Role of Whole Body MRI in the Evaluation of Multiple Myeloma

Essay

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Summary and Conclusion

Multiple myeloma is a neoplastic disorder of plasma B cell characterised by bone marrow infiltration and overproduction of monoclonal immunoglobulins. It accounts for approximately 10% of all haematological malignancies and 1% of all cancers with an increasing incidence. It predominantly affects patients in the seventh decade and has high morbidity and mortality. Patient survival has improved over the past decade with the introduction of novel chemotherapeutic agents

Extraosseous involvement of multiple myeloma, which can arise in any tissues, can be seen clinically or radiologically in approximately 10-20% of patients at the time of initial diagnosis and may develop in an additional 15% of patients during the course of the disease.

Wb-MRI became possible because of improvements in hardware, such as extended table translation, and the availability of a high number of simultaneous receiver channels.

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Summary & Conclusion

- Wb-MRI approaches will shift the spectrum of indications from dedicated characterisation of single pathologies towards assessment of systemic disease (atherosclerosis, metastatic disease, malformations)
- Wb-MRI appears to be a valuable alternative to PET-CT in children or in FDG-negative tumours
- Combined wb-MR protocols lead to a dramatic increase in image data, and might result in an increase in false negative findings.
- Imaging and further improvements in coil technology for faster data acquisition (parallel imaging), with the goal of reducing total examination costs

Whole-body imaging is increasingly successfully applied in musculo-skeletal imaging, especially in the field of systemic malignant diseases affecting the bone and in diseases predisposing to malignant transformation.

WB-MRI is able to depict bone marrow pathologies with high resolution and excellent soft tissue contrast by demonstrating signal alterations due to changes in its fat,

water, and hematopoietic cell components with high resolution and excellent soft tissue contrast.

Regarding bone metastases, the sensitivity was significantly higher when using WB - MRI (85%) instead of PET-CT (62%). In asuspensed bone metastases WB_ MRI showed a significantly higher diagnostic accuracy than PET-CT (91% vs. 78%).

Scintigraphy provides only limited spatial resolution and at an early stage of disease lesions may remain invisible in the absence of an osteoblastic response

WB – MRI reliably detected more confirmed skeletal metastases(91%)than bone scintigraphy(85%).

Conclusion

Whole – body imaging is increasingly successfully applied in musculoskeletal imaging , especially in the field of systemic malignant diseases affecting the bone and in diseases predisposing to malignant transformation. Whole-body MRI is able to depict bone marrow pathologies with high resolution and excellent soft tissue contrast by demonstrating signal alterations due to changes in its fat, water, and hematopoietic cell components with high resolution and excellent soft tissue contrast. Together with CT or PET-CT and its valuable additional metabolic information, it has great potential in the more comprehensive, more accurate, and earlier diagnosis of musculoskeletal diseases. Although further evaluation of the true potential of whole -body applications is awaited, they arepromising tools aiding the more efficient management of patients suffering from systemic malignant or benign diseases of the soft tissue and bone.

In conclusion whole-body MRI may offer an alternative non-ionizing, more available and much less cost method of staging and detecting marrow involvement.

Summary & Conclusion

Techniques of Whole Body MRI

MRI provides good contrast between the different soft tissues of the body, which makes it especially useful in imaging the brain, muscles, the heart, and cancers compared with other medical imaging techniques such as computed tomography (CT) or X-rays. Unlike CT scans or traditional X-rays, MRI does not use ionizing radiation ***(Squire,1997)***.

How MRI works:

The body is largely composed of water molecules. Each water molecule has two hydrogen nuclei or protons. When a person is inside the powerful magnetic field of the scanner, the magnetic moments of some of these molecules become aligned with the direction of the field. A radio frequency transmitter is briefly turned on, producing a further varying electromagnetic field. The photons of this field have just the right energy, known as the resonance frequency, to be absorbed and flip the spin of the aligned protons in the body. The frequency at which the protons resonate depends on the strength of the

applied magnetic field. After the field is turned off, those protons which absorbed energy revert to the original lower-energy spin-down state. A hydrogen dipole has two spins, 1 high spin and 1 low. In low spin both dipole and field are in parallel direction and in high spin case it is antiparallel. They release the difference in energy as a photon, and the released photons are detected by the scanner as an electromagnetic signal, similar to radio wave As a result of conservation of energy, the resonant freque frequency also dictates the frequency of the released photons. The photons released when the field is removed have an energy and therefore a frequency which depends on the energy absorbed while the field was active. It is this relationship between field-strength and frequency that allows the use of nuclear magnetic resonance for imaging. An image can be constructed because the protons in different tissues return to their equilibrium state at different rates, which is a difference that can be detected. Five different tissue variables spin density, T_1 and T_2 relaxation times and flow and spectral shifts can be used to construct images ***(Wikipedia 2011).***

By changing the settings on the scanner, this effect is used to create contrast between different types of body tissue or between other properties, as in fMRI and diffusion MRI. The 3D position from which photons were released is learned by applying additional fields during the scan. This is done by passing electric currents through specially wound solenoids, known as gradient coils .These fields make the magnetic field strength vary depending on the position within the patient which in turn makes the frequency of released photons dependent on their original position in a predictable manner, and the original locations canbe mathematically recovered from the resulting signal by the use of inverse Fourier transform ***(Wikipedia., 2011)***.

