SCMR Recommended Adult Cardiac Protocols User's Guide 2019

SIEMENS Healthineers

Introduction

20 Disease-specific Indications – 4 Exam Strategies – Dot Workflows

This user's guide describes the SCMR Recommended Cardiac MRI protocols based on the Cardiac Dot Engine that have been clinically optimized for the Siemens MAGNETOM family of MRI scanners, including 3T MAGNETOM Skyra and Vida as well as 1.5T MAGNETOM Aera and Sola.

Dot technology enables easy examination setup with quick and efficient workflow by providing guidance and automating many steps of the exam. For example, Auto Localization, Auto Shim, Auto Trigger, Auto Breath-Hold, etc.

The protocols are organized by common cardiac diseases and strategically sub-organized by the patient's cooperative abilities. For example:

- Routine
- Arrhythmia
- Tachycardia
- Free breathing

Clinical Disease-Specific Indications

- Acute Infarct
- Chronic Ischemia
- Hypertrophic LV
- Hypertension
- Non-Compaction
- Dilated LV
- Arrhythmic RV
- Siderotic
- Restrictive LV
- Sarcoidosis
- Myocarditis
- Onco Drugs
- Transplant
- Aortic MRA
- Coronary MRA
- Pulmonary Veins
- Valves
- Pericardium
- Tumor – Thrombus
- Library

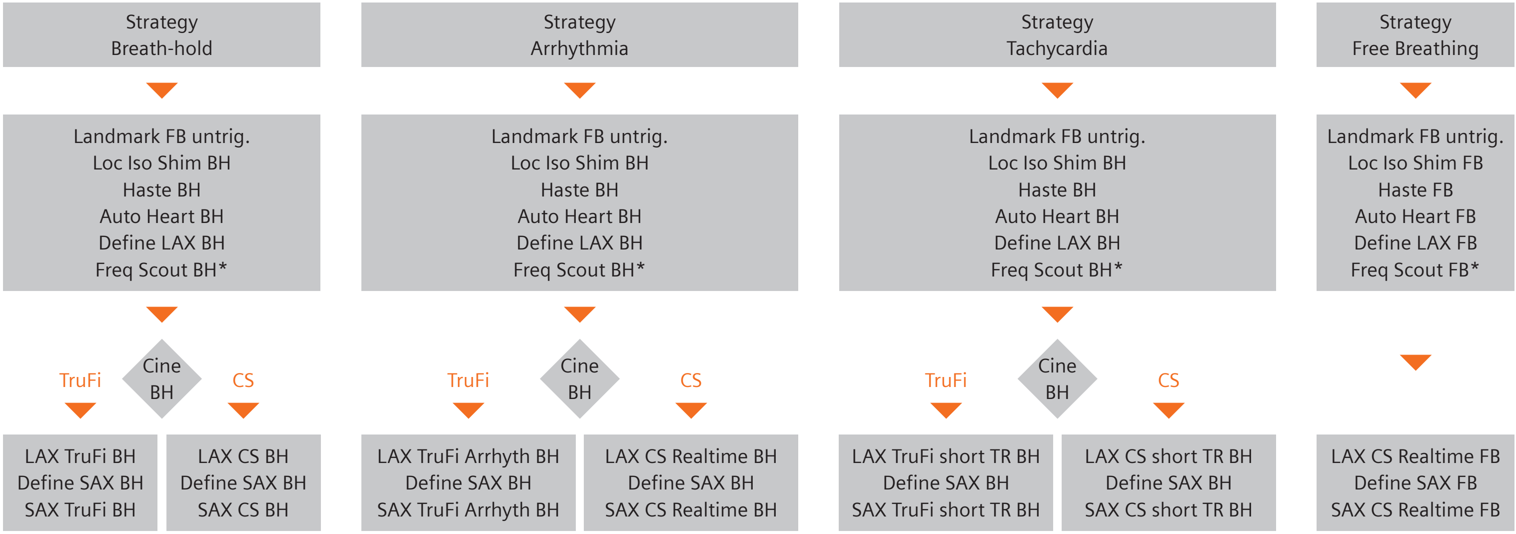
SCMR Guidelines for Adults

- All protocols comply with SCMR Guidelines
  Kramer et al. Journal of Cardiovascular Magnetic Resonance 2013, 15:91
  http://jcmr-online.com/content/15/1/91
- Default spatial and temporal resolutions are closely matched to SCMR guidelines for adults, but may need to be adapted to patient conditions. As heart rate increases, the TR should be decreased accordingly.

ADULT 360 mm FOV, 18-channel Body Array Coil

CINE	1.5 x 1.5 x 6 mm; TR 45 ms	LGE	2.2 x 1.4 x 8 mm; TR 140 ms
FLOW	2.5 x 1.9 x 6 mm; TR 45 ms	PERF	2.8 x 2.3 x 8 mm; TR 134 ms
T1 MAP	2.3 x 1.5 x 8 mm; TR 214 ms	3DMRA	1.5 x 1.2 x 1.2 mm
DB TSE	1.9 x 1.4 x 8 mm; TR 71 ms	TWIST	1.8 x 1.3 x 1.3 mm; TR 3.0 s

Localization and Cardiac Function Modules



** Freq Scout only at 3T*

1. During patient registration, select the clinical disease-specific protocol group. In the initial Dot step before running the Landmark, decide the optimal strategy according to the patient's capability. ROUTINE strategy should be used for patients with no special requirements who are able to breath-hold. ARRHYTHMIA strategy enables arrhythmia rejection on TruFi Cines and single-shot methods for various other sequences. TACHYCARDIA strategy enables faster temporal resolution for all sequences. FREE-BREATHING strategy should be used as a last resort for patients who can not breath-hold, and this employs only single-shot or navigator-based methods.

2. LANDMARK acquires 9 localizer slices in 3 planes to see where the heart is located within the bore. Just apply the sequence with no setup or positioning. This sequence is non-triggered & free-breathing.

3. LOC ISO SHIM acquires 9 localizer slices in 3 planes to move the heart to isocenter and define the cardiac shim volume. Position the center of the slice groups at the center of the heart. Adjust the green shim box to match the position & size of the heart, including from above the aortic arch to below the apex. The isocenter & shim settings derived from this step will be automatically propagated to next steps in the exam. This sequence automatically adapts to the patient's heartrate and automatically adapts to multiple breath-holds.

