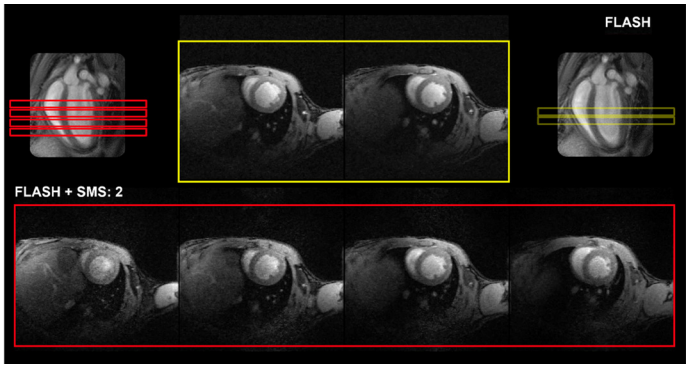


# Bruker Preclinical Cardiac MR: Rapid Setup > Fast Scans > AI Analysis.

Preclinical MR is a well-established imaging technique to investigate a multitude of small animal cardiac disease models. While CT contrast agents (e.g. iodinated agents) typically used in clinical CT cardiograph protocols clear too quickly for use in small animal models, preclinical MR provides strong cardiac contrast for both enhanced and non-enhanced contrast imaging. As mice and rats have heart rates up to 5x faster than humans, high-contrast CINE imaging with good slice and/or frame coverage is often required to 1) resolve exquisitely small features of rodent cardiac tissue, and 2) to obtain functional measurements such as ejection fraction.

Preclinical MR hardware and software methods that allow for high signal-to-noise ratios (SNR) while minimizing total scan time can be highly beneficial in small animal cardiology. Bruker MR system hardware and method features including ergonomically designed cardiac array coils, fast gradients and amplifiers, self-gated methods (i.e. IntraGate), and new acceleration techniques can significantly reduce overall measurement times to increase cardiac imaging performance. Beyond improvements of the preclinical cardiac measurement method itself, a streamlined and robust workflow from setup to evaluation of cardiac parameters makes cardiac investigations and analysis a straightforward process.

## Ergonomic Cardiac Array Coils: Highest SNR & Fastest Throughput

Array coils can provide enhanced SNR versus volume coils (Figure 1A/B1). Because the Bruker cardiac array coils are embedded in the cradle structure (Figure 1B2), subjects can be positioned prone with the heart directly on the coil elements for maximum sensitivity. The Bruker platform has a well-organized setup for animal monitoring cables that does not obstruct the cradle/coils and does not need to be re-seated for each scan. The MRI instruments have direct service-end and patient-end bore access and coils connect at the service end via an automatically recognized smart plug.

