

DSMR Cookbook 2005

Version 3.1

A Guide to Dobutamine-Atropine Stress Exams for the Detection of Ischemic Wall Motion Abnormalities With Cardiac MR Imaging

Release 9 and higher

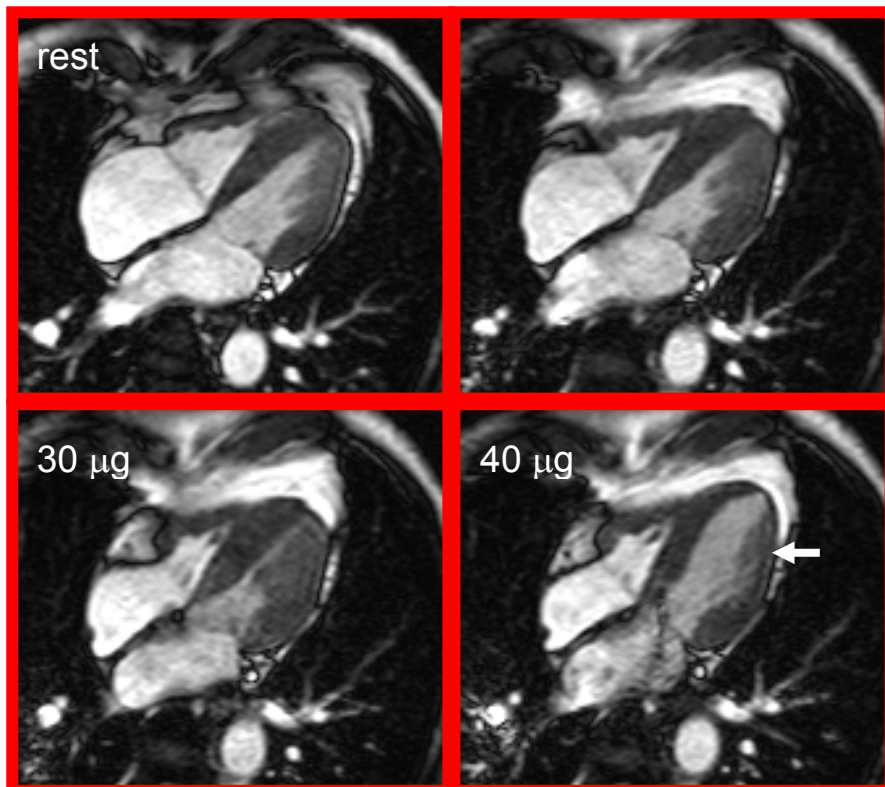
Exam card can be found at: <http://netforum.medical.philips.com/>

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Purpose

Coronary artery disease can result in three different pathophysiological conditions of the myocardium, which can occur at the same time:

- (1) inducible ischemia
- (2) myocardial infarction (necrosis)
- (3) viable myocardium

Whereas myocardial infarction and viability can be detected at rest, inducible ischemia can only be detected under stress conditions. One of the earliest signs of myocardial ischemia are wall motion abnormalities during increasing stress which occur much earlier than ECG changes or anginal pain.

Stress conditions can be induced by physical exercise or standardized stress protocols with pharmacological agents such as dobutamine/atropine or adenosine infusion. These pharmacological agents have been shown to be safe, well tolerated, and to reproducibly induce myocardial ischemia.

Dobutamine has been shown to be more accurate for the detection of inducible wall motion abnormalities than adenosine and is the only pharmacologic stress agent discussed here.

The current document is a guide to pharmacological stress examinations of the heart with a standard dobutamine/atropine scheme for the diagnosis of inducible myocardial ischemia using CMR.

Hard- and Software Requirements

The methodology has been developed for a Gyroscan ACS NT or INTERA 1.5 Tesla (T) whole body system equipped with a 30 mT Master gradient system (slew rate: 150 mT/m/s), using a 5-element cardiac synergy coil. Software: Release 9 and higher.

