SCMR Recommended Congenital Cardiac Protocols User's Guide 2019

SIEMENS Healthineers

Introduction

10 Disease-specific Indications – 3 Age Groups – 2 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.

Clinical Disease-Specific Indications

- Aortic Coarctation
- Tetrology of Fallot
- Dloop Trans Arterial Switch
- Dloop Trans Atrial Switch
- Secundum Atrial Septal Defect
- Anomolous Plumonary Veins
- Sinus Venosus Septal Defect
- Ebstein Anomoly
- Single Ventricle Stage 1-2 Repair
- Single Ventricle Fontan Repair
- Library

Age Groups

- Teen/Adult
- Child
- Infant

Strategies

- Breath-Hold
- Free-Breathing

Dot Workflows

- Auto Localization
- Auto Shim
- Auto Trigger
- Auto Breath-Hold
- Easily skip out of Dot

SCMR Guidelines for Congenitals

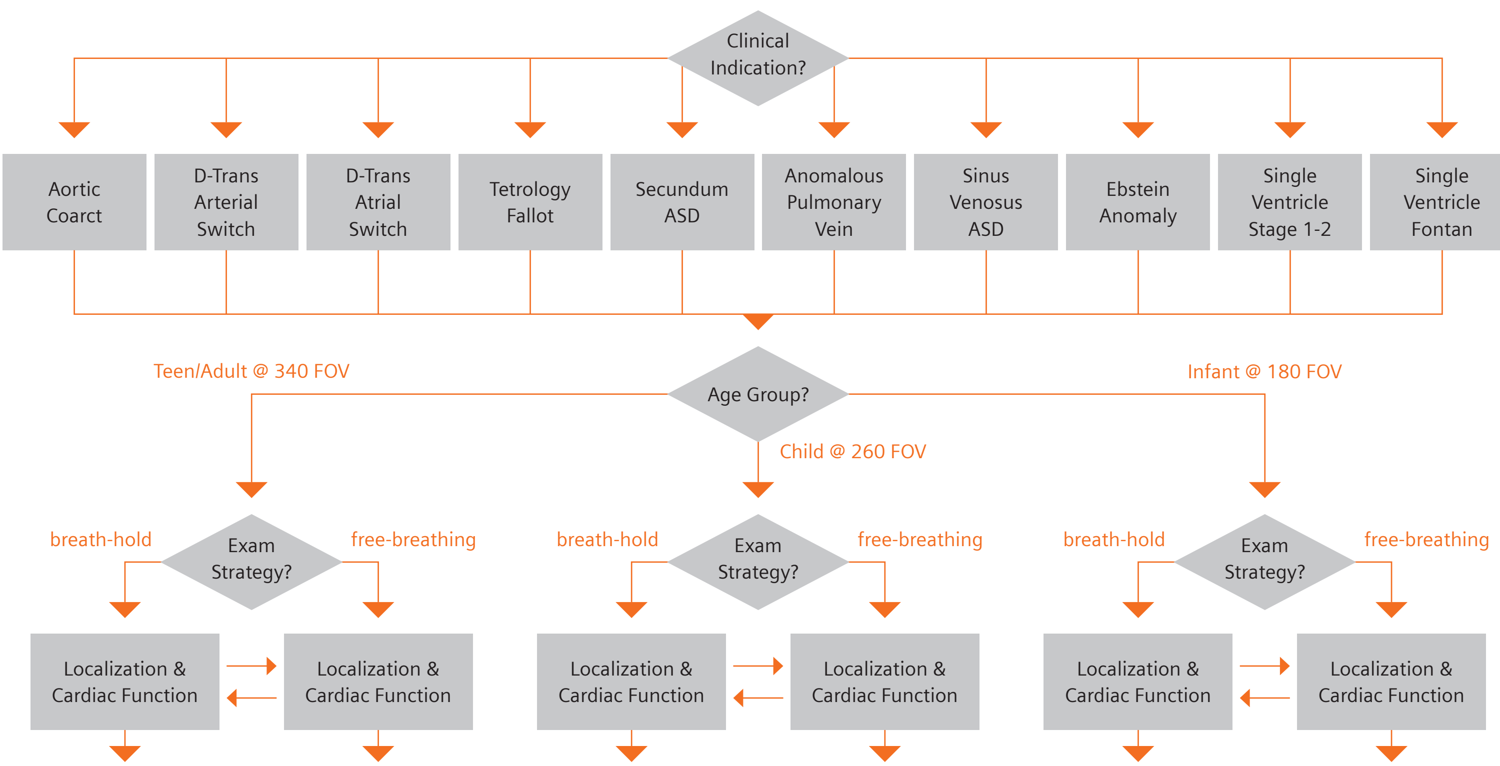
- All protocols comply with SCMR Guidelines
  Fratz et al Journal of Cardiovascular Magnetic Resonance 2013, 15:51
- Default spatial and temporal resolutions are closely matched to pediatric age groups, but may need to be adapted to patient conditions. As heart rate increases, the TR should be decreased accordingly.

Teen/Adult	**340 mm FOV, 18-ch Body Array Coil**		
CINE	1.8 x 2.1 x 7 mm; TR 43 ms	LGE	1.8 x 1.3 x 8 mm
FLOW	1.5 x 1.2 x 6 mm; TR 36 ms	PERF	2.7 x 2.1 x 9 mm
TWIST	1.5 x 1.5 x 1.5 mm; TR 3.0 s	3DMRA	1.5 x 1.5 x 1.5 mm

Child	**260 mm FOV, 18-ch Body Array Coil**		
CINE	1.7 x 2.0 x 6 mm; TR 38 ms	LGE	1.6 x 1.3 x 7 mm
FLOW	1.3 x 1.1 x 5 mm; TR 29 ms	PERF	2.6 x 2.0 x 8 mm
TWIST	1.3 x 1.3 x 1.3 mm; TR 2.7 s	3DMRA	1.3 x 1.3 x 1.3 mm

Infant	**180 mm FOV, 4-ch Small Flex Coil**		
CINE	1.6 x 1.9 x 5 mm; TR 34 ms	LGE	1.3 x 1.1 x 6 mm
FLOW	1.2 x 1.0 x 4 mm; TR 23 ms	PERF	1.9 x 1.9 x 8 mm
TWIST	1.1 x 1.1 x 1.1 mm; TR 2.2 s	3DMRA	1.1 x 1.1 x 1.1 mm

