

Treatment Categories based on where and when treatment is needed.

FORMAT FOR INTERVENTIONAL CARDIAC MRI SAFETY PROTOCOL

I. General considerations

- a. Final responsibility safety policies: medical director of the department of radiology (optional to share responsibility with medical director of the department of cardiology)
- b. Serious and adverse events are reported to the medical director < 24 hours after the event occurrence

II. General MR safety considerations:

The presence of a patient, care provider or employee in the magnetic space of an MRI system involves a number of risks. To use the MRI scanner safely, users must be aware of these risks. A number of agreements have therefore been made in MUMC+ regarding the use of clinical MRI systems. These agreements are in accordance with ACR guidance document on MR safe practices¹ and the local protocol, and are fully implemented in the current intervention Cardiac MR (iCMR) protocol.

Treatment Categories based on where and when treatment is needed.

| A. Tx inside MR scanner | B. Tx outside MR scanner | C. Transfer to EP lab | D. Transfer to OR | E. Occurrence and/or Tx after procedure |
|--------------------------|-------------------------------|------------------------|------------------------|--|
| Air embolism | | | | Arteriovenous fistula |
| Hematoma | | | | Cardiac perforation / cardiac tamponade |
| Hypertension | | | | CVA / TIA |
| Hypotension | | | | Congestive heart failure |
| Vasovagal reactions | | | | Endocarditis |
| Arrhythmias | VT/VF | | | Hematoma |
| Congestive heart failure | Congestive heart failure | | | Hemothorax |
| Allergic reaction | Allergic reaction | | | Hypotension |
| Hypoxemia | Hypoxemia (req. reintubation) | | | Infections |
| Complete heart block | Complete heart block | Complete heart block | | Major bleeding |
| | Cardiac tamponade | Cardiac tamponade | Cardiac tamponade | Nerve injury (phrenic/vagus /diaphragmatic paralysis) |
| | | Coronary artery injury | Coronary artery injury | Pericarditis |
| | | | | Pleural effusion |
| | | | | Pneumonia |
| | | | | Pseudoaneurysm |
| | | | | Pulmonary embolism |
| | | | | Skin burns |
| | | | | Valvular damage |
| | | | | Vascular trauma (perforation/dissection/rupture/obstruction) |

Table: Potential complications categorized to where and when treatment should be executed. (Tx = treatment; MR = magnetic resonance; EP = electrophysiology; OR = operating room; VT = ventricular tachycardia; VF = ventricular fibrillation; CVA = Cerebrovascular accident; TIA = Transient Ischemic Attack; req. = requiring)

Treatment Categories based on where and when treatment is needed.

A. Treatment within the MRI scanner (i.e. within zone 4)

There are potential complications during the MR guided electrophysiological study (iCMR) that can be treated while the patient is still in the MRI scanner.

Air Embolism

Air embolism can cause ST elevation which is transient and procedure can be continued. In case this is complicated by cardiac arrhythmia, treat accordingly.

Allergic reaction

Mild => treat in the MRI scanner with medication administration according to the hospital protocol.

Arrhythmias

- Induced arrhythmias (e.g. atrial flutter, atrial tachycardia, AV (nodal) reentrant tachycardia) can be treated with pacing manoeuvres.
- New onset of atrial fibrillation can be treated with medication administration (e.g. Flecainide). If not terminated then the patient will be transferred to the EP lab for further treatment (cardioversion and completion of the ablation) according to the evacuation protocol.

Complete heart block or sinus arrest

- Immediate pacing through the electrophysiology (EP) catheters.
- If transient => the procedure can be continued after restoration of rhythm.
- If remaining with escape rhythm => go to category C.
- If remaining without escape rhythm => go to category B.

Congestive heart failure

Mild => treat with loop diuretics.

Hematoma

Mild => treat with manual compression.

Hypertension/ hypotension/ vasovagal reactions

Treat according to the hospital protocol.

Treatment Categories based on where and when treatment is needed.

Hypoxemia

- This can be treated in the MRI scanner with appropriate manoeuvres (e.g. chin lift) by the anesthesiologists.
- If hypoxemia persists (e.g. due to tube dislocation) and there is need for (re-)intubation => go to category B.

B. Treatment outside of the MRI scanner (i.e. outside zone 4)

Only complications that are life threatening for the patient, or that require immediate treatment with MR unsafe equipment, will be treated outside of the MRI scanner (i.e. outside zone 4).

The patient will be transferred outside the iCMR scanner room following the evacuation protocol.

Cardiac or respiratory arrest within the iCMR scanner room:

- Immediate warning of hospital incident response team.
- Immediate start of BLS by trained personnel.
- Removal of the patient out of zone 4 to magnetic safe location for further execution of the ALS procedure according to hospital protocol.
- See further explanation below under hypoxemia and ventricular tachycardia/fibrillation.

Ventricular tachycardia/fibrillation

The patient will be immediately evacuated from the MRI scanner (according to evacuation plan) and be transferred to the area outside the iCMR scanner room (i.e. outside zone 4) for external defibrillation; CPR will be executed by the operating physician until defibrillation.

Hypoxemia (requiring re-intubation)

In case of hypoxemia of an intubated patient under general anaesthesia due to tube-dislocation, then re-intubation with MRI unsafe equipment is necessary. Then move the patient outside of the MRI scanner (using the evacuation plan) and transfer outside the iCMR scanner room (i.e. outside zone 4) for treatment.

Cardiac tamponade

In case of hemodynamic instability, when the patient does not respond to initial treatment (intravenous fluid) and there is no time to transfer the patient to EP lab, then echocardiography-guided

Treatment Categories based on where and when treatment is needed.

pericardiocentesis is the current technique of choice. This has the highest rate of procedural success and the lowest rate of major complications compared with blind or surgical methods.² This procedure is to be performed outside the iCMR scanner room (i.e. outside zone 4)

Complete heart block or sinus arrest

- Immediate pacing through the EP catheters.
- If the patient remains without escape rhythm then the patient will be evacuated from the MRI scanner (by following the evacuation protocol) while being paced through the EP catheters (long cables will be already attached to the catheter from the beginning of the procedure) to outside the iCMR scanner room (i.e. outside zone 4); there the defibrillator will be attached on the patient for transcutaneous pacing => go to category C.

Allergic reaction

Moderate or severe => Treat according to hospital protocol or international guidelines.³

Congestive heart failure

Acute cq. severe => Treat according to hospital protocol.

C/D. Transfer to fluoroscopy EP lab / operating room (OR)

The patient will be transferred from the MRI environment to the fluoroscopy EP lab following the evacuation protocol in case of the following adverse events.

1. Cardiac tamponade in a hemodynamic stable patient where there is time to transfer the patient to the EP lab: for fluoroscopy-guided pericardiocentesis.
2. