Magnetic Resonance Imaging will Replace Computer Tomography

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Introduction

The introduction of tomographic imaging revolutionized the way we look at medical images. Compared to X-ray projective image, Computer Tomography (CT) offers the possibility of analyzing anatomical structures on a three-dimensional, slice-to-slice approach. On the other hand, limitations of CT consist of poor soft tissue contrast and ionizing radiation [1], while the advantages are distortion-free images and fast scan times [2]. Indeed, CT has been the modality of choice in many applications, going from diagnostic imaging to image-guided therapeutic solutions [3,4].

The advent of Magnetic Resonance Imaging (MRI) represented a further quantum leap in tomographic imaging in that soft tissue contrast was dramatically superior to CT with no radiation dose. On the other hand, MRI suffered from image distortion and long scan times, as well as limitation in scanning regions where metal implants are present. MRI offers a wide range of contrast generation, which makes it probably the modality with the highest potential in the imaging arena. This is reflected in the introduction of new MRI sequences in the range of 5-10 per year.

Though MRI held significant advantages over CT, the late introduction and the complexity of the systems (and their high associated costs) have led MRI to be a follower of CT in many applications. The introduction of hardware and software solutions to mitigate the traditional weakness of MRI such as image distortion (new systems are able to reach a sub-millimeter accuracy [5]) and long scan time (parallel imaging [6] and compressed sensing methods [7] have dramatically decreased the scan time down to less than 1 minute) are making MRI become the natural successor to CT in many applications at an expense comparable to that of a mid-high end CT. On top of that, the traditional advantages of MRI over CT such as huge soft tissue contrast (see new sequence such as fat-water quantification [8]) and molecular/functional imaging (see new hyperpolarized contrast agents [9]) are even increasing in the last years. Let us have a look at some specific examples.

Integration of MRI into Hybrid Medical Devices

CT has been historically the modality of choice for image guided therapy such as in radiotherapy (see CT-on-rails [10] or cone-beam CT [11] associated with linear accelerators) or in surgery, including robotic applications [12]. The drivers were the distortion-free images and the low complexity of the CT systems compared to MRI, also in terms of behavior of electrons/ferromagnetic tools within a magnetic field. The capability of MRI to dramatically reduce distortion and the availability of MRI-compatible devices (e.g., waveguides to be placed in magnetic fields [13]) and tools (e.g., MRI compatible surgical tools [14]) has elevated MRI to the modality of future for image-guided solutions, such as High Focused Ultrasound [15] (HIFU) due to the ability of MRI to create temperature maps [16] or surgical suites due to ability of MRI to accurately differentiate tumors versus healthy tissue.

Another example is given by the integration of morphological into molecular imaging. Historically, CT has been the modality of choice in the integration with Positron Emission Tomography (PET) or Single Photon Emission Tomography (SPECT) in CT-PET or CT-SPECT. It is a common belief that MRI will add additional information to PET images when acquired simultaneously. Hence, MRI-PET hybrid systems have been proposed and are currently under investigation to understand their value in clinical routine beyond research areas [17].

MRI-guided robotic applications [18] and drug delivery [19] are the challenges of future which could enable MRI to exploit its untapped potential in a variety of different applications.

Integration of MRI into First Aid Department

Historically CT has been the modality of choice in first aid, as an evolution of projective x-ray images. This has been motivated by the fast CT acquisition and by the ability to accurately visualize traumatic results. In terms of MRI, the introduction of parallel imaging and new fast sequences has decreased the acquisition time to a level more suitable for first aid. Compressed sensing in a similar approach to iterative reconstruction in CT holds the potential to significantly decrease the acquisition time but, as of now, this is paid in terms of reconstruction time, which makes it not suitable for first aid purposes. In future, if the processing time will decrease, compressed sensing could play an important role also in first aid applications. Regarding the advantage of CT for traumatic events, new MRI pulse sequences makes it possible to visualize musculo-skeletal structures in greater detail as well as regions close to metallic implants [20]. This will make MRI very competitive against the high Z artifacts produced by CT images in the presence of metallic implants. In addition to all these improvements, MRI holds the potential to offer functional information (perfusion and diffusion), which may be very useful in some application like post-stroke therapy [21]. Therefore, interest in the use of MRI as a substitute of CT in first aid department is growing worldwide.

MRI in Cardiac Imaging

Historically, CT images represented the gold standard in cardiac applications, especially after the introduction of ultra-fast CT. The ability to quickly image multi-phase cardiac data with high spatial resolution together with a reduction in the dose whilst maintaining reasonably image quality has supported the use of CT in an increasing number of patients being examined with cardiac pathologies [22]. The introduction of fast sequences, parallel imaging and iterative reconstruction methods are shifting the attention of the community to cardiac MRI, especially due to no dose, when multiple acquisitions are needed. In addition to
that, new acquisition and post-processing techniques hold the potential to provide information about flow [23], ischemic heart disease [24] functional information as well as morphological information of heart.

In conclusion, the aforementioned examples suggest that MRI is filling the gap compared to CT, making it potentially the future modality of choice in imaging and therapeutic applications. Also, the potential offered by functional and molecular MRI is likely to differentiate even more this modality leading to the substitution of CT with MRI in the future.

References