Congenital Cardiac Protocols



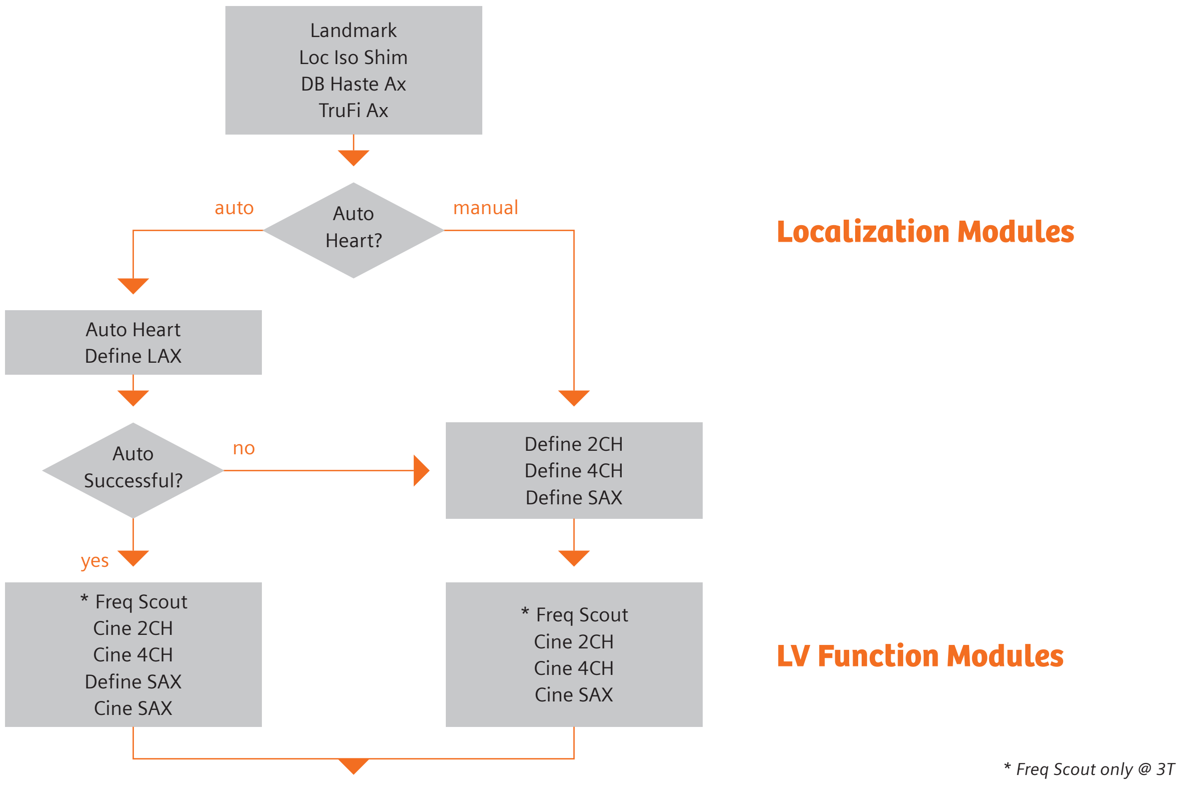
1. During patient registration, select the indication-specific and age-specific protocol group for your patient.

2. In the initial Dot step before the first sequence is run, decide between BREATH-HOLD vs FREE-BREATHING exam strategies according to the patient's capability. The default is BREATH-HOLD, which requires the user to set an upper limit on duration (eg, 15 sec) and the auto voice commands.

3. Begin the exam by performing the Localization and Cardiac Function modules.

4. At any time during the exam you can switch back-and-forth between these two breathing strategies in the Dot config menu of the Exam card.

Localization & LV Function Modules



Localization Modules

1. LANDMARK acquires 9 localizer slices in each of 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.

2. LOC ISO SHIM acquires 9 localizer slices in each of 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 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 breath-hold.

3. HASTE AX acquires 30 axial dark blood slices to survey the entire chest. This sequence automatically adapts to the patient's heartrate and breath-hold. For heartrates faster than 100 bpm DO NOT use Capture Cycle: set Trig Pulses to 3, set Acq Window to span through 2 beats, set TR equal to Acq Window.

4. TRUFI AX acquires 30 axial bright blood slices to survey the entire chest. This sequence automatically adapts to the patient's heartrate and breath-hold.

5. Choose between the AUTO method or the MANUAL method for localization. Benefit of the auto method is that standard cardiac views (2CH, 3Ch, 4CH, SAX) are automatically calculated by Dot, which works well for typical heart orientations & shapes. However, the manual method may be needed for atypical (congenital) hearts. For both methods the defined slice positions are automatically propagated throughout the entire exam.

6. If the AUTO method is chosen, the AUTO HEART step acquires 18 localizers in the short axis view (SAX). During planning move the slice group up or down as needed to cover the entire heart from base to apex, but DO NOT change the angle of the slices. This sequence automatically adapts to the patient's heartrate and breath-hold.

7. If the AUTO method is chosen, the DEFINE LAX step acquires 3 localizers in each of the long axis views (2CH, 3CH, 4CH). Although this step automatically calculates the slice positions and Phase FOV, you should interactively optimize them as needed during planning. This sequence automatically adapts to the patient's heartrate and breath-hold. These slice positions are used throughout the entire exam.

8. If the MANUAL method is chosen (or) if the AUTO method is unsuccessful, three steps (DEFINE 2CH, DEFINE 4CH, DEFINE SAX) allow you to manually plan the localizer slice positions and Phase FOV for each group, respectively. These sequences automatically adapt to the patient's heartrate and breath-hold. These slice positions are used throughout the entire exam.

LV Function Modules

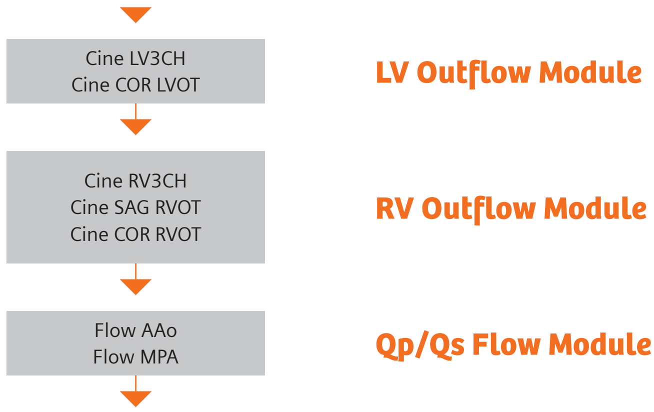
1. Only if 3T is used, the FREQUENCY SCOUT step acquires a single slice in the 4CH long axis view. Review these images before proceeding, and select the frequency which provides optimal image quality (lack of dark bands within the heart, with best contrast between blood pool and myocardium). Enter the optimal frequency into the Trufi Delta Freq parameter in the following Trufi Cine sequences.

2. Cine 2CH & Cine 4CH acquires 3 cine slices in each of these long axis views, and allows fine-tuning of slice position and FOV which are propagated to next steps in the exam. This sequence automatically adapts to the patient's heart-rate and breath-hold. For heartrates faster than 100 bpm decrease TR by reducing Segments accordingly. For free-breathing use multiple averages.

3. Only if Auto Heart method is used, the DEFINE SAX step acquires a stack of localizer slices in the SAX short axis views, and automatically adjusts the Phase FOV. 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 levels of the left ventricle, and should be planned on a systolic cine image of the long axis. This sequence automatically adapts to the patient's heartrate and breath-hold.

4. Cine SAX acquires a full stack of short axis cines, and allows fine-tuning of slice position and FOV which are propagated to next steps in the exam. This sequence automatically adapts to the patient's heartrate and breath-hold. For heartrates faster than 100 bpm decrease TR by reducing Segments accordingly. For free-breathing use multiple averages.

Ventricular Outflow & Qp/Qs Flow Modules



LV Outflow Module

1. CINE LV3CH acquires 3 cine slices in the left ventricular 3 chamber view, and allows fine-tuning of slice position and FOV which is propagated to next steps in the exam. This sequence automatically adapts to the patient's heartrate and breath-hold. For heartrates faster than 100 bpm decrease TR by reducing Segments accordingly. For free-breathing use multiple averages.