**Figure 1**

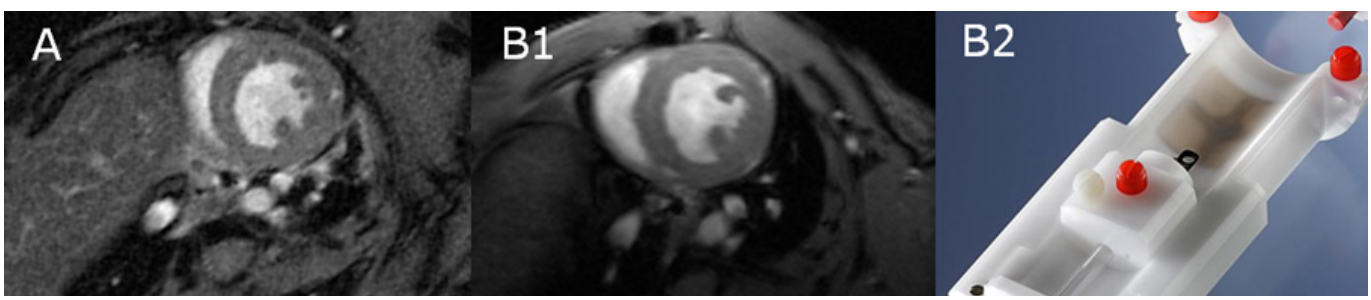


Figure 1. Cardiac images obtained with standard volume coil (A) Versus ergonomic cardiac array coil (B1). (A) versus (B1) show mouse short axis diastolic phase images obtained using a 40 mm circ. pol. volume and a cardiac array respectively. (B2) shows the inbuilt cardiac array coil designed for high sensitivity imaging and simple subject loading. Scans were acquired with a Bruker BioSpec 70/30. Parameters: Method: FcFLASH, TE: 2.5 / 2.4 ms, TR: 8 ms, FA: 15°, Mtx: 192x192, FOV: (25x25) $mm^2$ Res.: (130x130) $\mu m^2$ Slice Thick.: 800 µm Slices: 1 Movie Frames: 14 / 12 Voxel: 13.6 nl Triggered Acquisition.

Because of the organized setup of the coils and animal supply chains requiring no changes between samples, sample setup/exchange is little more involved than positioning the animal in a cradle, allowing for higher throughput in sequential animal imaging and shortest individual animal anesthesia times.

## Gradients & Amplifiers Boost Temporal Resolutions

Due to the rapid heart rate of rodent models, fast imaging is required to obtain resolved cardiac CINE frames. Bruker's fast gradients and amplifier configurations can allow collection of a high number of frames per cardiac cycle (Figure 2).

**Figure 2**

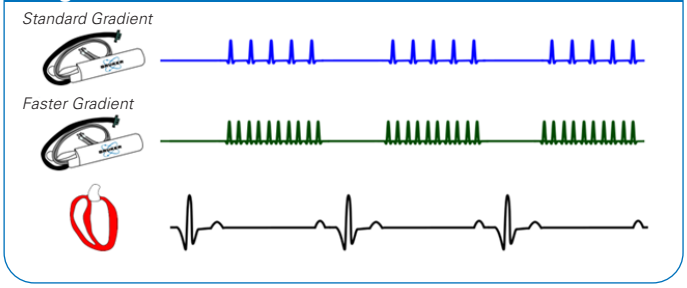


Figure 2. Cardiac frames possible using a standard gradient (blue) versus a fast gradient (green).

## IntraGate: Simplest Setup & Improved Data

Self-gated techniques like the Bruker IntraGate methods allow for retrospective gating without the need of ECG electrodes. Thus, not only a significant amount of time is saved per cardiac setup but also any gradient-electrode signal interference that could occur and could degrade the cardiac experiment is avoided. In IntraGate methods, the gating signal is collected via an MR navigator which is incorporated in IntraGate FLASH and IntraGate UTE methods which are both available within the software, ParaVision. Since IntraGate methods reconstruct the cardiac data retrospectively, additional reconstructions of the cardiac data can be created after the experiments is finished. Thus, for example, if the SNR is sufficient, more CINE frames can be reconstructed on the same acquired dataset (Figure 3). As a consequence, IntraGate methods can provide higher cardiac framing compared to conventional ECG triggered sequences that are inherently limited by the ECG rate and scanner hardware directly.

Due to its short echo time and radial readout IntraGateUTE is well suited for cardiac imaging even at higher field strengths. The short echo time reduces turbulence artifacts while the radial readout further benefits the minimization of motion artifacts. Furthermore, self-gated methods, such as IntraGateUTE are more robust against missing k-space lines, compared to a cartesian readout.

## New Acceleration Techniques and Cardiac Methods

MR acceleration techniques (e.g. simultaneous multi-slice (SMS)) show promise for achieving faster preclinical cardiac imaging and coverage in cardiac studies. For example, employing an array coil and an SMS method, it was possible to double the slice coverage without increasing scan time compared to conventional CINE imaging (Figure 4). This capability is particularly valuable where functional measurements are desired. For example, left ventricle function analysis requires a large coverage area and is often time consuming, though could potentially be achieved much faster employing multi-slice imaging.

