Clinical Approach of BioMatrix Beat Sensor Cardiac Triggering

Christina Karamarkou, M.D.; Catharina Thielmann, M.D.

Department of Cardiology and Angiology, Contilia Heart and Vascular Centre, Elisabeth-Krankenhaus Essen, Germany

Introduction

The BioMatrix Beat Sensor cardiac triggering technology from Siemens Healthineers is based on constant RF signals which are modulated by the physiological motion of the heart and respiratory system. The modulated signal is received by a standard local body array (BioMatrix Body 12 and BioMatrix Body 18). The Beat Sensor is directly embedded in the coil. The resulting information about the cardiac motion is encoded and used to trigger the MR acquisitions. Because ECG-trigger distortion is always a challenge in cardiac MR (CMR), this technology, in contrast to the usual gold-standard ECG triggering, enables us to increase image quality and scan consistency, which limits costly and time-consuming rescans.

In our current clinical routine, we mainly use the new technology for cardiac patients with conditions that present challenges for scanning, such as pronounced cardiac arrhythmia (atrial fibrillation, ventricular ectopic beats). In this way we can personalize the examination and optimize the results for patients who do not fit the standard application. The successful sampling of high-quality image data remains the basis of diagnostic interpretation, diagnosis, and further therapeutic management.

However, there are also a few pitfalls in data acquisition, so the processor must be well trained, and a few additional steps are necessary. Our clinical experience shows that, with proper handling of the existing tools and modified sequences, the short acquisition time and high image quality are indisputable.

1 Positioning the BioMatrix Body 18 coil.
Clinical examples

1. Heart failure

Patient history: A 54-year-old woman with undefined shortness of breath and palpitations. Medication with prednisolone for 12 months. Pacemaker implantation in 2022 due to sick sinus syndrome and third-degree AV block with total loss of consciousness.

Previously performed diagnostics: PET-CT with suspected cardiac sarcoidosis without extracardiac manifestation. Myocardial biopsy with no indication of cardiac sarcoidosis by sampling error. ECG showed pronounced ventricular extrasystoles, ventricular runs, and ventricular pacemaker rhythm. Echocardiography showed an ejection fraction of 40% with undefined hypokinesia.

Clinical diagnosis: Heart failure of unknown cause

MRI indication: Confirmation of expected cardiac sarcoidosis

Materials and methods:

1.5T CMR system (MAGNETOM Sola, Siemens Healthcare, Erlangen, Germany)

Protocol included electrocardiography-gated and Beat Sensor cardiac-triggered steady state free precession (bSSFP) images of long-axis (LA) 2-, 3-, and 4-chamber views, and short-axis (SA) stacks. For T1 mapping, conventional 5(3)3 modified Look-Locker inversion recovery (MOLLI) sequences were performed before administration of a gadolinium contrast. Phase-sensitive inversion recovery gradient echo sequences were acquired 15–20 minutes after the gadolinium bolus injection for late gadolinium enhancement (LGE) assessment.

The initial electrocardiography-gated (bSSFP) sequences produced a lower image quality due to arrhythmias.

A challenging case executed with high performance thanks to Beat Sensor cardiac triggering.

2 (2A) Cine 3-chamber view with ECG triggering; (2B) Cine 4-chamber view with ECG triggering. After changing to the Beat Sensor cardiac triggering, a higher image quality was achieved. (2C) Cine 3-chamber view with Beat Sensor cardiac triggering; (2D) Cine 4-chamber view with Beat Sensor cardiac triggering.

3 (3A) LGE in basal SA, (3B) midventricular SA, and (3C) apical SA; (3D) 2-chamber LA; (3E) 4-chamber LA with Beat Sensor cardiac triggering.
2. Ischemia

Patient history: A 59-year-old female patient with palpitations, coronary anomalies, progressed peripheral artery disease (PAD), and cerebral circulatory disorders with continued nicotine abuse.

Previously performed diagnostics: 24-hour ECG with pronounced ventricular extrasystoles. Echocardiography showed an ejection fraction of 55%.

