

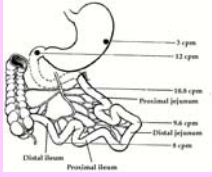
Biomagnetic Assessment of Gastrointestinal Physiology and Pathophysiology

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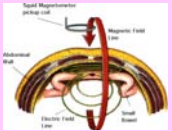
GI Physiology

The stomach and intestines process food by mixing and propulsion. Digestion depends on coordinated electrical activity in GI smooth muscle cells.

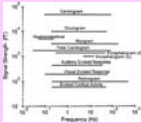


The electrical activity is present even if the muscle cells are not contracting. It is a periodic activity with a frequency that depends on the type of cell.

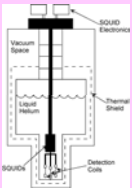
The Biomagnetic Method



Electrical activity usually produces magnetic fields. Magnetic fields may be easier to detect outside the abdomen than electric fields, even though the magnetic fields may be very weak.



Superconducting QUantum Interference Device

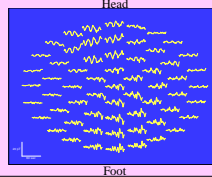


SQUID magnetometers are capable of detecting magnetic fields billions of times weaker than a typical refrigerator magnet!

GI electrical activity is only about 10 billion times weaker than the magnetic field of a typical refrigerator magnet.

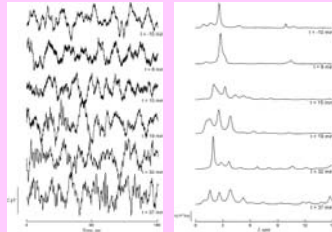
Parameters of GI Slow Wave Indicate Health

SQUIDs can detect the normal gastric and intestinal slow wave

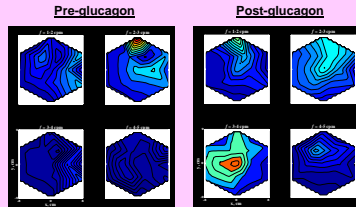


In this recording from a 61-channel SQUID system, we obtained simultaneous measurements of gastric and intestinal slow wave. The normal gastric slow wave, oscillating 3 times during the one-minute recording, is seen in the upper part of the array while the faster intestinal slow waves are seen in the lower part of the array.

SQUIDs can identify slow wave changes caused by hyperglycemia



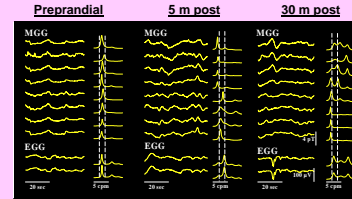
Hyperglycemia (too much blood sugar) causes dysrhythmias in the gastric slow wave. Before administration of glucagon, normal 3 cpm gastric slow waves are seen. Hyperglycemia causes immediate changes in the gastric slow wave frequency: bradygastria (frequencies lower than normal) and tachygastria (frequencies higher than normal).



These maps allow us to visualize the location of frequency effects on the magnetic field. Normal pre-glucagon slow wave activity is indicated in the 2-3 cpm range, while post-glucagon maps show activity spread over a wider range of frequencies, indicating gastric uncoupling.

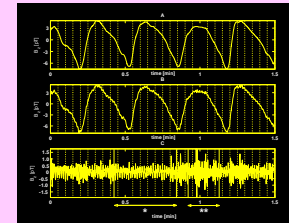
SQUIDs can distinguish changes caused by diabetic gastroparesis

Diabetic patients often have stomach problems called gastroparesis, literally "impaired stomach". Gastroparesis is related to a malfunction of the electrical signals in the stomach that control motility.



These data were obtained from a diabetic gastroparetic before a meal and at 5 minutes and 30 minutes after the meal. Signal changes in the MGG signal illustrate the impaired function of the stomach with both lower-than-normal and higher-than-normal gastric frequencies evident.

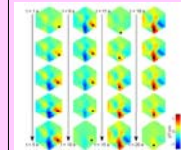
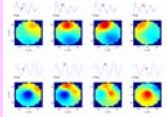
SQUIDs can detect electrical activity of contraction



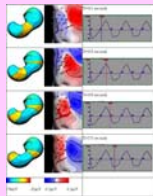
Gastrointestinal slow waves are always present and therefore useful diagnostic tools, but they are not necessarily associated with the contraction of gastric smooth muscle. However, SQUIDs also allow us to detect the higher-frequency spiking electrical response activity that corresponds to gastric contraction.

SQUIDs can quantify gastric slow wave propagation

False-color maps of the magnetic field plotted at different time intervals allow us to visualize the propagation of the gastric slow wave.



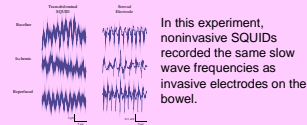
Surface current density (SCD) maps computed from magnetic field data provide more direct quantification of the propagation of the gastric slow wave and allow us to estimate propagation velocity.



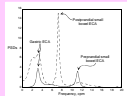
Sophisticated computer models allow us to correlate anatomical information obtained from MRI or CT with our magnetic field data to improve the diagnostic capability.

SQUIDs can measure changes caused by mesenteric ischemia

Mesenteric ischemia is a life-threatening condition with no easy diagnosis available. SQUIDs can measure the slow wave frequency decrease caused by ischemia.



In this patient, SQUID recording identified ischemia by the decrease in slow wave frequency. After corrective surgery, no frequency decrease occurs.



Vanderbilt University Gastrointestinal SQUID Technology (VU-GIST) Laboratory



We have installed a state-of-the-art magnetic field detection system at Vanderbilt University Hospital capable of measuring gastrointestinal biomagnetic field activity from humans. The VU-GIST facility includes a magnetically shielded room to reduce magnetic noise.



Future Plans

Ultimately, we hope to use SQUID magnetometers as a method for the routine diagnosis of gastric and intestinal disease.

We plan to continue our studies in patients with chronic mesenteric ischemia and diabetic gastroparesis. We will investigate the application of magnetic assessments of GI electrical activity to irritable bowel syndrome, Chron's disease and ulcerative colitis.



Dr. Crusher uses a SQUID magnetometer to diagnose this patient's gastric disease on Star Trek: The Next Generation.

Acknowledgements

Research funded by



Additional support



Faculty Research Position