Stress Agent

Pharmacon: Dobutamine-HCl
concentration: preferably 5 mg/ml,
i.v. administration

Pharmacon: Atropine
concentration: 0.25 mg fractions
(maximal dose 2 mg)

Mode of action

Dobutamine is a sympathomimetic drug with beta-1, beta-2, and slight alpha-1 receptor stimulation properties. The drug exerts its pharmacological effects in a dose dependent manner and intravenous infusion of the drug increases cardiac contractility, heart rate and decreases systolic vascular resistance: During low-dose infusion ($\leq 10 \mu\text{g/kg/min}$) the major effect is an increase in contractility; at higher doses (up to max. $40 \mu\text{g/kg/min}$) the increase in heart rate together with the concomitant increase in myocardial oxygen consumption causes contraction abnormalities in myocardial segments supplied by stenotic coronary arteries, as oxygen demand exceeds availability and induces myocardial ischemia.

To fully exert its effects patients should refrain from β -blockers and nitrates 24 hours prior to the examination, since these drugs counteract the dobutamine action (see table 1).

In our clinical experience it has been sufficient to ask the patients to refrain from their morning medication.

Safety

During stress examinations with low or high dose dobutamine monitoring of the patient within the magnet is mandatory. In general, monitoring during a MR examination requires the same precautions and emergency equipment as any other stress examination. Specific recommendations are listed in Table 2. Apart from the known specific contraindications for MR, contraindications are identical to those for stress echocardiography and are listed in table 3.

Whereas only minimal side effects are to be expected during low dose dobutamine, high dose dobutamine stress may cause severe complications in 0.25% of patients including infarction (0.07%), ventricular fibrillation

(0.07%) and sustained ventricular tachycardia (0.1%). Thus, although adverse events are rare, preparation and practice for rapid removal of the patient from the magnet is needed in addition to a stringent adherence to the termination criteria (Table 4).

The monitoring of blood pressure, cardiac rhythm and patients' symptoms can either be done by placing standard equipment outside the scanner room connected to the patient with special extensions through a waveguide in the radiofrequency cage, or by using special CMR compatible equipment which exists at many CMR sites (see figure 1). A defibrillator and all drugs for emergency treatment must be available at the CMR site. A specific

problem for monitoring within the magnet is that of assessing the changes of ST-segments from the ECG. However, since wall motion abnormalities precede ST changes and such abnormalities can be readily detected with CMR imaging, monitoring is effective without a diagnostic ECG. This requires an on-line assessment of the wall motion during image reconstruction performed immediately after image acquisition with Auto-View switched on. In previous guidelines pulse oximetry has been recommended as an additional means for rhythm control mainly in case of ECG failure. When the Vector-ECG is used, pulse oximetry is not required.



Figure 1: Set-up for DSMR examination. Normally used 1.5 Tesla clinical whole body MR tomography (Philips, Best, The Netherlands) is shown. For quickest possible evacuation of a patient, a trolley is under the mobile table. Signs indicate: (A) infusion pump for administration of contrast agents; (B) blood-pressure monitoring system; (C) infusion pumps for stress agents.

Table 1: Preparation for dobutamine stress examination and antidote

Patient instructions	Antidote
No β -blockers and nitrates 24 hours prior to the examination	β -blocker (esmolol) 0.5 mg/kg as slowly injected bolus; additional bolus of 0.2 mg/kg as needed sublingual nitroglycerine

Table 2: Monitoring requirements for stress MR imaging

	Dobutamine + atropine
Heart rate and rhythm*	Continuously
Blood pressure	Every minute
Pulse oximetry*	Continuously
Symptoms	Continuously
Wall motion abnormalities	Every dose increment

When the Vector-ECG is used, pulse oximetry is not required.

