., Waterloo, Belgium), a signal amplifier with isolation circuit, the magnet’s computing system and a SUN workstation (SUN Microsystems, Mountain View, CA, USA). The miniature radiofrequency coil is attached to the patient’s skin overlying the anatomy of interest and is therefore called an “external” tracking coil (Fig. 1). The position of this tracking coil is determined prior to the acquisition of dynamic-motion MR images by applying an ultrashort tracking MR pulse sequence (containing a nonselective radiofrequency pulse and a readout magnetic field gradient pulse for determining the location of an MR signal source, to be repeated for each x, y and z axis) that uses a Hadamard multiplexing scheme (reducing the acquisition of positional information to four instead of six excitations) [10]. The tracking coil receives signal from the proton pool in its surrounding reservoir. The signal pattern received by the tracker coil will vary according to the location of the tracker coil in the magnet’s imaging field. These signals are, after amplification, sent to the SUN workstation. Analysis of the signal pattern on the SUN workstation determines the location of the tracker coil in the magnet’s imaging volume within a few milliseconds. This information is