2. CINE COR LVOT acquires 1 cine slice in the coronal left ventricular outflow view of the aorta, and allows fine-tuning of slice position and FOV for use in planning the next step in the exam. This sequence automatically adapts to the patient's heartrate and breath-hold. For heartrates faster than 100 bpm decrease TR by reducing Segments accordingly. For free-breathing use multiple averages.

RV Outflow Module

1. CINE RV3CH acquires 1 cine slice in the right ventricular 3 chamber view, and allows fine-tuning of slice position and FOV which is used for planning the next step in the exam. This sequence automatically adapts to the patient's heartrate and breath-hold. For heartrates faster than 100 bpm decrease TR by reducing Segments accordingly. For free-breathing use multiple averages.

2. CINE SAG RVOT acquires 1 cine slice in the sagittal right ventricular outflow view of the main pulmonary artery, and allows fine-tuning of slice position and FOV which is used for planning the next step in the exam. This sequence automatically adapts to the patient's heartrate and breath-hold. For heartrates faster than 100 bpm decrease TR by reducing Segments accordingly. For free-breathing use multiple averages.

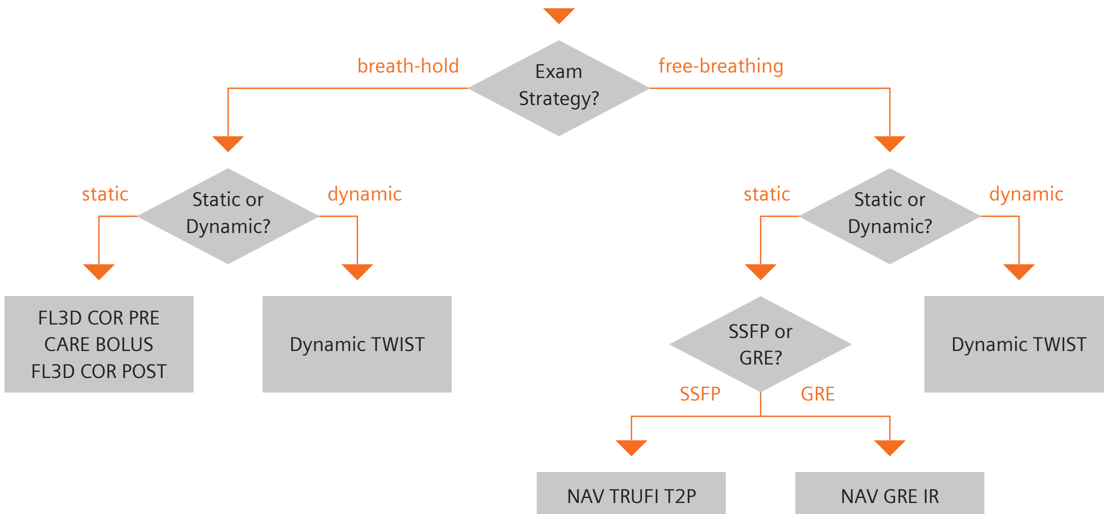
3. CINE COR RVOT acquires 1 cine slice in the coronal right ventricular outflow view of the main pulmonary artery, and allows fine-tuning of slice position and FOV which is used for planning the next step in the exam. This sequence automatically adapts to the patient's heartrate and breath-hold. For heartrates faster than 100 bpm decrease TR by reducing Segments accordingly. For free-breathing use multiple averages.

Qp/Qs Flow Module

1. FLOW AAo acquires 1 through-plane flow slice at VENC 200 cm/s, perpendicular to the aortic root at the ascending aorta. This sequence automatically adapts to the patient's heartrate and breath-hold. For heartrates faster than 100 bpm decrease TR by reducing Segments accordingly. For free-breathing use multiple averages.

2. FLOW MPA acquires 1 through-plane flow slice at VENC 200 cm/s, perpendicular to the pulmonic root at the main pulmonary artery. This sequence automatically adapts to the patient's heartrate and breath-hold. For heartrates faster than 100 bpm decrease TR by reducing Segments accordingly. For free-breathing use multiple averages.

Thoracic MRA Module



1. The Breath-hold MRA module provides 2 options:

   - Breath-Hold Care Bolus – Plan a 3D coronal slab covering the entire thorax. 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.

   - Breath-hold Dynamic TWIST – Plan a 3D coronal slab covering the entire thorax. The first measurement is acquired pre-contrast during a breath-hold. Contrast bolus is injected immediately after the 1st measurement is completed during the automatic 10 second pause. Remaining measurements are acquired during a long breath-hold during the first pass of contrast agent. The first measurement is automatically subtracted from all remaining measurements, and then automatically MIP'd.

2. The Free-breathing MRA module provides 3 options:

   - NAV TRUFI T2P – Plan a 3D transverse slab covering the entire heart, setup the navigator on the upper lobe of the liver to detect diaphragm motion (adjust Search Position in Scout mode), setup the cardiac triggering to acquire data during the most quiescent period of the cardiac cycle (adjust Segments and Trig Delay), and acquire the scan during free-breathing. No contrast agent is required.

   - NAV GRE IR – Plan a 3D sagittal slab covering the entire heart, setup the navigator on the upper lobe of the liver to detect diaphragm motion (adjust Search Position in Scout mode), setup the cardiac triggering to acquire data during the most quiescent period of the cardiac cycle (adjust Segments and Trig Delay), and acquire the scan during free-breathing. A slow infusion of intravascular contrast agent or a bolus injection of extravascular contrast agent is required.

   - Free-Breathing Dynamic TWIST – Plan a 3D coronal slab covering the entire thorax. The first measurement is acquired pre-contrast during shallow free-breathing. Contrast bolus is injected immediately after the 1st measurement is completed during the automatic 5 second pause while patient continues shallow free-breathing. Remaining measurements are acquired during continued shallow breathing during the first pass of contrast agent. The first measurement is automatically subtracted from all remaining measurements, and then automatically MIP'd.