Table 3: Contraindications for dobutamine

- Severe arterial hypertension ($\geq 220/120$ mmHg)
- Unstable angina pectoris
- Significant aortic stenosis (aortic valve gradient >50 mmHg or aortic valve area $< 1\text{cm}^2$)
- Complex cardiac arrhythmias
- Significant hypertrophic obstructive cardiomyopathy
- Myocarditis, endocarditis, pericarditis

Table 4: Termination criteria

- Submaximal heart rate reached $[(220 - \text{age}) \times 0.85]$
- Blood pressure decrease > 20 mmHg systolic below baseline systolic blood pressure or decrease > 40 mmHg from a previous level
- Blood pressure increase $> 240/120$ mmHg
- Intractable symptoms
- New or worsening wall motion abnormalities in at least 2 adjacent left ventricular segments (out of 17)
- Complex cardiac arrhythmias

Image interpretation

Wall motion abnormalities

For image interpretation multiple cine loop display is recommended displaying at least four different stress levels for each slice simultaneously. This can be done by using the Cardiac Analysis tool as implemented on the scanner or an external workstation (e.g. View Forum ...). The ventricle is analyzed by 17 segments per stress level (see attachment), Analysis is carried out visually according to the standards suggested by the American Society of Echocardiography. Image quality is graded as good, acceptable or bad and the number of diagnostic segments is reported. Segmental wall motion is classified as normokinetic, hypokinetic, akinetic or dyskinetic and assigned one to four points, respectively. The sum of points is divided by the number of analyzed segments and yields the wall motion score. Normal contraction results in a wall motion score of one, a higher score is indicative of wall motion abnormalities. During dobutamine stress with increasing doses, a lack of increase in either wall motion or systolic wall thickening, a reduction of both or significant changes in the rotational pattern of left ventricular myocardium ("tethering") are indicative of pathological findings.

Recommended reading:

1: Nagel E, Lorenz C, Baer F, Hundley WG, Wilke N, Neubauer S, Sechtem U, van der Wall E, Pettigrew R, de Roos A, Fleck E, van Rossum A, Pennell DJ, Wickline S. Stress cardiovascular magnetic resonance: consensus panel report. *J Cardiovasc Magn Reson.* 2001;3(3):267-81. Review

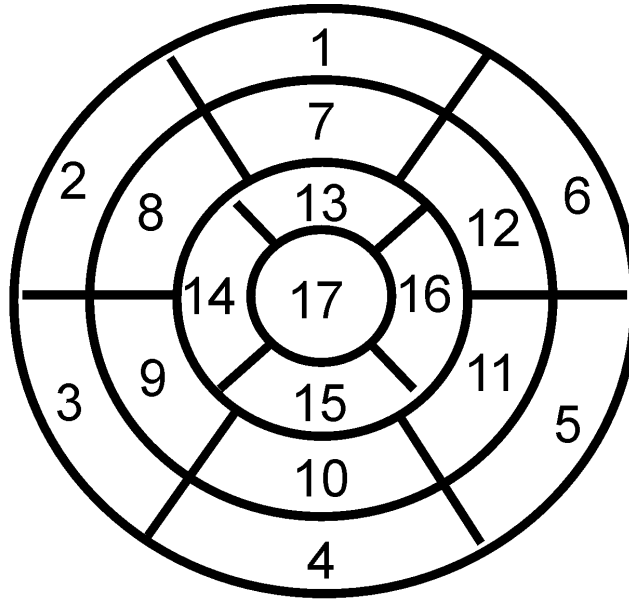
2: Wahl A, Paetsch I, Gollesch A, Roethemeyer S, Foell D, Gebker R, Langreck H, Klein C, Fleck E, Nagel E. Safety and feasibility of high-dose dobutamine-atropine stress cardiovascular magnetic resonance for diagnosis of myocardial ischaemia: experience in 1000 consecutive cases. *Eur Heart J.* 2004 Jul;25(14):1230-6.

3: Paetsch I, Jahnke C, Wahl A, Gebker R, Neuss M, Fleck E, Nagel E. Comparison of dobutamine stress magnetic resonance, adenosine stress magnetic resonance, and adenosine stress magnetic resonance perfusion. *Circulation.* 2004 Aug 17;110(7):835-42.

4: Nagel E, Lehmkuhl HB, Klein C, Schneider U, Frantz E, Ellmer A, Bocksch W, Dreyse S, Fleck E. Influence of image quality on the diagnostic accuracy of dobutamine stress magnetic resonance imaging in comparison with dobutamine stress echocardiography for the noninvasive detection of myocardial ischemia. *Z Kardiol.* 1999 Sep;88(9):622-30. German.