4. HASTE acquires 30 axial dark blood slices to survey the entire chest. This sequence automatically adapts to the patient's heartrate and automatically adapts to multiple breath-holds. For faster heartrates DO NOT use Capture Cycle: set Trig Pulses to 3, set Acq Window to span through 2 beats, set TR equal to Acq Window.

5. AUTO-HEART acquires 18 localizer slices in a "pseudo" short axis view which covers from base to apex. It automatically calculates the standard long axis views (2CH, 3CH, 4CH). During slice planning, slide the slice group up or down as needed to cover the entire heart, but DO NOT change the angle of the slices. This sequence automatically adapts to the patient's heartrate, and acquires all slices in a single breath-hold.

6. DEFINE LAX acquires 3 localizer slices in each long axis view, and automatically adjusts the Phase FOV to fit the patient's chest size. This sequence automatically adapts to the patient's heartrate, and acquires all slices in a single breath-hold. During slice planning, make slight adjustments in slice orientations as necessary to optimize the 2ch, 3ch, 4ch views based on the previous "pseudo" short axis views obtained from the AUTO-HEART step.

7. FREQUENCY SCOUT (only @ 3T) acquires a single slice in the 4-chamber-view, automatically adapts to the patient's heartrate, and requires only a single breath-hold. Review the images to select the best image quality: minimal dark banding artifacts through the heart and maximal contrast between the blood and the myocardium. Determine the TruFi delta frequency of your best image, and enter that value into the next TruFi or CS cine sequence.

8. CINE 2CH, 3CH, 4CH acquires 3 cines in each long axis view using either TruFi or CS. This sequence allows fine-tuning of slice position, orientation, and Phase FOV during slice planning. All changes you make during slice planning will be automatically propagated forward to all subsequent long axis views. This sequence automatically adapts to the patient's heartrate, automatically adapts to multiple breath-holds, automatically adapts to the cardiac shim, and automatically adapts to the TruFi delta frequency (3T).
   - TruFi and CS methods have approx equivalent temporal resolution and SNR. TruFi method has slightly better spatial resolution, but CS method is significantly faster.
   - Breath-hold strategy assumes patient is fully cooperative with breath-holds, and has normal heartrate, and has no arrhythmias.
   - Arrhythmia strategy assumes patient is fully cooperative with breath-holds, and has normal heartrate, but has moderate arrhythmias. The TruFi method uses Retrospective Triggering with RR-based Arrhythmia Rejection. The CS method uses a real-time acquisition with Adaptive Triggering, but in extreme cases (PVC, AF, Bigeminy) it may be necessary to turn off the Adaptive Triggering.
   - Tachycardia strategy assumes patient is fully cooperative with breath-holds, and has no arrhythmias, but has tachycardia (> 90 bpm). The TruFi method has moderately higher temporal resolution (< 35 ms), whereas the CS method has significantly higher temporal resolution (< 25 ms).
   - Free-Breathing strategy assumes patient is unable to breath-hold, but has normal heartrate and no arrhythmias. The CS method uses a real-time acquisition with Adaptive Triggering, and is faster with better image quality than traditional multi-averaged segmented TruFi.

9. DEFINE SAX acquires a stack of localizer slices in the short axis view, and automatically adjusts the Phase FOV to fit the patient's chest size. This sequence automatically adapts to the patient's heartrate, and acquires all slices in a single breath-hold. During slice planning, make slight adjustments in slice orientations as necessary to optimize the short axis views based on the previous long axis cines. SAX ALL is a full stack with coverage from base to apex, and should be planned on a diastolic cine image of the long axis. SAX SUBSET is a short stack with only 3 slices located at base, mid, and apex level of the left ventricle and should be planned on a systolic cine image of the long axis. During slice planning it may be helpful to visually overlay the subset stack with the full stack to appreciate their coverages (using the provided tick box).

10. CINE SAX acquires a full stack of cines in the short axis view using either TruFi or CS. This sequence allows fine-tuning of slice position, orientation, and Phase FOV during slice planning. All changes you make during slice planning will be automatically propagated forward to all subsequent short axis views. This sequence automatically adapts to the patient's heartrate, automatically adapts to multiple breath-holds, automatically adapts to the cardiac shim, and automatically adapts to the TruFi delta frequency (if Frequency Scout was used @ 3T).

Parametric Mapping Module

Strategy Breath-hold	Strategy Arrhythmia	Strategy Tachycardia	Strategy Free Breathing
SAX T1 Map BH SAX T2 Map BH SAX T2* Map BH	SAX T1 Map BH SAX T2 Map BH SAX T2* Map BH	SAX T1 Map BH SAX T2 Map BH SAX T2* Map BH	SAX T2Prep FB

1. T1 Mapping acquires 3 slices in the SAX views (base, mid, apex) which adapts to the patient's heartrate and adapts to multiple breath-holds, using the IR-prep 5(3)3 sampling scheme.
   - Breath-hold and Arrhythmia strategies use nominal spatial and temporal resolution.
   - Tachycardia strategy uses a lower spatial resolution to achieve a higher temporal resolution.
   - Free-breathing strategy is unavailable.

2. T2 Mapping acquires 3 slices in the SAX views (base, mid, apex) which adapts to the patient's heartrate and adapts to multiple breath-holds, using the T2-prep (0, 30, 55 ms) sampling scheme.
   - Breath-hold and Arrhythmia strategies use nominal spatial and temporal resolution.
   - Tachycardia strategy uses a longer recovery period.
   - Free-breathing strategy is unavailable.

3. T2* Mapping acquires 3 slices in the SAX views (base, mid, apex) which adapts to the patient's heartrate and adapts to multiple breath-holds, using the multi-echo (2–18 ms) sampling scheme.
   - Breath-hold, Arrhythmia, and Tachycardia strategies all use nominal spatial and temporal resolution.
   - Free-breathing strategy is unavailable.

Delayed Enhancement Module

Strategy Breath-hold	Strategy Arrhythmia	Strategy Tachycardia	Strategy Free Breathing
TI Scout BH LAX Seg PSIR BH SAX Seg PSIR BH	TI Scout BH LAX SS MoCo PSIR BH SAX SS MoCo PSIR BH	TI Scout BH LAX Seg short TR PSIR BH SAX Seg short TR PSIR BH	TI Scout FB LAX SS MoCo PSIR FB SAX SS MoCo PSIR FB

1. TI SCOUT is run within the first 10 minutes post-contrast to determine the optimal TI value for myocardial nulling. There are no differences in the sequence parameters among the various strategies, except the breathing maneuvers.