MRI indication: Verification of ischemia

Materials and methods:

1.5T CMR system (MAGNETOM Sola, Siemens Healthcare, Erlangen, Germany)

Protocol included electrocardiography-gated and Beat Sensor cardiac-triggered steady state free precession (bSSFP) images of long-axis (LA) 2-, 3-, and 4-chamber views, and short-axis (SA) stacks. For T1 mapping, conventional 5(3)3 modified Look-Locker inversion recovery (MOLLI) sequences were performed before administration of a gadolinium contrast. Phase-sensitive inversion recovery gradient echo sequences were acquired 15–20 minutes after the gadolinium bolus injection for late gadolinium enhancement (LGE) assessment.

The learning phase

In the current implementation, the Beat Sensor requires some additional steps to

1) collect and train the signal for the coil elements;
2) calibrate the signal with respect to RF interference.

Therefore, we position the body array on the thorax, taking care to ensure the coil is fixed securely to the table. The Beat Sensor is positioned right on top of the heart. The center of the coil should be over the heart in the head-feet direction. The BioMatrix Body 18 coil cable should leave the coil in the feet direction. When using the BioMatrix Body 12 coil, the cable should leave the coil in the head direction. After finalizing the table position, the localizer-heart protocol is performed. The software acts like a coil memory for subsequent Beat Sensor cardiac-triggered acquisition, and the learning phase starts. The calibration protocol starts immediately after the learning phase with a series of RF pulses which are then used to calibrate the sensor signal. After these essential sequences, further diagnostic scans can be performed.
Gold-standard ECG triggering vs. Beat Sensor cardiac triggering in cardiac imaging

Overall we scanned approximately 50% of our patients in particular with an adenosine stress protocol using the Beat Sensor with a BioMatrix Body 18 array coil on a 1.5T MAGNETOM Sola system (Siemens Healthcare, Erlangen, Germany).

Especially in patients with cardiac arrhythmia, we find this to be a time-saving alternative to the gold-standard ECG triggering, which is susceptible to artifacts. The Beat Sensor triggering avoids potential problems such as low-voltage ECG due to poor skin contact, suboptimal electrode placement, anatomical/disease-related conditions (COPD, respiratory problems), and magnetohydrodynamic signal distortion, especially at high field strengths. It also removes the need for time-consuming procedures like chest-shaving for optimal electrode contact and monitoring the ECG signal to ensure sufficient quality.

Using the Beat Sensor means we can achieve high-quality results and, thanks to shorter scan times, we save time in our clinical routine and give patients a more comfortable examination experience.

A typical ECG-triggered CMR examination is timed so that the static acquisitions are performed in the late diastolic phase by placing the acquisition as late as possible in the cardiac cycle. The trigger time of the Beat Sensor is 200 milliseconds later than the R-wave, in response to the systolic contraction. This time shift is automatically generated based on the collected data from the learning phase. No ECG triggering is required.

For static acquisitions in the end-diastolic resting phase of the heart cycle, the sequences have been modified so that it is possible to adjust the acquisition window to the end-diastolic resting phase of the heart cycle. When using this feature, recognizing when the processor is exchanged between scans is crucial. Otherwise, there is a risk of missing triggers and unstable signal in the switching phase, which will make further manual modifications necessary. Alternatively, you can set a fixed interval for the entire examination.

Challenges

There are some clinical constellations in which the Beat Sensor technology does not lead to satisfactory image data acquisition. In these cases, it may be necessary to rescan the image record, or it might not even be possible to create acceptable results. We have found that obese female patients with very large chest areas are a particularly vulnerable group in this regard. The presence of more tissue can make it challenging or even impossible to achieve proper signal acquisition from the Beat Sensor.

Conclusion

We started the Beat Sensor cardiac triggering as part of a clinical study of specific patient groups, such as patients with pronounced arrhythmia and expected poor image quality. The time savings achieved by the reduction in rescans and by shorter acquisition times were significant.

Having compared Beat Sensor triggering with gold-standard ECG triggering across multiple CMR applications, we found the image quality to be subjectively equivalent. The function, LGE, and perfusion maps showed no significant difference in all measurements we have performed so far. The high-quality results with arrhythmia patients and the need for only a few/short examination requirements were convincing. We also see great potential and further scope for validation in a more diverse patient cohort, such as patients with abnormal anatomy and body habitus. By incorporating respiratory gating and prospective slice correction, we are continuing our development efforts to improve accuracy and precision.