5: Hundley WG, Rerkpattanapipat P, Little WC, Link KM, Morgan TM. Relation of cardiac prognosis to segment location with apical left ventricular ischemia. *Am J Cardiol.* 2003 Nov 15;92(10):1206-8.

6: Hundley WG, Morgan TM, Neagle CM, Hamilton CA, Rerkpattanapipat P, Link KM. Magnetic resonance imaging determination of cardiac prognosis. *Circulation.* 2002 Oct 29;106(18):2328-33.



- 1. basal anterior
- 2. basal anteroseptal
- 3. basal inferoseptal
- 4. basal inferior
- 5. basal inferolateral
- 6. basal anterolateral

- 7. mid anterior
- 8. mid anteroseptal
- 9. mid inferoseptal
- 10. mid inferior
- 11. mid inferolateral
- 12. mid anterolateral

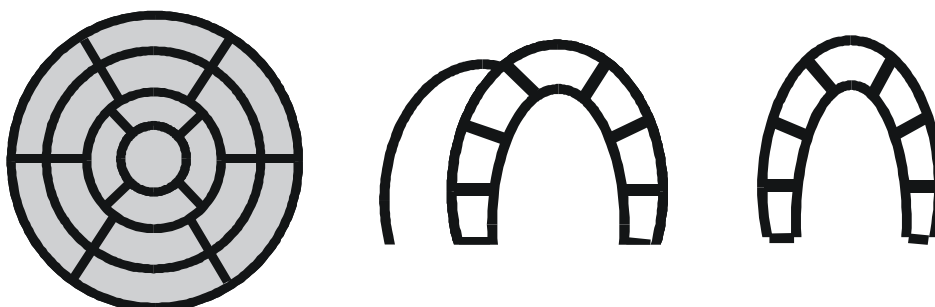
- 13. apical anterior
- 14. apical septal
- 15. apical inferior
- 16. apical lateral
- 17. apex