2. DELAYED ENHANCEMENT sequences should be run within the first 10 minutes post-contrast. They acquire 1 slice in each of the LAX views (2ch, 3ch, 4ch) and the entire stack of slices in the SAX view (all). These sequences adapt to the patient's heartrate and adapt to multiple breath-holds. Segmented TurboFlash PSIR is used for BREATH-HOLD strategy. Single-shot Motion-corrected TruFi PSIR is used for ARRHYTHMIA and FREE BREATHING strategies. For TACHYCARDIA (RR < 700 ms) use a segmented TurboFlash PSIR with slightly fewer Segments for improved temporal resolution, manually adjust the Acquisition Window to span through 2 heartbeats, manually adjust the TR for diastolic gating on the 2nd heartbeat, and manually adjust the Trigger Pulses to 3 in order to allow sufficient T1 recovery.

3. (OPTIONAL) EARLY ENHANCEMENT sequences run exactly same as above, except within the first 3 minutes post-contrast to detect microvascular obstruction. There is no need to run TI SCOUT because a fixed long TI is used (600 ms @ 1.5T, 800 ms @ 3T). In order to achieve such long TI it may be necessary to manually adjust the Acquisition Window to span through 2 heartbeats and manually adjust the TR for diastolic gating on the 2nd heartbeat. Further, for TACHCARDIA strategy it is also necessary to use slightly fewer segments and manually adjust the Trigger Pulses to 3.

Myocardial Perfusion Module

Strategy Breath-hold	Strategy Arrhythmia	Strategy Tachycardia	Strategy Free Breathing
Perfusion Test BH Perfusion Stress BH Perfusion Rest BH	Perfusion Test BH Perfusion Stress BH Perfusion Rest BH	Perfusion Test BH Perfusion Stress BH Perfusion Rest BH	Perfusion Test FB Perfusion Stress FB Perfusion Rest FB

1. PERFUSION TEST runs for only 10 heartbeats to verify that the slice locations and FOVs are optimal before running the actual perfusion scans with contrast agent and stress agent. It acquires 3 slices in the SAX (base, mid, apex) and 1 slice in the LAX (2-chamber).

2. PERFUSION STRESS runs for 60 heartbeats during the administration of contrast agent and stress agent. The same 4 slices are acquired (as described above). The temporal resolution of each slice is 160 ms, thus the minimum Acquisition Window is 640 ms to acquire all 4 slices within one heartbeat. This typically suffices for Rest Perfusion, but for Stress Perfusion the heartrate is much faster and it may be necessary to use 2 concatenations to spread the 4 slices evenly over 2 successive heartbeats. Although this is typically acquired as a breath-hold, motion correction (MoCo) helps adjust for a small amount of residual breathing if the patient is not fully compliant.

3. SCMR recommends at least 10 mins delay between the two perfusion scans to allow all contrast and stress agents to fully washout.

4. PERFUSION REST runs for 60 heartbeats during the administration of only contrast agent. The same 4 slices are acquired (as described above). The temporal resolution of each slice is 160 ms, thus the minimum Acquisition Window is 640 ms to acquire all 4 slices within one heartbeat. MoCo is applied.

Dobutamine Module

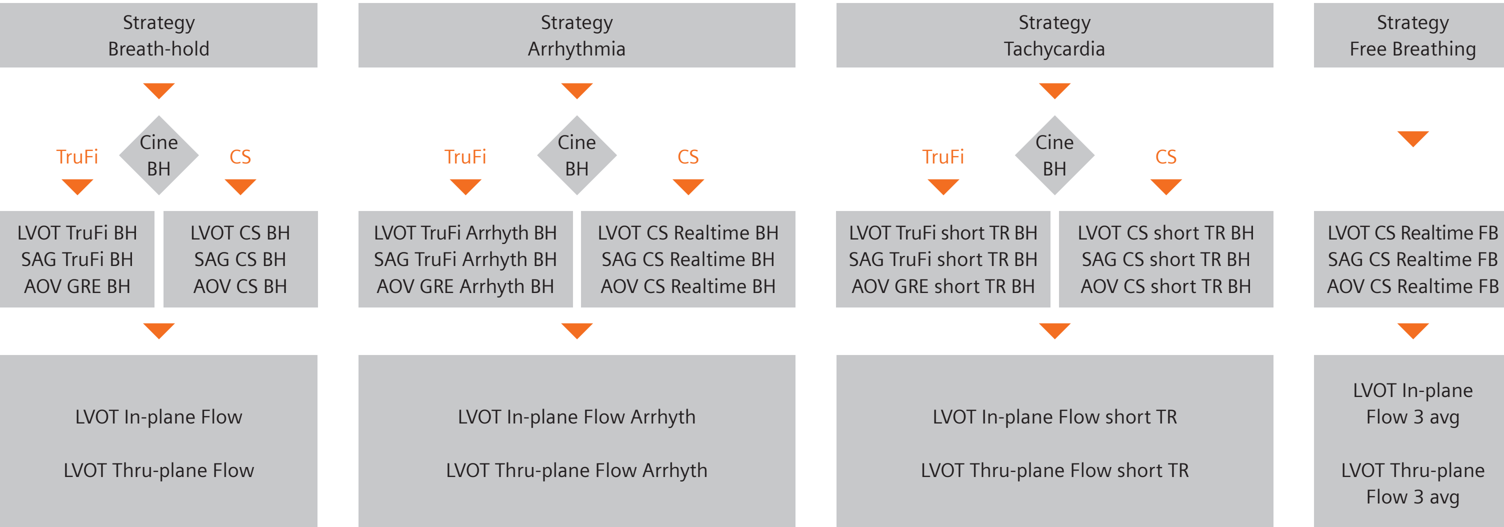
Strategy Breath-hold	Strategy Arrhythmia	Strategy Tachycardia	Strategy Free Breathing
LAX TruFi Cine BH SAX TruFi Cine BH	LAX TruFi Cine Arrhyth BH SAX TruFi Cine Arrhyth BH	LAX TruFi Cine short TR BH SAX TruFi Cine short TR BH	LAX CS Realtime Cine FB SAX CS Realtime Cine FB

1. CINE LAX acquires 1 cine in each long axis view (2ch, 3ch, 4ch) which have been defined in prior steps. This sequence automatically adapts to the patient's heartrate, automatically adapts to multiple breath-holds, automatically adapts to the cardiac shim, and automatically adapts to the TruFi delta frequency (3T).