**Figure 4**

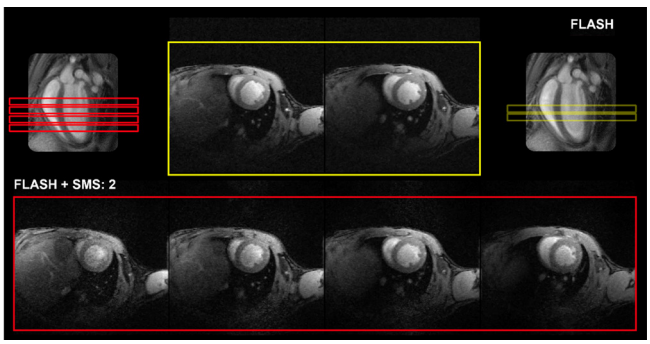


Figure 4. Accelerated SMS (Red) CINE imaging provides more slice coverage compared conventional (Yellow) CINE imaging without increasing scan time. Scans were acquired on a BioSpec 70/30 with a mouse cardiac array, and only varying SMS Factor (None or SMS2) and Slice Number (2 or 4). All other parameters were constant TE/TR: 1.6/10 ms, Res.: (130 x 130) $\mu m^2$, Slice Thick.: 800 µm Movie Frames: 12, Acquisition Time (triggered): ~8 m 30 s.

**Figure 3**

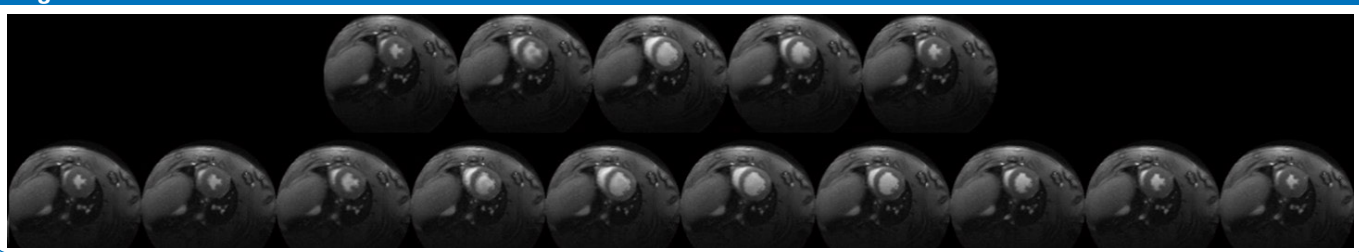

Figure 3. The IntraGate technique allows to retrospectively reconstruct different numbers of CINE frames if SNR is high enough. Same IntraGateUTE dataset with two reconstructions. Top-row: 5 CINE frames were reconstructed, Bottom row 10 CINE frames were reconstructed.

## New Functional Cardiac Analysis

ParaVision 360 provides seamless DICOM export to the PMOD DICOM server. PMOD recently introduced its AI Framework PAI for AI-based segmentation. This flexible framework has already been leveraged to support preclinical cardiac functional measurements (Figure 5, AI-based epi- and endocardial contours as part of a streamlined workflow in PCARDM), including common metrics used in assessing cardiac disease models: Ejection Fraction, End Diastolic/Systolic, Stroke Volume, Heart Rate, and Cardiac Output.

## Conclusions

Bruker MR systems provide intelligently integrated system components that translate to high useability in preclinical cardiac studies. Gradients, coils, and methods meet signal and speed requirements critical for cardiac applications. Combined with new analytical tools and integrated software workflows, the time between initiating the study and obtaining quantitative metrics is shorter than ever. Combinations of many features including coils, IntraGate methods, acceleration methods, and analytics have the potential to synergistically multiply capabilities in preclinical MR cardiac studies in a growing number of ways.