Patient: _____

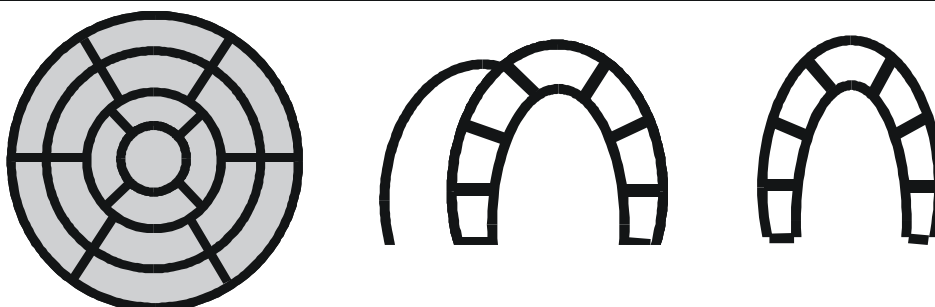
Date of birth - - -

Date of DSMR: - - -

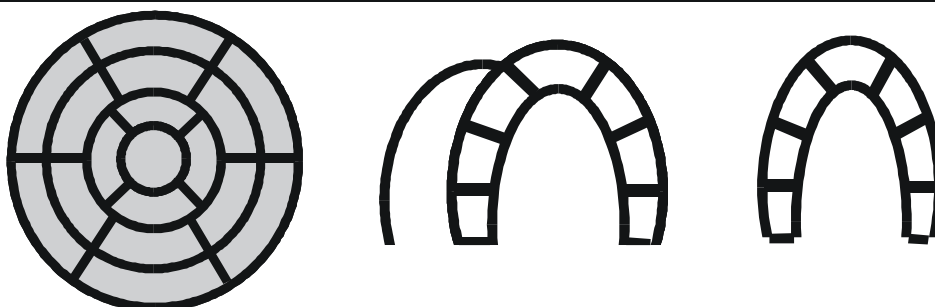
rest



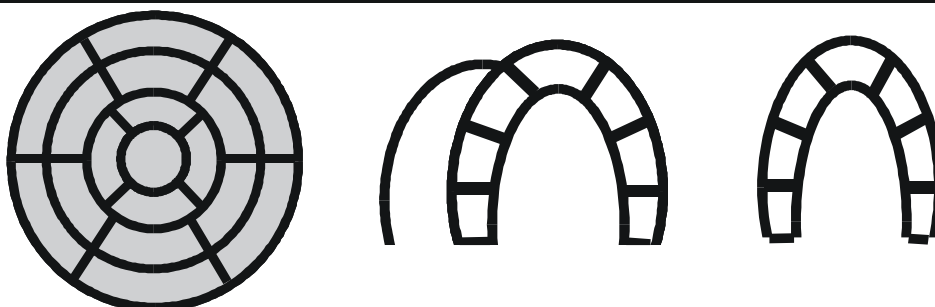
10 μ g



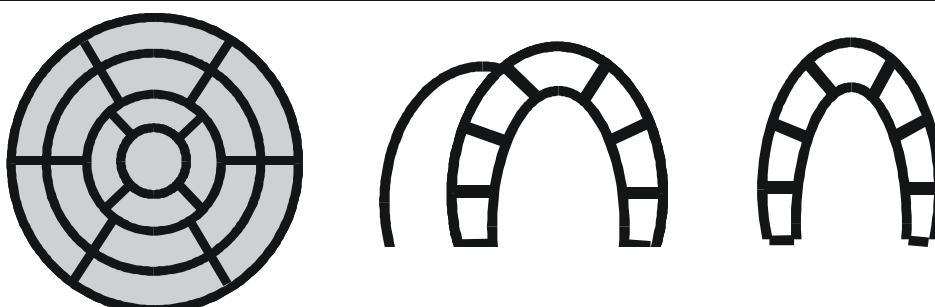
20 μ g



30 μ g



40 μ g



Protocol overview

All 17 segments of the heart can be covered by a combination of 3 short axis and 2 long axis views (4-chamber and 2-chamber). The optimal planning of these scans is explained in the Philips Application Guide Volume 3.

The study includes the following scans, which are all breathhold, multiphase-bTFE scans at endexpiratory level (scan duration ranging from 8 to 12 sec.), except for the first survey, which acquires multiple slices during free-breathing:

- (1) Multistack survey (bTFE)
- (2) Single-angulated survey (bTFE)
- (3) Double-angulated survey (bTFE)
- (4) Short axis view (bTFE, 3 slices)
- (5) 4-chamber view (bTFE)
- (6) 2-chamber view (bTFE)
- (7) 3-chamber view (bTFE)

Scan (4) - (7) will be performed at rest and repeated during all dobutamine levels.

Step by step protocol

Patient preparation

It is of special importance to explain to the patient not only the course of the examination but also the breathhold procedure. Generally the breathhold should be performed during endexpiration to ensure reproducible slice geometry and -if SENSE is employed- to rule out foldover artifacts. Patient's written informed consent must be obtained in advance.

- Put venous line in cubital vein (≥ 18 gauge).
- Monitor blood pressure and heart rate on contralateral arm.

Scan procedure:

Scan 1 (Multistack survey, [cardiac synergy coil]: all elements): Look at the images and check if the coil is positioned well.

Scan 2 (single-angulated survey):

Define the plane on transversal slices parallel to the septum through the apex of the left ventricle and the coaptation point of the mitral

valve.

Scan 3 (Repeat scan 2, bTFE):

Flip the orientation (90°) and adjust the plane on the single-angulated image through the apex and the middle of the mitral valve to get a double-angulated long axis view (similar to a 4 or 5-chamber view). This slice orientation helps to prevent any angulation errors while planning the short axis views.

Scan 4 (bTFE):

Make use of the double-angulated image to define 3 slices perpendicular to the long axis of the heart representing the short axis geometry.

Note: Under stress conditions even the normal heart experiences a change in its basal-to-apex dimensions. To avoid visualization of the left ventricular outflow tract at higher dobutamine levels as well as to ensure sufficient imaging of the left ventricular cavity (esp. critical is the apical slice), we recommend to perform the planning on the *endsystolic* images: divide the distance from the apical epicardial border to the mitral valve plane in 5 equal parts. Then, distribute the 3 short axes equally within the inner three-fifth of the distance with adaptation of slice gap.