Myocardial Perfusion Module

Perfusion Test
Perfusion Stress
Perfusion Rest

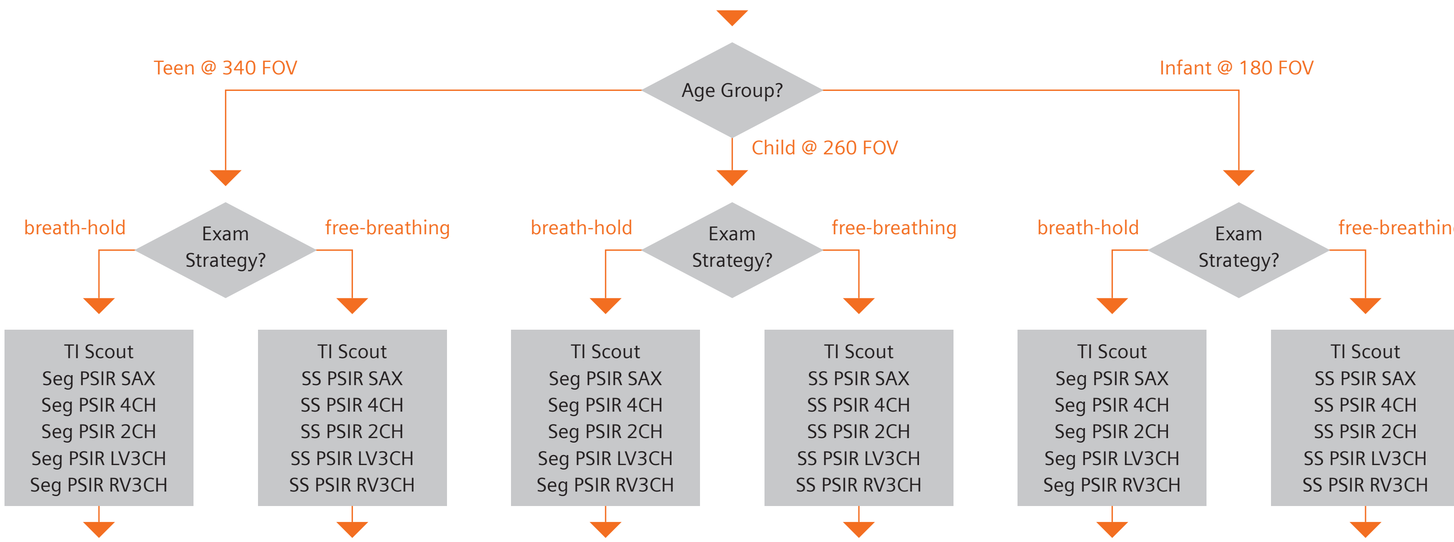
1. PERFUSION TEST runs for only 10 heartbeats to verify that the slice locations and FOVs are optimal before running the actual perfusion scans with contrast agent and stress agent. It acquires 3 slices in the SAX (base, mid, apex). This is typically run in free-breathing without Motion Correction (MoCo).

2. PERFUSION STRESS runs for 60 heartbeats during the administration of contrast agent and stress agent. The same 3 slices are acquired (as described above). The temporal resolution of each slice is 160 ms, thus the minimum Acquisition Window is 480 ms to acquire all 3 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 3 slices 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 3 slices are acquired (as described above). The temporal resolution of each slice is 160 ms, thus the minimum Acquisition Window is 480 ms to acquire all 3 slices within one heartbeat. MoCo is applied.

Delayed Enhancement Module

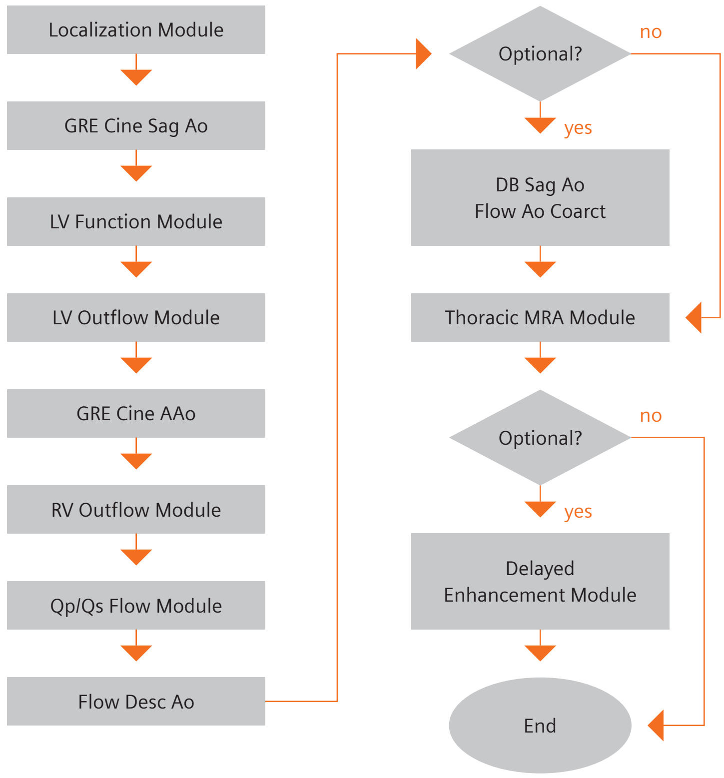


1. TI SCOUT is run within the first 10 minutes post-contrast to determine the optimal TI value for myocardial nulling for the next exam steps. At 1.5T add approx. 20-30 ms to the TI with maximal myocardial nulling in this TI Scout. At 3T add approx. 60-70 ms to the TI with maximal myocardial nulling in this TI Scout.

2. DELAYED ENHANCEMENT sequences should be run within the first 10 minutes post-contrast. Acquire the entire stack of LV short axis slices (SAX), 3 slices in each of the LV long axis views (2CH, 4CH, LV3CH), and 1 slice in the RV3CH view. These sequences adapt to the patient's heartrate and breath-hold. Initially use the optimal TI valued as determined above from the TI Scout, and then slightly increase the TI value as time progresses during the exam (increase approx. 10 ms every couple minutes under typical conditions).

   - The BREATH-HOLD strategy uses Segmented TurboFlash PSIR. For heartrates faster than 100 bpm, DO NOT use Capture Cycle: slightly reduce 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.
   - The FREE-BREATHING strategy uses Single-shot TruFi PSIR. Multiple averages + Motion Correction should be used if available (currently Sola and Vida systems).

Aortic Coarctation



1. Localization Module.

2. GRE CINE SAG Ao acquires 1 cine slice in the sagittal oblique aortic candy cane view, planned from the axial view. This sequence automatically adapts to the patient's heartrate and breath-hold. For heartrates faster than 100 bpm decrease TR by reducing Segments accordingly. For free-breathing use multiple averages.

3. LV Function Module.

4. LV Outflow Module.

5. GRE CINE AAo acquires 5 thin contiguous cine slices across the ascending aortic root, using a GRE cine to assess for turbulent flow. This sequence automatically adapts to the patient's heartrate and breath-hold. For heartrates faster than 100 bpm decrease TR by reducing Segments accordingly. For free-breathing use multiple averages.

6. RV Outflow Module.

7. Qp/Qs Flow Module.

8. FLOW Desc Ao acquires 1 through-plane VENC 200 cm/s flow slice perpendicular to the descending aorta at the level of the diaphragm, planned from sagittal and coronal views. This sequence automatically adapts to the patient's heartrate and breath-hold. For heartrates faster than 100 bpm decrease TR by reducing Segments accordingly. For free-breathing use multiple averages.