2. CINE SAX same as above, except acquires 1 cine at base, mid, and apex short axis views which have been defined in prior steps as "SAX Subset".

   - The Breath-hold strategy uses Segmented TruFi Cine, assumes patient is fully cooperative with breath-holds, and has normal heartrate, and has no arrhythmias. This method uses Retrospective Triggering with higher temporal resolution (< 30 ms).
   - The Arrhythmia strategy uses Segmented TruFi Cine, assumes patient is fully cooperative with breath-holds, and has normal heartrate, but has moderate arrhythmias. This method uses Retrospective Triggering with higher temporal resolution (< 30 ms), and RR-based Arrhythmia Rejection.
   - The Tachycardia strategy uses Segmented TruFi Cine, assumes patient is fully cooperative with breath-holds, and has no arrhythmias, but has tachycardia (> 90 bpm). This method uses Retrospective Triggering with higher temporal resolution (< 30 ms).
   - The Free-Breathing strategy uses Realtime CS, assumes patient is unable to breath-hold, but has normal heartrate and no arrhythmias. This method has higher temporal resolution (< 35 ms), uses Adaptive Triggering, and is faster with better image quality than traditional multi-averaged segmented TruFi.

Left Ventricular Outflow Module



1. CINE LVOT acquires 1 slice in the paracoronal left ventricular outflow view using either TruFi or CS sequences. This sequence automatically adapts to the patient's heartrate, requires only 1 breath-hold, automatically adapts to the cardiac shim, and automatically adapts to the TruFi delta frequency (3T).
   - TruFi and CS methods have approx equivalent temporal resolution and SNR. TruFi method has slightly better spatial resolution, but CS method is significantly faster.
   - Breath-hold strategy assumes patient is fully cooperative with breath-holds and has normal heartrate, and has no arrhythmias.
   - Arrhythmia strategy assumes patient is fully cooperative with breath-holds and has normal heartrate, but has moderate arrhythmias. The TruFi method uses Retrospective Triggering with RR-based Arrhythmia Rejection. The CS method uses a real-time acquisition with Adaptive Triggering, but in extreme cases (PVC, AF, Bigeminy) it may be necessary to turn off the Adaptive Triggering.
   - Tachycardia strategy assumes patient is fully cooperative with breath-holds and has no arrhythmias, but has tachycardia (> 90 bpm). The TruFi method has moderately higher temporal resolution (< 35 ms), whereas the CS method has significantly higher temporal resolution (< 25 ms).
   - Free-Breathing strategy assumes patient is unable to breath-hold, but has normal heartrate and no arrhythmias. The CS method uses a real-time acquisition with Adaptive Triggering, and is faster with better image quality than traditional multi-averaged segmented TruFi.

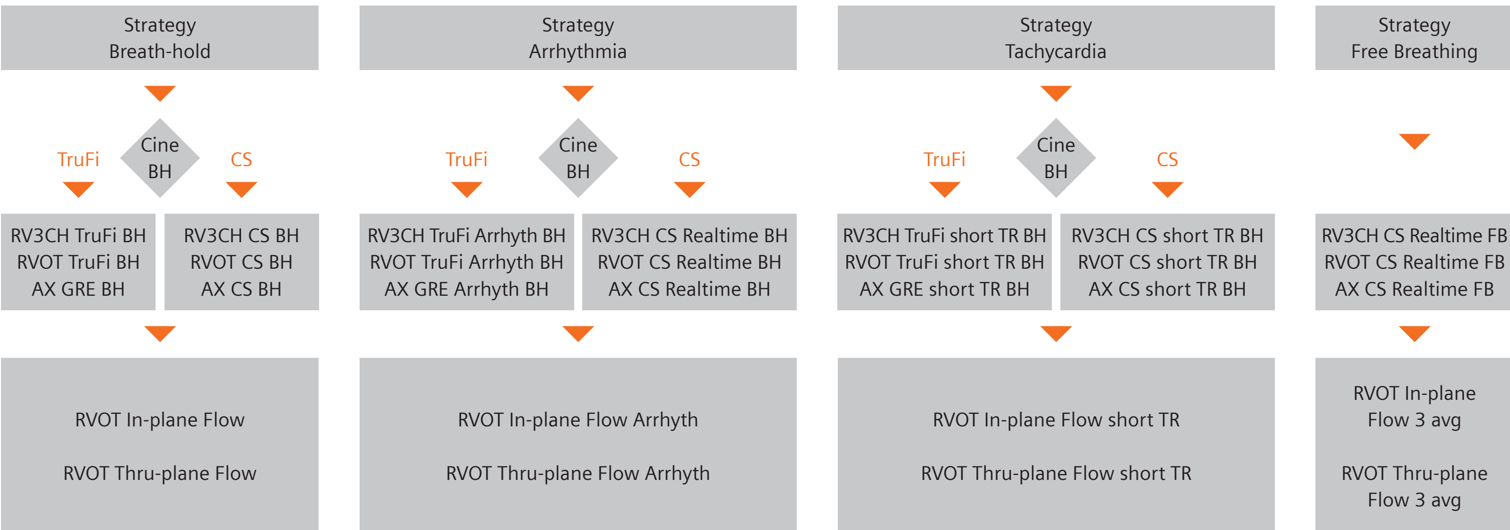
2. CINE SAG acquires 1 cine slice in the parasagittal aortic arch view using either TruFi or CS sequences. This sequence automatically adapts to the patient's heartrate, requires only 1 breath-hold, automatically adapts to the cardiac shim, and automatically adapts to the TruFi delta frequency (3T). Same strategies as previous CINE LVOT.

3. CINE AOV acquires 3 cine slices above, below, and through the aortic valve view using GRE sequence. This sequence automatically adapts to the patient's heartrate, automatically adapts to multiple breath-holds, and automatically adapts to the cardiac shim. Same strategies as previous CINE LVOT.

4. IN-PLANE FLOW acquires 1 in-plane flow slice in the aortic outflow view to visualize stenotic or regurgitant flow jets in the LVOT. VENC is set to 150 cm/s by default, but may need to be increased for high velocity jets.
   - Breath-hold strategy uses standard spatial and temporal resolution.
   - Arrhythmia strategy uses arrhythmia rejection.
   - Tachycardia strategy uses short TR.
   - Free-breathing strategy uses multiple averages.

