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Simulations of Magnetic Activity Generated from Gastric Electrical Activity

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Abstract

Magnetic activity generated from gastric electric activity (GEA) can be recorded by Superconducting Quantum Interference Devices (SQUIDs). Typically, only magnetic activity perpendicular to the anterior body is recorded. Also, external anatomical landmarks are used to position the SQUID over the stomach. In the work presented here, we use detailed models to simulate GEA and its corresponding magnetic activity. Using these data, we investigate the affects of using a fixed SQUID location and the contribution the vertical magnetic component makes to the the full 3D magnetic field. We find that most of the magnetic activity occurs in a plane parallel to the body. We also find that using a fixed SQUID position can be suboptimal.

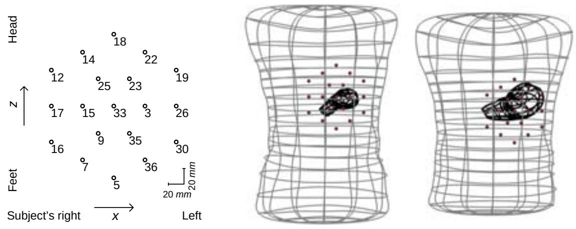

Figure 1. Names and locations of the SQUID (left) and the two different torso geometries showing the locations of the stomachs (center and right). The fixed location of the 19 channels used in the Vanderbilt University MGG SQUID are shown by the small dots.

1. Introduction

It has been shown that magnetic activity generated from GEA can be recorded by a SQUID [1]. SQUID recordings are usually only obtained and/or analyzed in the vertical direction to the anterior body, however, the importance of the activity in the other directions is uncertain. Also, the SQUID is usually positioned over a subject without specific knowledge of the subject's stomach location. Due to the variability of the stomach position within a torso, such positioning may not yield the best recordings.

To investigate these two issues, we carefully analyzed detailed simulation results of magnetic field intensity (MFI) arising from GEA to (i) see whether the magnetic activity in the vertical direction is the only one to be considered and (ii) how sensitive the SQUID location is on recorded data.

2. Method

Using our in-house software, magnetic activity was simulated using two sets of different geometries of torsos and stomachs. These torso models were constructed from CT images of two male volunteers. In each subject-specific stomach, normal GEA was simulated [2]. Using these GEA results, we then computed the magnetic activity external to the torso at 19 positions [3] corresponding to the locations of the SQUID sensors used to record magnetogastrograms (MGGs) at Vanderbilt University. The names and locations of these channels are shown in Figure 1.

For each torso geometry, we produced results at two different SQUID locations. One location was chosen to cover the entire stomach (referred to here as the customized location), and in the second set of results, the SQUID was positioned according to the recording protocols used at Vanderbilt University (referred to as fixed location since it is positioned using fixed external anatomical landmarks). An illustration of the fixed location for the two different torsos is given in Figure 1.

It is worth noting that in practice, the fixed location is used because the stomach location with the torso is typically not known a priori. As we can see in Figure 1, the SQUID center was higher than the stomach center for Subject 1, which means the fixed location of the SQUID was higher than that for the customized location. However, for Subject 2, the fixed location was lower than the customized location.

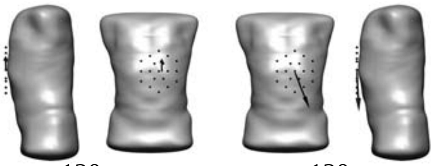

Figure 2. Simulated mean MFI (shown by the arrow) for Subject 1 using the fixed SQUID location.

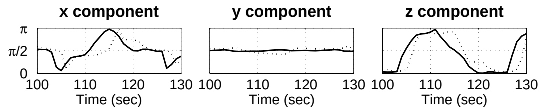

Figure 3. Angles of the mean MFI to the x, y, and z-axes using the fixed SQUID location for Subjects 1 (solid curves) and 2 (dotted).

3. Results for Magnetic Field Intensity

During simulations, the MFI at the 19 SQUID channels was computed. In order to determine how the magnetic activity changed over time and space, the average MFI for the 19 channels was calculated at each second. This averaged activity is shown by an arrow in Figure 2. To generate the averaged activity, the length was taken to be proportional to the intensities, and the center was defined by a weighted sum of the centers for the 19 channels, where the weight is proportional to the intensity and the sum of all weights is 1.

To investigate the relative importance of the magnetic activity in the y-direction (which is the component that is most commonly recorded and analyzed in practice), we plotted the angle of the averaged MFI to each of the 3 principal directions in Figure 3. These directions are the subject's right-to-left (x), front-to-back (y) and bottom-to-top (z). It can be clearly seen that the activity occurs almost entirely in a plane perpendicular to the recording direction.

Next, we determined how the MFI changed at each of the 19 channels for x, y, and z components separately. Figure 4 shows the results from two channels for each geometry. For the x and z components, the MFI did not change much with customized and fixed locations at all the 19 channels. However, the y component showed a significant relative change when using fixed versus customized locations for the SQUID.

The MFI in the y-direction had similar trends between customized and fixed locations at most of the channels. At channel 33, the trend, however, is quite different for both Subjects 1 and 2. As mentioned before, for the fixed location the SQUID was higher than the customized one for

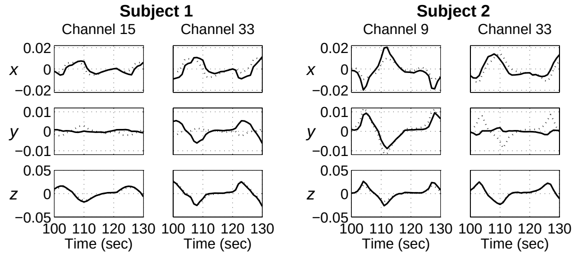

Figure 4. MFI ($\mu A/mm$) for customized (solid curves) and fixed (dotted) SQUID locations.

Subject 1, but lower for Subject 2. This is reflected in the differing patterns between simulated recordings of the y component for the fixed and customized locations for Subjects 1 and 2.

4. Conclusions

We sought to address two questions associated with recorded MGGs. The questions were whether recording the y component of the MGG was representative of the full 3 dimensional MGG, and whether using a fixed SQUID location was appropriate. Using detailed simulations, we have shown that the magnetic activity was weak in the y-direction (the most routinely recorded direction) compared to the x and z-directions. Also, the y component was more sensitive to the SQUID location than the x and z components, which means the SQUID location mainly affects the y-direction. These results indicate that it is important to record and analyze the activity not only in the y-direction but also the x and z-directions.

Acknowledgements

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References

[1] L. A. Bradshaw, W. Richards, and J. P. W. Jr. Volume conductor effects on the spatial resolution of magnetic fields and electric potentials from gastrointestinal electrical activity. *Med Biol Eng Comput.*, 39(1):35–43, 2001.

[2] M. L. Buist, L. K. Cheng, K. M. Sanders, and A. J. Pullan. Multiscale modelling of human gastric electric activity: can the electrogastrogram detect functional electrical uncoupling? *Exp Physiol*, 91(2):383–390, 2006.

[3] M. L. Buist, L. K. Cheng, R. Yassi, L. A. Bradshaw, W. O. Richards, and A. J. Pullan. An anatomical model of the gastric system for producing bioelectric and biomagnetic fields. *Physiol Meas*, 25(4):849–861, 2004.