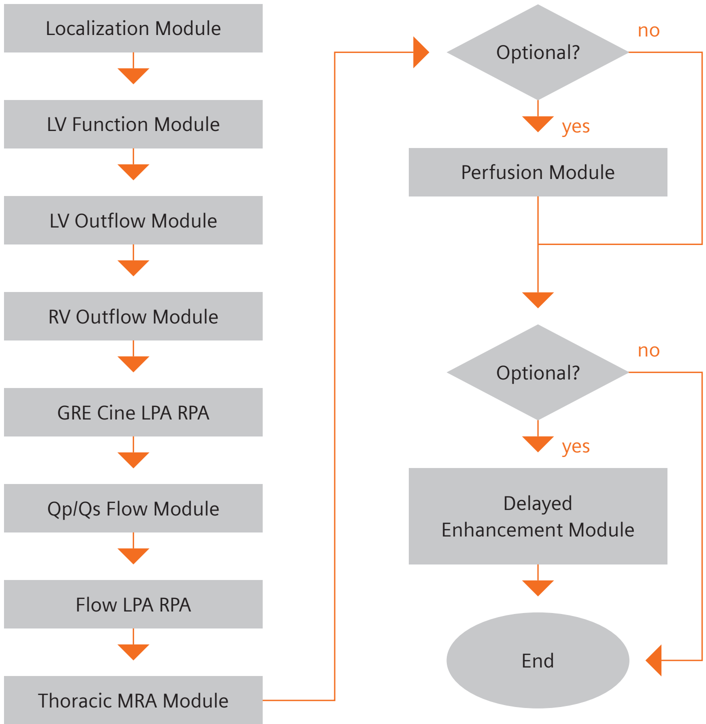
9. (optional) DB SAG Ao acquires 1 dark blood slice in the sagittal oblique aortic candy cane view. It automatically adapts to the patient's heartrate and adapts to multiple breath-holds. For breath-hold use DB TSE: for faster heartrates DO NOT use Capture Cycle but set Trig Pulses to 3, set Acq Window to span through 2 beats, set TR equal to Acq Window, and slightly reduce Turbo Factor. For free-breathing use DB TSE BLADE: for faster heartrates slightly reduce the Turbo Factor (no other adaptions required).

10. (optional) FLOW Ao COARCT acquires 1 through-plane VENC 200 cm/s flow slice perpendicular to the aorta at the level of the coarctation, planned from the sagittal aortic view. This sequence automatically adapts to the patient's heartrate and breath-hold. For heartrates faster than 100 bpm decrease TR by reducing Segments accordingly. For free-breathing use multiple averages.

11. Thoracic MRA Module.

12. (optional) Delayed Enhancement Module.

D-Trans Arterial Switch



1. Localization Module.

2. LV Function Module.

3. LV Outflow Module.

4. RV Outflow Module.

5. GRE CINE LPA RPA acquires 5 thin contiguous cine slice in the axial oblique views of the branch pulmonary arteries. This sequence automatically adapts to the patient's heartrate and breath-hold. For heartrates faster than 100 bpm decrease TR by reducing Segments accordingly. For free-breathing use multiple averages.

6. Qp/Qs Flow Module.

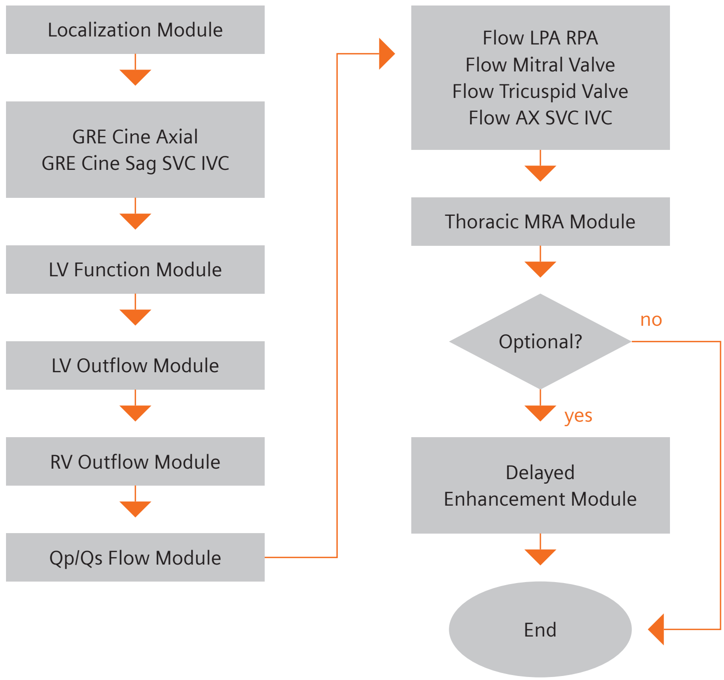
7. FLOW LPA RPA acquires 1 through-plane VENC 100 cm/s flow slice in the sagittal oblique views of the branch pulmonary arteries. This sequence automatically adapts to the patient's heartrate and breath-hold. For heartrates faster than 100 bpm decrease TR by reducing Segments accordingly. For free-breathing use multiple averages.

8. Thoracic MRA Module.

9. (optional) Perfusion Module.

10. (optional) Delayed Enhancement Module.

D-Trans Atrial Switch



1. Localization Module.

2. GRE Cine Ax acquires an axial stack of cine slices from mid-liver to top of aortic arch. This sequence automatically adapts to the patient's heartrate and breath-hold. For heartrates faster than 100 bpm decrease TR by reducing Segments accordingly. For free-breathing use multiple averages.

3. GRE Cine Sag SVC IVC acquires 1 cine slice in the sagittal oblique views of the SVC and IVC. It automatically adapts to the patient's heartrate and adapts to multiple breath-holds. This sequence automatically adapts to the patient's heartrate and breath-hold. For heartrates faster than 100 bpm decrease TR by reducing Segments accordingly. For free-breathing use multiple averages.

4. LV Function Module.

5. LV Outflow Module.

6. RV Outflow Module.

7. Qp/Qs Flow Module.

8. Flow LPA RPA acquires 1 through-plane VENC 100 cm/s flow slice in the sagittal oblique views of the branch pulmonary arteries. This sequence automatically adapts to the patient's heartrate and breath-hold. For heartrates faster than 100 bpm decrease TR by reducing Segments accordingly. For free-breathing use multiple averages.

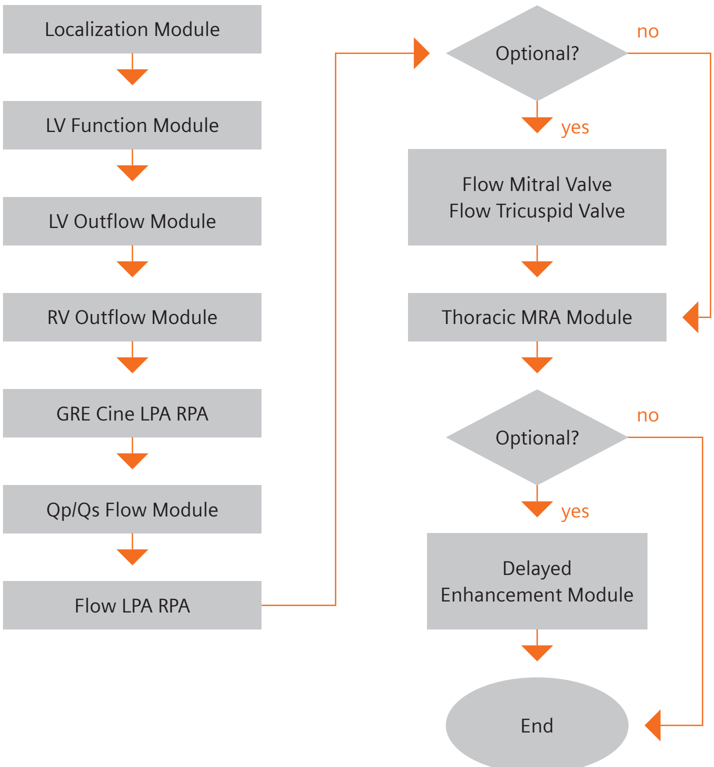
9. Flow Mitral and Tricuspid Valves acquires 1 through-plane VENC 200 cm/s flow slice across the mitral and tricuspid valves. Mitral valve is planned from 4CH and 2CH views. Tricuspid valve is planned from 4CH and RV3CH views. This sequence automatically adapts to the patient's heartrate and breath-hold. For heartrates faster than 100 bpm decrease TR by reducing Segments accordingly. For free-breathing use multiple averages.