5. THROUGH-PLANE FLOW acquires 3 through-plane flow slices above, below, and through the aortic valve to visualize stenotic or regurgitant flow jets in the LVOT. VENC is set to 150 cm/s by default, but may need to be increased for high velocity jets. Same strategies as previous IN-PLANE FLOW.

Right Ventricular Outflow Module



1. CINE RV3CH acquires 1 slice in the right ventricular 3-chamber-view using either TruFi or CS sequences. This sequence automatically adapts to the patient's heartrate, requires only 1 breath-hold, automatically adapts to the cardiac shim, and automatically adapts to the TruFi delta frequency (3T).
   - TruFi and CS methods have approx equivalent temporal resolution and SNR. TruFi method has slightly better spatial resolution, but CS method is significantly faster.
   - Breath-hold strategy assumes patient is fully cooperative with breath-holds and has normal heartrate, and has no arrhythmias.
   - Arrhythmia strategy assumes patient is fully cooperative with breath-holds and has normal heartrate, but has moderate arrhythmias. The TruFi method uses Retrospective Triggering with RR-based Arrhythmia Rejection. The CS method uses a real-time acquisition with Adaptive Triggering, but in extreme cases (PVC, AF, Bigeminy) it may be necessary to turn off the Adaptive Triggering.
   - Tachycardia strategy assumes patient is fully cooperative with breath-holds and has no arrhythmias, but has tachycardia (> 90 bpm). The TruFi method has moderately higher temporal resolution (< 35 ms), whereas the CS method has significantly higher temporal resolution (< 25 ms).
   - Free-Breathing strategy assumes patient is unable to breath-hold, but has normal heartrate and no arrhythmias. The CS method uses a real-time acquisition with Adaptive Triggering, and is faster with better image quality than traditional multi-averaged segmented TruFi.

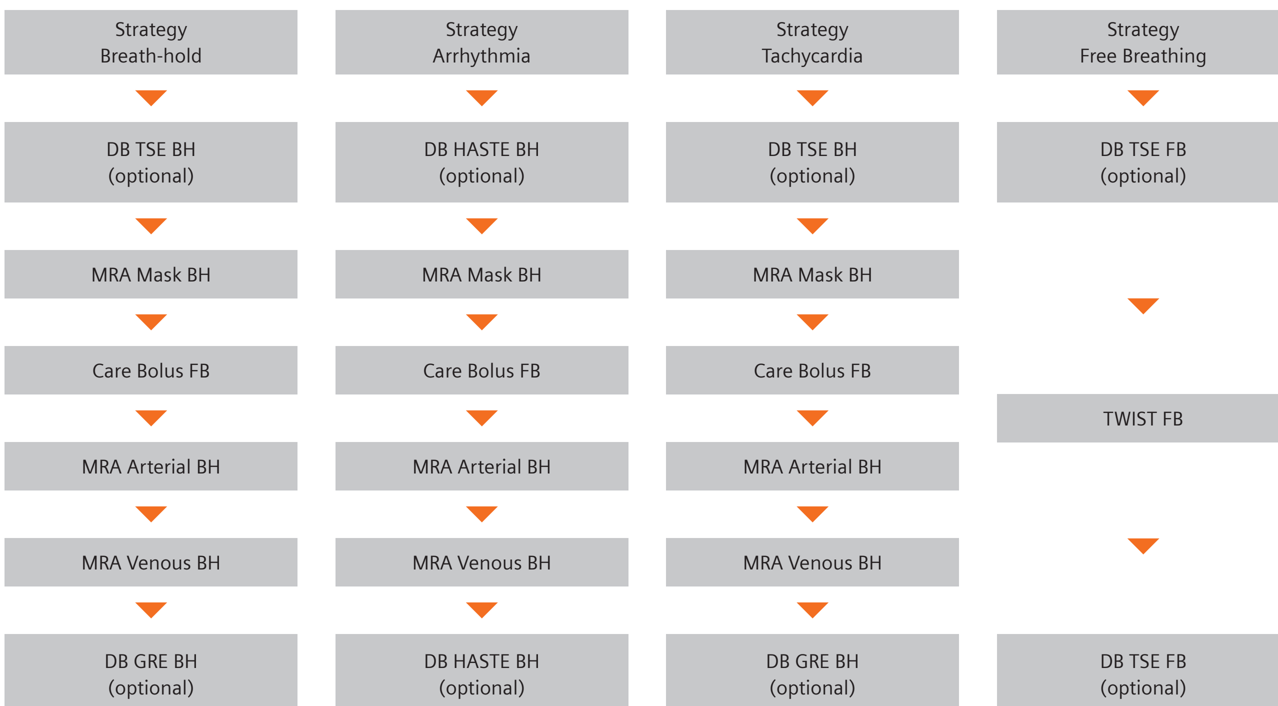
2. CINE RVOT acquires 1 cine slice in the right ventricular outflow view using either TruFi or CS sequences. This sequence automatically adapts to the patient's heartrate, requires only 1 breath-hold, automatically adapts to the cardiac shim, and automatically adapts to the TruFi delta frequency (3T). Same strategies as previous CINE RV3CH.

3. CINE AX acquires a stack of axial cine slices covering the entire right ventricle using GRE sequence. This sequence automatically adapts to the patient's heartrate, automatically adapts to multiple breath-holds, and automatically adapts to the cardiac shim. Same strategies as previous CINE RV3CH.

4. IN-PLANE FLOW acquires 1 in-plane flow slice in the pulmonic outflow view to visualize stenotic or regurgitant flow jets in the RVOT. VENC is set to 100 cm/s by default, but may need to be increased for high velocity jets.
   - Breath-hold strategy uses standard spatial and temporal resolution.
   - Arrhythmia strategy uses arrhythmia rejection.
   - Tachycardia strategy uses short TR.
   - Free-breathing strategy uses multiple averages.

5. THROUGH-PLANE FLOW acquires 3 through-plane flow slices above, below, and through the pulmonic valve to visualize stenotic or regurgitant flow jets in the RVOT. VENC is set to 100 cm/s by default, but may need to be increased for high velocity jets. Same strategies as previous IN-PLANE FLOW.