Scan 5 (bTFE):

Plan the 4-chamber view on the equatorial short axis view, the stack should be aligned through the apex of the right ventricle and the papillary muscles. Click through the single phases to ensure sufficient visualization of LV cavity throughout the cardiac cycle.

Scan 6 (bTFE):

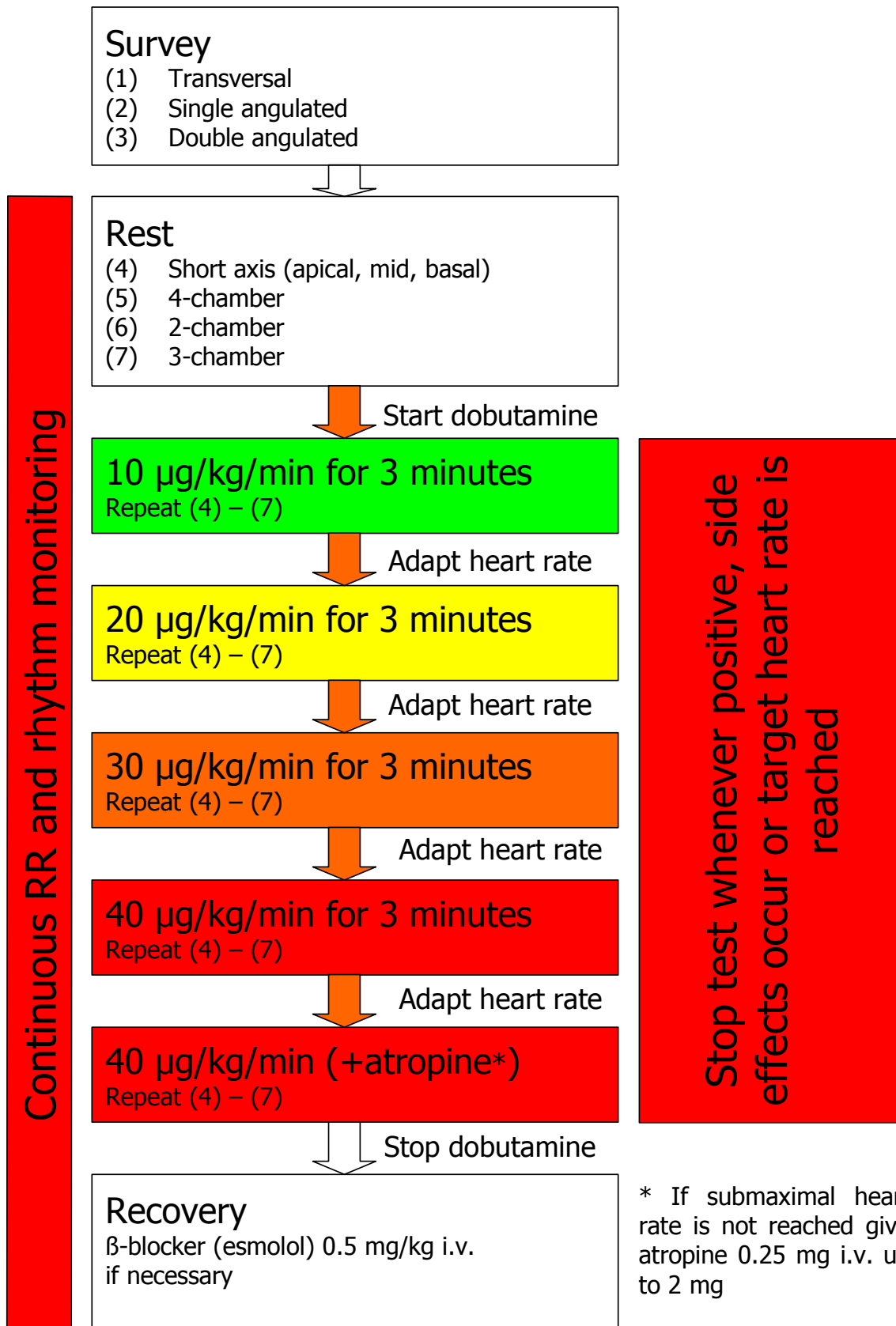
Plan the 2-chamber view on the previously acquired 4-chamber view by just switching the slice orientation and adjust the angulation (through the left ventricular apex and the coaptation point of the mitral valve). Click through the single phases to ensure sufficient visualization of LV cavity.