10. Flow Axial SVC IVC acquires 1 through-plane VENC 80 cm/s flow slice in the axial plane across the SVC and IVC. This sequence automatically adapts to the patient's heartrate and breath-hold. For heartrates faster than 100 bpm decrease TR by reducing Segments accordingly. For free-breathing use multiple averages.

11. Thoracic MRA Module.

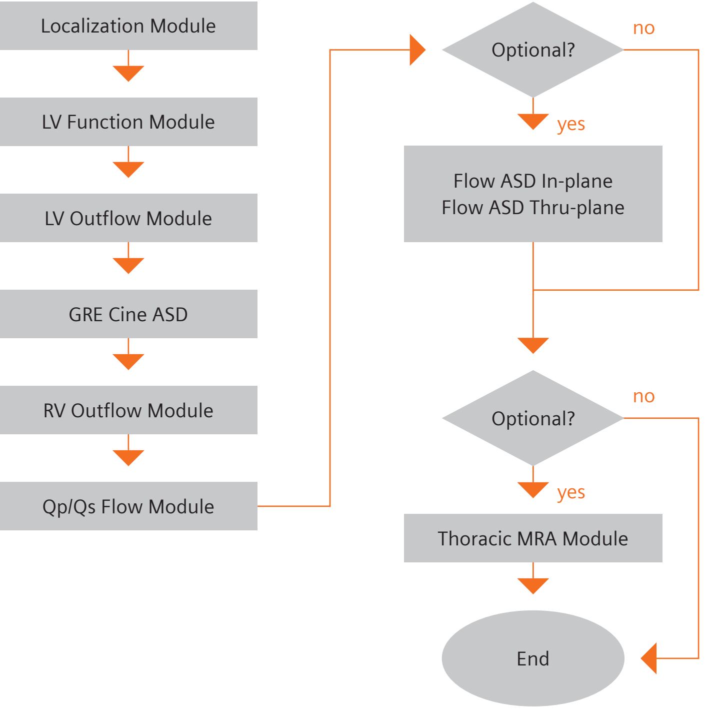
12. (optional) Delayed Enhancement Module.

Tetrology of Fallot



1. Localization Module.
2. LV Function Module.
3. LV Outflow Module.
4. RV Outflow Module.
5. GRE CINE LPA RPA acquires 5 thin contiguous cine slices in the axial oblique views of the branch pulmonary arteries. This sequence automatically adapts to the patient's heartrate and breath-hold. For heartrates faster than 100 bpm decrease TR by reducing Segments accordingly. For free-breathing use multiple averages.
6. Qp/Qs Flow Module.
7. Flow LPA RPA acquires 1 through-plane VENC 100 cm/s flow slice in the sagittal oblique views of the branch pulmonary arteries. This sequence automatically adapts to the patient's heartrate and breath-hold. For heartrates faster than 100 bpm decrease TR by reducing Segments accordingly. For free-breathing use multiple averages.
8. (optional) Flow Mitral and Tricuspid Valves acquires 1 through-plane VENC 200 cm/s flow slice across the mitral and tricuspid valves. Mitral valve is planned from 4CH and 2CH views. Tricuspid valve is planned from 4CH and RV3CH views. This sequence automatically adapts to the patient's heartrate and breath-hold. For heartrates faster than 100 bpm decrease TR by reducing Segments accordingly. For free-breathing use multiple averages.
9. Thoracic MRA Module.
10. (optional) Delayed Enhancement Module.

Secundum ASD



1. Localization Module.

2. LV Function Module.

3. LV Outflow Module.

4. GRE CINE ASD acquires 5 thin contiguous cine slices of the ASD in a sagittal oblique view planned from a 4CH view. This sequence automatically adapts to the patient's heartrate and breath-hold. For heartrates faster than 100 bpm decrease TR by reducing Segments accordingly. For free-breathing use multiple averages.

5. RV Outflow Module.

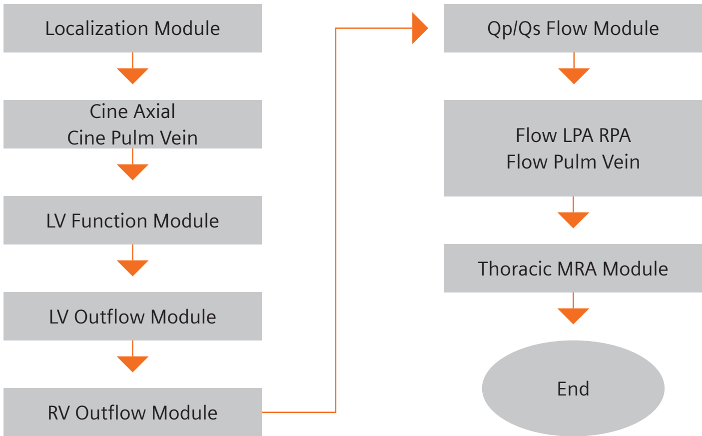
6. Qp/Qs Flow Module.

7. (optional) FLOW ASD IN-PLANE acquires 5 thin contiguous in-plane VENC 200 cm/s flow slices of the ASD in a sagittal oblique view planned from 4CH view. This sequence automatically adapts to the patient's heartrate and breath-hold. For heartrates faster than 100 bpm decrease TR by reducing Segments accordingly. For free-breathing use multiple averages.

8. (optional) FLOW ASD THRU-PLANE acquires 5 thin contiguous through-plane VENC 200 cm/s flow slices in an en face view of the ASD, planned from 4CH view and previous ASD IN-PLANE view. This sequence automatically adapts to the patient's heartrate and breath-hold. For heartrates faster than 100 bpm decrease TR by reducing Segments accordingly. For free-breathing use multiple averages.

9. (optional) Thoracic MRA Module.

Anomalous Pulmonary Vein



1. Localization Module.

2. GRE Cine Ax acquires an axial stack of cine slices from mid-liver to top of aortic arch. This sequence automatically adapts to the patient's heartrate and breath-hold. For heartrates faster than 100 bpm decrease TR by reducing Segments accordingly. For free-breathing use multiple averages.

3. GRE Cine Pulm Vein acquires 1 cine slice in the coronal oblique view of the anomalous pulmonary veinThis sequence automatically adapts to the patient's heartrate and breath-hold. For heartrates faster than 100 bpm decrease TR by reducing Segments accordingly. For free-breathing use multiple averages.

4. LV Function Module.

5. LV Outflow Module.

6. RV Outflow Module.

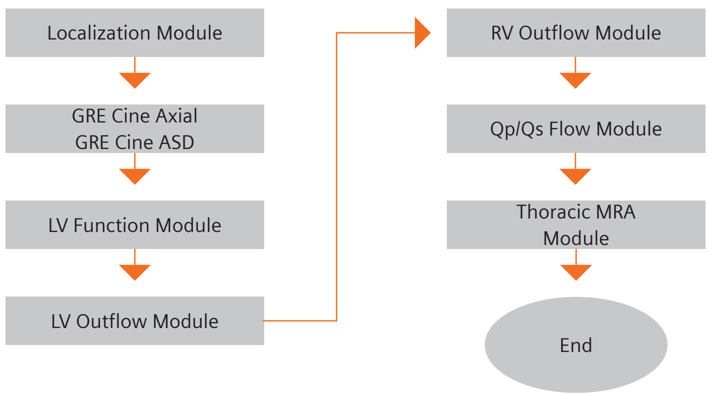
7. Qp/Qs Flow Module.