Aortic MRA Module



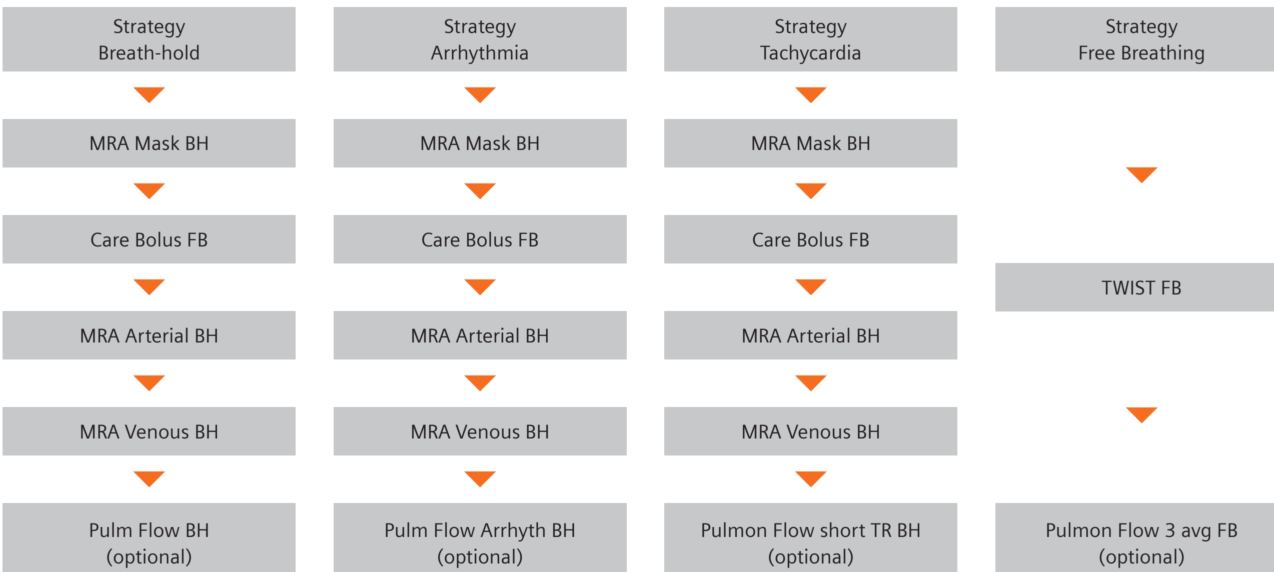
1. OPTIONAL DB TSE (pre-contrast) acquires 7 axial thin contiguous slices through the hematoma or aortic dissection. For ARRHYTHMIA strategy use HASTE single-shot. For TACHYCARDIA strategy manually set both acquisition window and TR to slightly less than 2x RR and set Trig Pulses to 3. For FREE-BREATHING strategy use Blade with Respiratory Trigger.

2. The MRA module provides 2 options:

   - Breath-Hold Care Bolus – Plan a sagittal slab covering the entire aorta. Both the pre- and post-contrast FL3D sequences must be acquired during breath-hold, but the care-bolus sequence is typically acquired during free-breathing. Contrast bolus in injected just after starting the care bolus sequence, and the care bolus sequence is stopped when the contrast arrives at the target vessel. Pre-contrast images are automatically subtracted from post-contrast images, and then automatically MIP'd.
   - Free-Breathing Dynamic TWIST – Plan a sagittal slab covering the entire aorta. Contrast bolus is injected immediately after the 1^{st} measurement is completed. Shallow breathing during entire scan. First measurement is automatically subtracted from all remaining measurements, and then automatically MIP'd.

3. OPTIONAL DB GRE (post-contrast) acquires 7 axial thin contiguous slices through the aortitis. For ARRHYTHMIA strategy use HASTE single-shot. For TACHYCARDIA strategy manually set both acquisition window and TR to slightly less than 2x RR and set Trig Pulses to 2. For FREE-BREATHING strategy use Blade with Respiratory Trigger.

Pulmonary Venous MRA Module



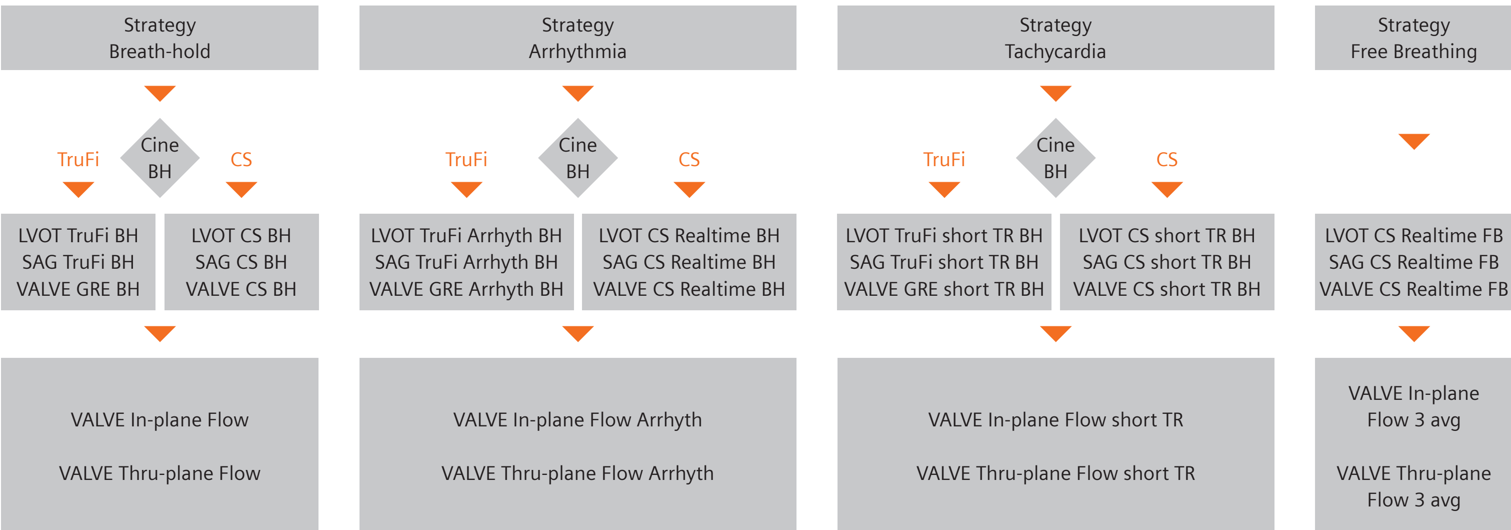
1. The Pulmonary Venous MRA module provides 2 options:

   • Breath-hold Care Bolus – Plan a coronal slab covering the entire left atrium and pulmonary veins. Both the pre- and post-contrast FL3D sequences must be acquired during breath-hold, but the care-bolus sequence is typically acquired during free-breathing. Contrast bolus in injected just after starting the care bolus sequence, and the care bolus sequence is stopped when the contrast arrives at the target vessel. Pre-contrast images are automatically subtracted from post-contrast images, and then automatically MIP'd.