Contrast agents maybe injected intravenously to enhance the appearance of blood vessels, tumors or inflammation. Contrast agents may also be directly injected into a joint in the case of arthrograms, MRI images of joints. Unlike CT, MRI uses no ionizing radiation and is generally a very safe procedure. Nonetheless the strong magnetic fields and radio pulses

can affect metal implants, including cochlear implants and cardiac pacemakers. In the case of cochlear implants, the US FDA has approved some implants for MRI compatibility be lethal, so patients with such implants are generally not eligible for MRI.***(Luechinger et al., 2004)***.

Since the gradient coils are within the bore of the scanner, there are large forces between them and the main field coils, producing most of the noise that is heard during operation. Without efforts to damp this noise, it can approach 130decibels (dB) with strong fields ***(Luechinger et al., 2004)***.

MRI is used to image every part of the body,and is particularly useful for tissues with many hydrogen nuclei and little density contrast, such as the brain, muscle, connective tissue and most tumors ***(Wikipedia, 2011)***.

***T_1*-weighted MRI**: Spin-lattice relaxation time T_1-weighted scans are a standard basic scan, in particular differentiating fat from water - with water darker and fat brighter use a gradient echo (GRE) sequence, with short T_E and short T_R. This is one of the basic types of MR contrast and is a commonly run clinical scan. The T_1

weighting can be increased (improving contrast) with the use of an inversion pulse as in an MP-RAGE sequence. Due to the short repetition time (T_R) this scan can be run very fast allowing the collection of high resolution 3D datasets. A T_1 reducing gadolinium contrast agent is also commonly used, with a T_1 scan being collected before and after administration of contrast agent to compare the difference. In the brain T_1-weighted scans provide good gray matter/white matter contrast; in other words, T_1-weighted images highlight fat deposition ***(Wikipedia,2011)***.

***T_2*-weighted MRI**: Spin-spin relaxation time ***T_2*-** weighted scans are another basic type. Like the T_1-weighted scan, fat is differentiated from water - but in this case fat shows darker, and water lighter. For example, in the case of cerebral and spinal study, the CSF (cerebrospinal fluid) will be lighter in T_2 -weighted images. These scans are therefore particularly well suited to imaging edema, with long T_E and long T_R. Because the spin echo sequence is less susceptible to in homogeneities in the magnetic field, these images have long been a clinical workhorse.

T2*: Spin-spin relaxation time (pronounced "T 2 star") weighted scans use a gradient echo (GRE) sequence, with long T_E and long T_R. The gradient echo sequence used does not have the extra refocusing pulse used in spin echo so it is subject to additional losses above the normal T_2 decay (referred to as T_2'), these taken together are called T_2. This also makes it more prone to susceptibility losses at air/tissue boundaries, but can increase contrast for certain types of tissue, such as venous blood.

Spin density, also called proton density, weighted scans try to have no contrast from either T2 or T1 decay, the only signal change coming from differences in the amount of available spins (hydrogen nuclei in water). It uses a spin echo or sometimes a gradient echo sequence, with short TE and long TR ***(Luechinger et al., 2004)***.

Specialized MRI scans:Diffusion MRI

Diffusion MRI measures the diffusion of water molecules in biological tissues. In an isotropic medium (inside a glass of water for example), water molecules naturally move randomly according to turbulence and Brownian motion. In biological tissues however where the Reynolds number is low enough for flows to be laminar, the diffusion may be anisotropic. For example, a molecule inside the axon of a neuron has a low probability of crossing the myelin membrane. Therefore the molecule moves principally along the axis of the neural fiber. If it is known that molecules in a particular voxel diffuse principally in one direction, the assumption can be made that the majority of the fibers in this area are going parallel to that direction.***(Filleret et al., 2010)***. The recent development of diffusion tensor imaging MRI is diffusion- weighted imaging (DWI). Following an ischemic stroke, DWI is highly sensitive to the changes occurring in the lesion. It is speculated that increases in restriction (barriers) to water diffusion, as a result of cytotoxic edema (cellular swelling), is responsible for the increase in signal on a DWI scan. The DWI enhancement