8. Flow LPA RPA acquires 1 through-plane VENC 100 cm/s flow slice in the sagittal oblique views of the branch pulmonary arteries. This sequence automatically adapts to the patient's heartrate and breath-hold. For heartrates faster than 100 bpm decrease TR by reducing Segments accordingly. For free-breathing use multiple averages.

9. FLOW Pulm Vein acquires 1 cross sectional sagittal oblique flow slice of the anomalous pulmonary vein with VENC 80 cm/s. This sequence automatically adapts to the patient's heartrate and breath-hold. For heartrates faster than 100 bpm decrease TR by reducing Segments accordingly. For free-breathing use multiple averages.

10. Thoracic MRA Module.

Sinus Venosus ASD



1. Localization Module.

2. GRE Cine Axial acquires an axial stack of cine slices from mid-liver to top of aortic arch. This sequence automatically adapts to the patient's heartrate and breath-hold. For heartrates faster than 100 bpm decrease TR by reducing Segments accordingly. For free-breathing use multiple averages.

3. GRE CINE ASD acquires 5 thin contiguous cine slices of the ASD in a sagittal oblique view planned from an axial view. This sequence automatically adapts to the patient's heartrate and breath-hold. For heartrates faster than 100 bpm decrease TR by reducing Segments accordingly. For free-breathing use multiple averages.

4. LV Function Module.

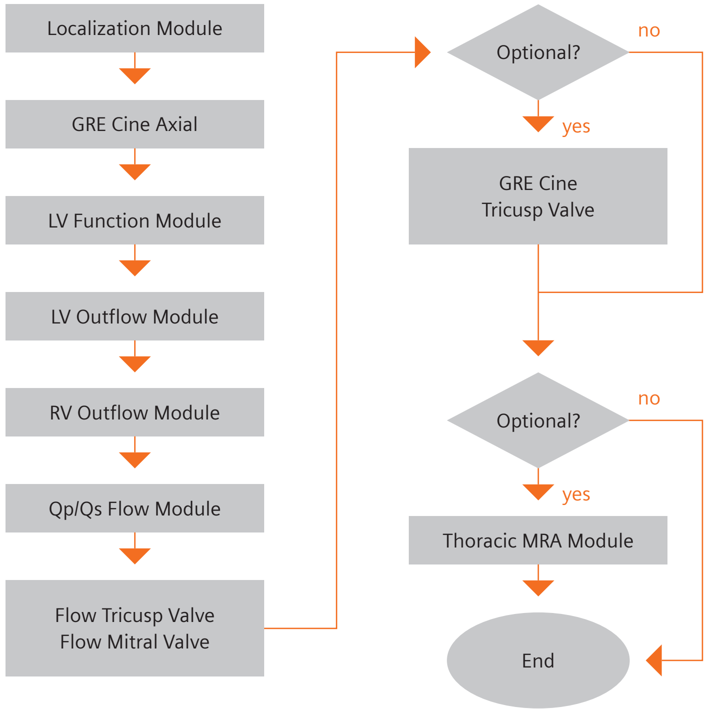
5. LV Outflow Module.

6. RV Outflow Module.

7. Qp/Qs Flow Module.

8. Thoracic MRA Module.

Ebstein Anomaly



1. Localization Module.

2. GRE Cine Ax acquires an axial stack of cine slices from mid-liver to top of aortic arch. This sequence automatically adapts to the patient's heartrate and breath-hold. For heartrates faster than 100 bpm decrease TR by reducing Segments accordingly. For free-breathing use multiple averages.

3. LV Function Module.

4. LV Outflow Module.

5. RV Outflow Module.

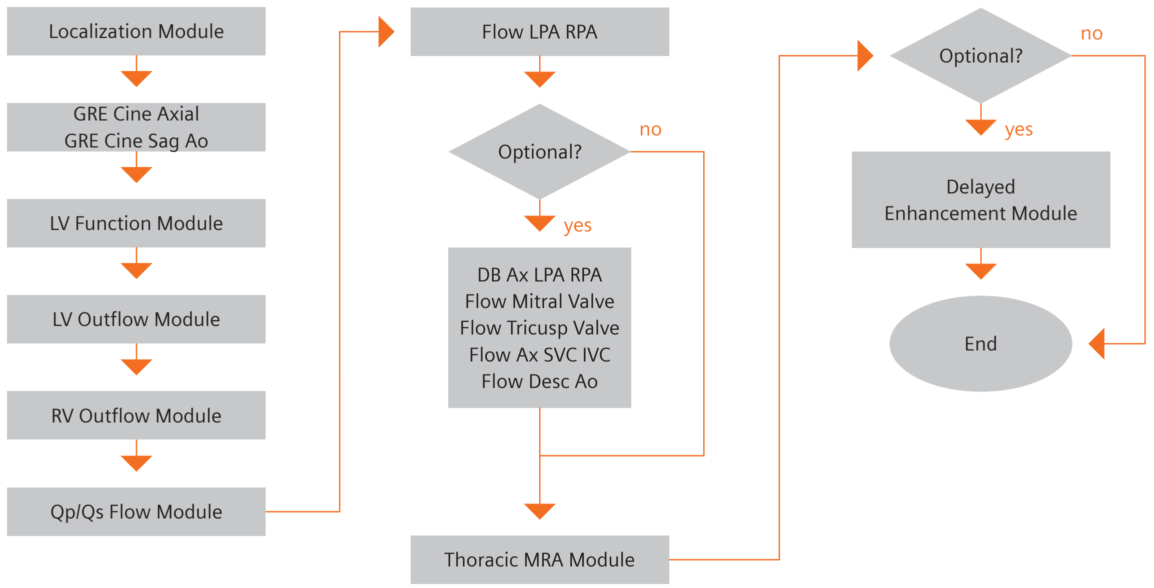
6. Qp/Qs Flow Module.

7. Flow Tricuspid and Mitral Valves acquires 1 through-plane VENC 200 cm/s flow slice across the tricuspid and mitral valves. Mitral valve is planned from 4CH and 2CH views. Tricuspid valve is planned from 4CH and RV3CH views. This sequence automatically adapts to the patient's heartrate and breath-hold. For heartrates faster than 100 bpm decrease TR by reducing Segments accordingly. For free-breathing use multiple averages.

8. (Optional) GRE Cine Tricuspid Valve acquires 5 thin contiguous cine slices of the tricuspid valve planned from an RV3CH view. This sequence automatically adapts to the patient's heartrate and breath-hold. For heartrates faster than 100 bpm decrease TR by reducing Segments accordingly. For free-breathing use multiple averages.

9. (Optional) Thoracic MRA Module.

Single Ventricle Stage 1-2



1. Localization Module.

2. GRE Cine Ax acquires an axial stack of cine slices from mid-liver to top of aortic arch This sequence automatically adapts to the patient's heartrate and breath-hold. For heartrates faster than 100 bpm decrease TR by reducing Segments accordingly. For free-breathing use multiple averages.

