An easy to exchange high performance head gradient insert for a 3T whole body MRI system: First results

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Introduction:

In Diffusion Tensor Imaging (DTI) [1] of the brain, long duration gradient lobes are applied for diffusion weighting. The highest possible gradient amplitudes are applied in combination with an echo-planar imaging (EPI) readout pulse sequence in order to encode diffusion and freeze motion of the head at the shortest possible echo time (TE). Typical TE's for b1000 on a whole body scanner are around 70-80 ms when no parallel imaging techniques are applied. As the signal to noise (SNR) increases with decreased TE it is therefore advantageous to decrease TE. This can most effectively be accomplished when using higher gradient performance. The limits in using a whole body gradient coil with respect to maximum gradient amplitude, G^{max}, in combination with high slew rates, SR, are in principle defined by the peripheral nerve stimulations (PNS) [2] and the available current and voltage applied to the coil [3, 4]. To overcome the PNS limits, higher gradient performance can only be reached when using smaller gradient coils, such as head sized coils. Reducing the radius, r, of such a coil also helps because the performance of a gradient coil scales with $1/r^5$ therefore allowing an increase in G^{max} and SR. Unfortunately, when using small head sized gradient coils you are limited to imaging heads only on your MRI scanner. In this paper we describe a new development in our lab which allows both, use of the whole body gradient coil for whole body applications with standard uncompromised clinical performance (G^{max} = 40 mT/m and SR 200 T/m/s) and use of an insertable head gradient set with significantly higher gradient performance (G^{max} > 90 mT/m and SR 800 T/m/s). A strong focus was placed on the method to switch the head gradient set in and out of the magnet as this is the crucial point for routine use, i.e. the swap time should be minimal. Overall swapping time is about 30 minutes at the moment and can be decreased to 5 - 10 minutes with further system integration, which will be comparable to a typical transit time from one patient to another patient.

Methods:

A high performance head gradient coil has been developed specifically for use inside a clinical whole body magnets with a patient bore diameter of 600 mm. The total length is 70cm at an inner diameter of 36 cm and an outer diameter of 52 cm. Similar to our existing dedicated head ALLEGRA 3T MRI scanner, this coil combines transverse asymmetric saddle coils together with longitudinal windings, which leave space for shoulder cut-outs. These allow a proper access of the subject's head to the imaging volume. The gradient coil is shielded and torque-balanced. It is vacuum-potted with a filled epoxy resin. Special skids allow easy longitudinal movement into and out of the patient bore.

Although it could also be integrated into a 1.5T whole body MRI system, this gradient insert coil has been integrated into a Siemens MAGNETOM 3T TRIO in order to benefit from the increased SNR at 3T. The gradient coil is used in combination with a special mechanical handling device that allows change of operational mode of the system between whole body and head insert gradients efficiently. The change procedure includes moving the coil manually by a crank and switching the gradient power cables and water cooling to the desired gradient coils with a single Y-switch. Both gradient operational modi use the same gradient power amplifier and system electronics. Close to the magnet, the insert´s gradient cables are guided by rolls to constrain movement caused by Lorentz forces. The change procedure needs about 30 minutes and can be performed by one person with the potential of a further reduction down to 10 minutes and can be performed by a single person. Acoustic noise produced by that coil is an issue to be considered carefully. Some sequences can reach noise levels above the legal limits if driven at a mechanical resonance frequency. Therefore sequence parameters must be constrained and a wider use in a clinical environment can only be allowed when this issue is resolved.

Results:

Technical data of the gradient insert coil are shown in Table 1. Diffusion tensor imaging with clinical b-value of 1000 was performed to show the advantages of that gradient coil. Figure 1 c) shows a diffusion weighted image at TE of 68ms, which is typical for whole body scanners. Figure 1d) shows the resulting image at the minimal TE of 49 ms achievable with the new head insert coil. Significant reduction in susceptibility artifacts as well improvement in SNR is obvious. All images are acquired without using parallel imaging techniques, which would further decrease echo time.

Axis	Sensitivity [μT/A/m]	Inductance [μH]	DSV [cm]	Deviation [%]
Transverse (x)	206	396	22	6.7
Transverse (y)	199	390	22	6.6
Longitudinal (z)	193	258	22	7.5

Table 1: Technical data of the insert head gradient coil

Discussion:

It has been shown that there are practicable mechanical integration solutions for high performance gradient inserts into whole body MRI scanners allowing an efficient and flexible use of whole body MRI scanners. A combination with parallel imaging methods can further increase the potential of applications.

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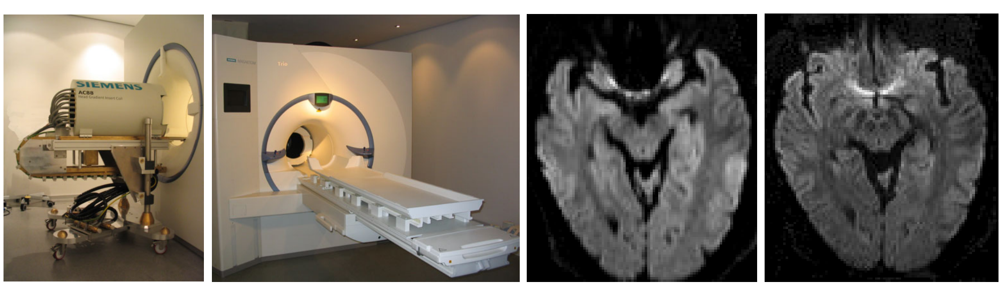

Fig.1a) Gradient coil servo drive 1b): Patient table and AC88 in target position 1c) DTI images with b1000, TE 68ms, BW 2790 Hz/pxl 1d) TE 49ms, BW 3550 Hz/pxl

a) b) c) d)

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