Effect and Mitigation of a NIOBE Magnetic Navigation System on a Proximal MR Imager

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Introduction

NIOBE magnetic navigation systems are relatively novel devices that permit remote catheter steering. The NIOBE system utilizes two permanent magnets mounted on articulating and pivoting arms, which move on either side of a cardiac catheterization patient table. These magnets generate magnetic navigation fields that are capable of deflecting custom catheters containing a small magnetic core. The peak magnetic field created by this device is approximately 0.15T, however, the polarity of this field can be inverted in a matter of seconds. Moreover, the open design of the magnets makes it very difficult to contain the stray field, which can extend a considerable distance from the NIOBE system. Workflow in a NIOBE navigation system requires that the magnets be moved from their stowed position remote from the patient table, and then manipulated to produce the desired pull on the intravascular catheter. The latter typically requires relatively small adjustments in the magnetic field, however, other coarse motions can produce substantially greater magnetic field changes in the periphery of the system. At our institution, a NIOBE system was installed 2 floors above an existing MR imager, with less than 50 linear feet separating the isocenters of the two systems. The NIOBE system was passively shielded with a complete enclosure of 0.29 inches of iron. Theoretical predictions estimated that these circumstance could produce time varying magnetic fields more than ten times our magnet vendors specifications (<5 mGuass peak to peak). We summarize the effects this type of magnetic field disturbance can produce and the steps taken to mitigate the NIOBE systems impact on MR imaging.

Methods

Direct magnetic field measurements were made at a location external to the magnet bore, but equidistant from the NIOBE and in a symmetrically opposite position. This data was correlated to the temporal effects seen on dynamic MR imaging series. All imaging was performed on a 1.5T state-of-the-art MR imaging system (Achieva, Philips Medical Systems). MR imaging included a shim check, gradient echo imaging, dynamic echo-planar imaging (EPI), and spectroscopy. The NIOBE system (Stereotaxis) was programmed to run in specific cycles representative of worst case coarse magnet movements and typical catheter navigation practice. Restrictions in the rate of NIOBE magnet motion were investigated to assess the effect of lowering the rate of magnetic field change at the MR. A Magnetic Active Compensation Systems (MACS, ETS-Lindgren) was also installed and optimized for the effects of the NIOBE system. The MACS system was subsequently either activated or deactivated during MR testing.

All imaging was performed with a 40cm diameter phantom positioned axially at magnetic isocenter. Spectrocopy was performed with a spherical phantom containing common brain chemical species. Imaging was performed with stationary NIOBE magnets as well as during coarse and fine NIOBE magnet motions. Images were analyzed for artifacts and temporal stability in time series data. Spectroscopic data were evaluated for line widths and peak heights.

Results

The NIOBE system produced time varying magnetic fields of ±20mG at the equidistant symmetric measurement location. These large sweeps occurred during coarse magnet movements associated with engaging or parking the magnets and occurred over 5-6 seconds. Spectra were not affected NIOBE movement, which is likely due to frequency locking on the MR system. There was also no perceptible effect on magnet shim as a result of any NIOBE motion. This is likely due to the far field position of the NIOBE magnet, which will produce a relatively homogeneous effect across the shim volume. Coarse magnet movements did produce image ghosting and signal instability on gradient echo images and in-plane distortion and translation of EPI images. The latter was measured with a region of interest (ROI) near the edge of a phantom whose intensity was measured over time (Figure 1). Activation of the MACS system helped to reduce these signal instabilities, typically to about 50% of their uncompensated levels. Rates of motion restrictions of the NIOBE system were then investigated to help further mitigate the NIOBE's effect on MR images. A model was developed in which NIOBE magnet motion was slowed down by a factor of 2 or 4 whenever a threshold of peripheral magnetic field change was exceeded. This model was based on the predicted change in magnetic field at the location of the MR imager without passive shielding around the NIOBE system. Accordingly, the units do not reflect the actual magnetic field disturbance, but thresholds of 10-40 mG/s were investigated. The lowest threshold (10 mG/s) was found to produce a demonstrably superior outcome that, in combination with the MACS system, improved EPI signal stability to near baseline levels. The impact of this NIOBE slowdown is to prolong coarse magnet motions to durations of 20-24s rather than 5-6s, while having virtually no effect of the fine magnet motions most commonly associated with catheter steering.

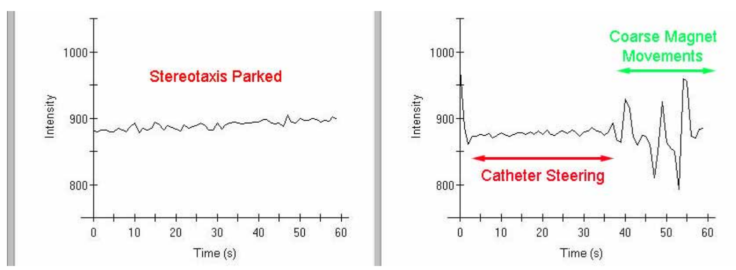

Figure 1: Signal intensity of an ROI near the edge of a homogeneous phantom during dynamic EPI imaging. The plot on the left shows baseline stability over 1 minute, while the right demonstrates stability during fine NIOBE motions (catheter steering) and coarse NIOBE magnet movements.

Conclusions

NIOBE magnetic navigation systems have the potential to affect image quality on surrounding MR systems. These affects manifest as ghosting and signal instability in gradient echo images and distortion and translation of EPI images. The use of a Magnetic Active Compensation System in combination with restrictions in the permissible rate of motion of the NIOBE system largely mitigated the effects seen on an MR system located 43 feet from the NIOBE magnetic navigation system.