3. GRE CINE SAG Ao acquires 1 cine slice in the sagittal oblique aortic candy cane view, planned from the axial view. This sequence automatically adapts to the patient's heartrate and breath-hold. For heartrates faster than 100 bpm decrease TR by reducing Segments accordingly. For free-breathing use multiple averages.

4. LV Function Module.

5. LV Outflow.

6. RV Outflow Module.

7. Qp/Qs Flow Module.

8. Flow LPA RPA acquires 1 through-plane VENC 100 cm/s flow slice in the sagittal oblique views of the branch pulmonary arteries. This sequence automatically adapts to the patient's heartrate and breath-hold. For heartrates faster than 100 bpm decrease TR by reducing Segments accordingly. For free-breathing use multiple averages.

9. (Optional) DB Axial LPA RPA acquires 1 axial slice of the branch pulmonary arteries. This sequence automatically adapts to the patient's heartrate and breath-hold. For breath-hold use DB TSE: for heartrates faster than 100 bpm DO NOT use Capture Cycle but set Trig Pulses to 3, set Acq Window to span through 2 beats, set TR equal to Acq Window, and slightly reduce Turbo Factor. For free-breathing use DB TSE BLADE: for heartrates faster than 100 slightly reduce the Turbo Factor (no other adaptions required).

10. (Optional) Flow Tricuspid and Mitral Valves acquires 1 through-plane VENC 200 cm/s flow slice across the tricuspid and mitral valves. Mitral valve is planned from 4CH and 2CH views. Tricuspid valve is planned from 4CH and RV3CH views. This sequence automatically adapts to the patient's heartrate and breath-hold. For heartrates faster than 100 bpm decrease TR by reducing Segments accordingly. For free-breathing use multiple averages.

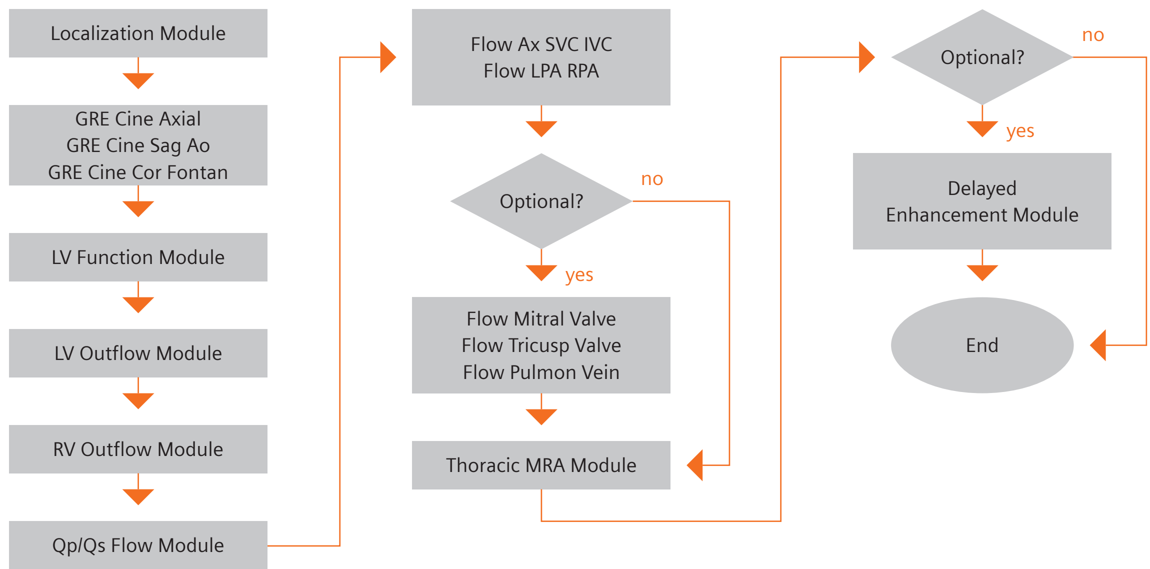
11. (Optional) Flow Axial SVC IVC acquires 1 through-plane VENC 80 cm/s flow slice in the axial plane across the SVC and IVC. This sequence automatically adapts to the patient's heartrate and breath-hold. For heartrates faster than 100 bpm decrease TR by reducing Segments accordingly. For free-breathing use multiple averages.

12. (Optional) Flow Desc Ao acquires 1 through-plane VENC 200 cm/s flow slice in the axial plane across the descending aorta. This sequence automatically adapts to the patient's heartrate and breath-hold. For heartrates faster than 100 bpm decrease TR by reducing Segments accordingly. For free-breathing use multiple averages.

13. Thoracic MRA Module.

14. (optional) Delayed Enhancement Module.

Single Ventricle Fontan



1. Localization Module.

2. GRE Cine Ax acquires an axial stack of cine slices from mid-liver to top of aortic arch. It automatically adapts to the patient's heartrate and adapts to multiple breath-holds. For heartrates faster than 100 bpm decrease TR by reducing Segments accordingly. For free-breathing use multiple averages.

3. GRE Cine Sag Ao acquires 1 cine slice in the sagittal oblique aortic candy cane view, planned from the axial view. It automatically adapts to the patient's heartrate and adapts to multiple breath-holds. For heartrates faster than 100 bpm decrease TR by reducing Segments accordingly. For free-breathing use multiple averages.

4. GRE Cine Cor Fontan acquires 1 cine slice in the coronal oblique view of the Fontan shunt. It automatically adapts to the patient's heartrate and adapts to multiple breath-holds. For heartrates faster than 100 bpm decrease TR by reducing Segments accordingly. For free-breathing use multiple averages.

5. LV Function Module.

6. LV Outflow Module.

7. RV Outflow Module.

8. Qp/Qs Flow Module.

9. Flow Axial SVC IVC acquires 1 through-plane VENC 80 cm/s flow slice in the axial plane across the SVC and IVC. This sequence automatically adapts to the patient's heartrate and adapts to multiple breath-holds. For heartrates faster than 100 bpm decrease TR by reducing Segments accordingly. For free-breathing use multiple averages.

10. Flow LPA RPA acquires 1 through-plane VENC 100 cm/s flow slice in the sagittal oblique views of the branch pulmonary arteries. It automatically adapts to the patient's heartrate and adapts to multiple breath-holds. For heartrates faster than 100 bpm decrease TR by reducing Segments accordingly. For free-breathing use multiple averages.

11. (optional) Flow Tricuspid and Mitral Valves acquires 1 through-plane VENC 200 cm/s flow slice across the tricuspid and mitral valves. Mitral valve is planned from 4CH and 2CH views. Tricuspid valve is planned from 4CH and RV3CH views. This sequence automatically adapts to the patient's heartrate and adapts to multiple breath-holds. For heartrates faster than 100 bpm decrease TR by reducing Segments accordingly. For free-breathing use multiple averages.

12. (optional) Flow Pulmonary Vein acquires 1 through-plane VENC 80 cm/s flow slice in a cross sectional oblique view of the anomalous pulmonary vein. This sequence automatically adapts to the patient's heartrate and adapts to multiple breath-holds. For heartrates faster than 100 bpm decrease TR by reducing Segments accordingly. For free-breathing use multiple averages.

13. Thoracic MRA Module.

14. (optional) Delayed Enhancement Module.

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