Scan 7 (bTFE):

Plan the 3-chamber view on the basal short axis view that displays the mitral valve opening, and the LV outflow tract towards the aortic valve.

Repeat scan 4, 5, 6, 7 on all dobutamine levels for wall motion imaging (see flow chart page 8).

Flow chart 1: Dobutamine Stress Protocol



Survey MST bTFE

Geometry	
Coil selection/ch. connection	Syn-Cardiac/12345
FOV(mm)/RFOV	450/100%
Matrix Scan/Reconstruction/Scan%	192/256/50
Slices/thickness(mm)/gap	20/10/0
Stacks/Type	3/parallel
Contrast	
ScanMode/Technique/Contrast/Fast Imaging	M2D/FFE/balanced/TFE
Shot mode	Single shot
Partial Echo	no
TE(ms)/Flip(deg)/TR(ms)	shortest/50/shortest
Half Scan	no
Water fat shift	min
Shim	auto
Motion	
Cardiac synchronization/device	no
Flow Comp./NSA	no/1
Dyn/Angio	
Angio/Q.Flow/Dyn. Study	no/no/no
Manual start	yes
Post Processing	
Recon Mode	real time

Angulated and double angulated survey

Geometry	
Coil selection/ch. connection	Syn-Cardiac/12345
FOV(mm)/RFOV	400/90%
Matrix Scan/Reconstruction/Scan%	176/256/100
Slices/thickness(mm)/gap	1/8/-
Stacks/Type	1/parallel
SENSE*/p reduction	yes/2 (optional)
Contrast	
Scan Mode/Technique/Contrast/Fast Imaging	M2D/FFE/balanced/TFE
Shot mode	default
Partial Echo	no
TE(ms)/Flip(deg)/TR(ms)	shortest/60/shortest
Half Scan	no
Water fat shift	min
Shim	volume
Motion	
Cardiac synchronization/device	retrospective/ECG
Card. Freq./RR%/ #Phase	70/15,15/25
Phase percentage	67 %
Arrhythmia rejection	yes
Respiratory compensation/slices per bh	breath hold/1
Flow Comp./NSA	no/1
Dyn/Angio	
Angio/Q.Flow/Dyn. Study	no/no/no
Post Processing	
Recon Mode	real time

*Alternatively: Half scan = yes

Cine SA/4CH/2CH/3CH bFFE

Geometry	
Coil selection/ch. connection	Syn-Cardiac/12345
FOV(mm)/RFOV	380/90%
Matrix Scan/Reconstruction/Scan%	192/256/110
Slices/thickness(mm)/gap	1-3/8/user def
Stacks/Type	1/parallel
SENSE*/p reduction	yes/2 (optional)
Contrast	
Scan Mode/Technique/Contrast/Fast Imaging	M2D/FFE/balanced/TFE
Shot mode	Default
Partial Echo	No
TE(ms)/Flip(deg)/TR(ms)	shortest/60/shortest
Half Scan	no
Water fat shift	min
Shim	volume
Motion	
Cardiac synchronization/device	retrospective/ECG
Card. Freq./RR%/ #Phase	70/15, 15/25
Phase percentage	50
Arrhythmia rejection	yes
Respiratory comp./slices per bh	breath hold/1
Flow Comp./NSA	no/1
Dyn/Angio	
Angio/Q.Flow/Dyn. Study	no/no/no
Post Processing	
Recon Mode	real time
Measured Voxel Size/mm	2 x 2 x 8

*Alternatively: Half scan = yes

This cookbook has been assembled from the knowledge available at the time of writing. The authors cannot take liability for dose regimen, infusion schemes, etc. If you find any errors or would like to suggest any improvements, please let us know at eike.nagel@dhzb.de or info@cmr-academy.com.