   • Free-Breathing Dynamic TWIST – Plan a coronal slab covering the entire left atrium and pulmonary veins. Contrast bolus is injected immediately after the 1st measurement is completed. Shallow breathing during entire scan. First measurement is automatically subtracted from all remaining measurements, and then automatically MIP'd.

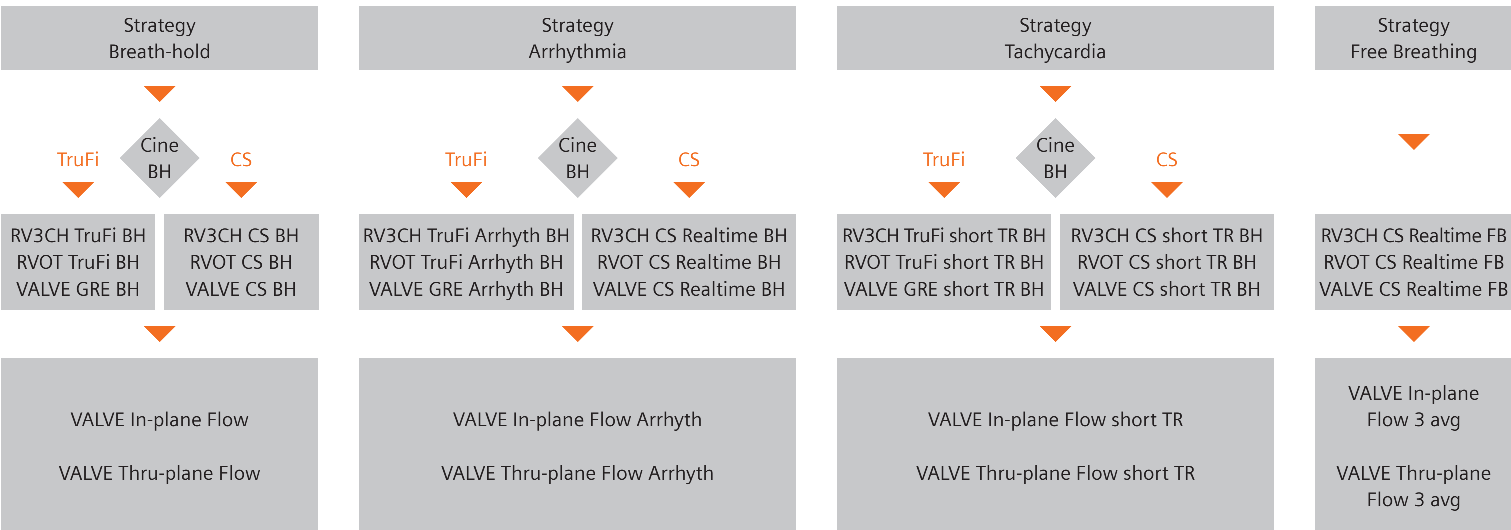
2. OPTIONAL FLOW PULM VEIN acquires 1 through-plane flow slice across the pulmonary veins. Default VENC is set to 60 cm/s. For ARRHYTHMIA strategy use Arrhythmia Rejection. For TACHYCARDIA strategy use short TR. For FREE-BREATHING strategy multiple averages.

Aortic / Mitral Valves Module



1. CINE LVOT acquires 1 slice in the paracoronal left ventricular outflow view using either TruFi or CS sequences. This sequence automatically adapts to the patient's heartrate, requires only 1 breath-hold, automatically adapts to the cardiac shim, and automatically adapts to the TruFi delta frequency (3T).
   - TruFi and CS methods have approx equivalent temporal resolution and SNR. TruFi method has slightly better spatial resolution, but CS method is significantly faster.
   - Breath-hold strategy assumes patient is fully cooperative with breath-holds and has normal heartrate, and has no arrhythmias.
   - Arrhythmia strategy assumes patient is fully cooperative with breath-holds and has normal heartrate, but has moderate arrhythmias. The TruFi method uses Retrospective Triggering with RR-based Arrhythmia Rejection. The CS method uses a real-time acquisition with Adaptive Triggering, but in extreme cases (PVC, AF, Bigeminy) it may be necessary to turn off the Adaptive Triggering.
   - Tachycardia strategy assumes patient is fully cooperative with breath-holds and has no arrhythmias, but has tachycardia (> 90 bpm). The TruFi method has moderately higher temporal resolution (< 35 ms), whereas the CS method has significantly higher temporal resolution (< 25 ms).
   - Free-Breathing strategy assumes patient is unable to breath-hold, but has normal heartrate and no arrhythmias. The CS method uses a real-time acquisition with Adaptive Triggering, and is faster with better image quality than traditional multi-averaged segmented TruFi.
2. CINE SAG acquires 1 cine slice in the parasagittal aortic arch view using either TruFi or CS sequences. This sequence automatically adapts to the patient's heartrate, requires only 1 breath-hold, automatically adapts to the cardiac shim, and automatically adapts to the TruFi delta frequency (3T). Same strategies as previous CINE LVOT.
3. CINE VALVE acquires 3 cine slices above, below, and through the aortic / mitral valves using GRE sequence. This sequence automatically adapts to the patient's heartrate, automatically adapts to multiple breath-holds, and automatically adapts to the cardiac shim. Same strategies as previous CINE LVOT.
4. IN-PLANE FLOW acquires 1 in-plane flow slice in the aortic / mitral valves to visualize stenotic or regurgitant flow jets. VENC is set to 150 cm/s by default, but may need to be increased for high velocity jets.
   - Breath-hold strategy uses standard spatial and temporal resolution.
   - Arrhythmia strategy uses arrhythmia rejection.
   - Tachycardia strategy uses short TR.
   - Free-breathing strategy uses multiple averages.
5. THROUGH-PLANE FLOW acquires 3 through-plane flow slices above, below, and through the aortic / mitral valves to visualize stenotic or regurgitant flow jets. VENC is set to 150 cm/s by default, but may need to be increased for high velocity jets. Same strategies as previous IN-PLANE FLOW.