**Figure 5**

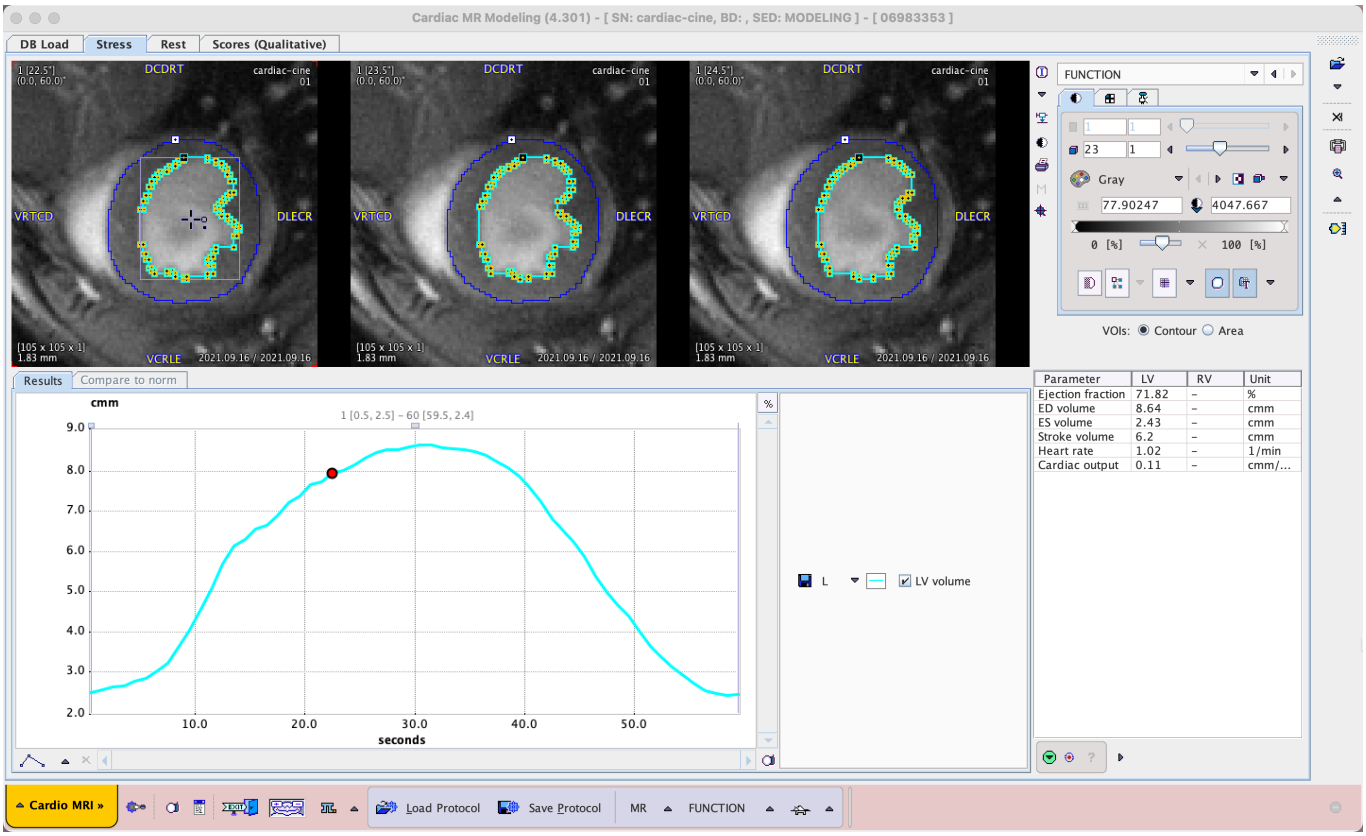


Figure 5. Streamlined cardiac function analysis leveraging AI-based segmentation in PMOD PCARDM. Epi- and endocardial contours are displayed and can be easily adjusted if necessary. The volume-cardiac-cycle curve is produced, and functional parameters tabulated.

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