Pulmonic / Tricuspid Valves Module



1. CINE RV3CH acquires 1 slice in the right ventricular 3 chamber view using either TruFi or CS sequences. This sequence automatically adapts to the patient's heartrate, requires only 1 breath-hold, automatically adapts to the cardiac shim, and automatically adapts to the TruFi delta frequency (3T).
   - TruFi and CS methods have approx equivalent temporal resolution and SNR. TruFi method has slightly better spatial resolution, but CS method is significantly faster.
   - Breath-hold strategy assumes patient is fully cooperative with breath-holds and has normal heartrate, and has no arrhythmias.
   - Arrhythmia strategy assumes patient is fully cooperative with breath-holds and has normal heartrate, but has moderate arrhythmias. The TruFi method uses Retrospective Triggering with RR-based Arrhythmia Rejection. The CS method uses a real-time acquisition with Adaptive Triggering, but in extreme cases (PVC, AF, Bigeminy) it may be necessary to turn off the Adaptive Triggering.
   - Tachycardia strategy assumes patient is fully cooperative with breath-holds and has no arrhythmias, but has tachycardia (> 90 bpm). The TruFi method has moderately higher temporal resolution (< 35 ms), whereas the CS method has significantly higher temporal resolution (< 25 ms).
   - Free-Breathing strategy assumes patient is unable to breath-hold, but has normal heartrate and no arrhythmias. The CS method uses a real-time acquisition with Adaptive Triggering, and is faster with better image quality than traditional multi-averaged segmented TruFi.
2. CINE RVOT acquires 1 cine slice in the right ventricular outflow view using either TruFi or CS sequences. This sequence automatically adapts to the patient's heartrate, requires only 1 breath-hold, automatically adapts to the cardiac shim, and automatically adapts to the TruFi delta frequency (3T). Same strategies as previous CINE RV3CH.
3. CINE VALVE acquires 3 cine slices above, below, and through the pulmonic / tricuspid valves using GRE sequence. This sequence automatically adapts to the patient's heartrate, automatically adapts to multiple breath-holds, and automatically adapts to the cardiac shim. Same strategies as previous CINE RV3CH.
4. IN-PLANE FLOW acquires 1 in-plane flow slice in the pulmonic / tricuspid valves to visualize stenotic or regurgitant flow jets. VENC is set to 100 cm/s by default, but may need to be increased for high velocity jets.
   - Breath-hold strategy uses standard spatial and temporal resolution.
   - Arrhythmia strategy uses arrhythmia rejection.
   - Tachycardia strategy uses short TR.
   - Free-breathing strategy uses multiple averages.
5. THROUGH-PLANE FLOW acquires 3 through-plane flow slices above, below, and through the pulmonic / tricuspic valves to visualize stenotic or regurgitant flow jets. VENC is set to 100 cm/s by default, but may need to be increased for high velocity jets. Same strategies as previous IN-PLANE FLOW.

Disease-specific Workflows

Acute Infarct
1. Localizer and Cardiac Function Modules
2. Parametric Mapping Module (optional)
3. Myocardial Perfusion Module (optional)
4. Early Enhancement Module (optional)
5. Delayed Enhancement Module

Chronic Ischemia
1. Localizer and Cardiac Function Modules
2. Parametric Mapping Module (optional)
3. Dobutamine Module (optional)
4. Myocardial Perfusion Module (optional)
5. Delayed Enhancement Module

Hypertrophic LV
1. Localizer and Cardiac Function Modules
2. Left Ventricular Outflow Module
3. Parametric Mapping Module (optional)
4. Myocardial Perfusion Module (optional)
5. Delayed Enhancement Module

Hypertension
1. Localizer and Cardiac Function Modules
2. Parametric Mapping Module (optional)
3. Myocardial Perfusion Module (optional)
4. Delayed Enhancement Module

Non Compaction
1. Localizer and Cardiac Function Modules
2. Parametric Mapping Module (optional)
3. Myocardial Perfusion Module (optional)
4. Delayed Enhancement Module

Dilated LV
1. Localizer and Cardiac Function Modules
2. Parametric Mapping Module (optional)
3. Myocardial Perfusion Module (optional)
4. Delayed Enhancement Module

Arrhythmic RV
1. Localizer and Cardiac Function Modules
2. Right Ventricular Outflow Module
3. DB TSE Module (optional)
4. Delayed Enhancement Module

Siderotic
1. Localizer and Cardiac Function Modules
2. Parametric Mapping Module
3. Myocardial Perfusion Module (optional)
4. Delayed Enhancement Module (optional)

Restrictive LV
1. Localizer and Cardiac Function Modules
2. Parametric Mapping Module (optional)
3. Deep Breathing Cine (optional)
4. Delayed Enhancement Module

Sarcoidosis
1. Localizer and Cardiac Function Modules
2. Parametric Mapping Module
3. Delayed Enhancement Module

Myocarditis
1. Localizer and Cardiac Function Modules
2. Parametric Mapping Module
3. Early Enhancement Module (optional)
4. Delayed Enhancement Module

Onco Drugs
1. Localizer and Cardiac Function Modules
2. Parametric Mapping Module (optional)
3. Myocardial Perfusion Module (optional)
4. Delayed Enhancement Module

Transplant
1. Localizer and Cardiac Function Modules
2. Parametric Mapping Module (optional)
3. Myocardial Perfusion Module (optional)
4. Delayed Enhancement Module

Aortic MRA
1. Localizer Module
2. Left Ventricular Outflow Module
3. Aortic MRA VModule

Coronary MRA
1. Localizer and Cardiac Function Modules
2. Hi-Resolution TruFi Cine FB
3. T2 TruFi NAV FB / IR GRE NAV FB / T2 GRE NAV FB

Pulmonary Veins
1. Localizer Module
2. Cardiac Function Module (optional)
3. Pulmonary MRA Module
4. Left Atrial LGE (optional)

Valves
1. Localizer and Cardiac Function Modules
2. Aortic / Mitral Valves Module (optional)
3. Pulmonic / Tricuspid Valves Module (optional)

Pericardium
1. Localizer and Cardiac Function Modules
2. LAX and SAX DB TSE (optional)
3. LAX and SAX Grid Tag (optional)
4. Deep Breathing Cine
5. Delayed Enhancement Module

Tumor / Thrombus
1. Localizer and Cardiac Function Modules
2. DB T1 TSE and FS T2 TSE (tumor)
3. Perfusion (tumor)
4. FS T1 TSE (tumor)
5. TruFi Cine (tumor)
6. Delayed Enhancement (tumor)

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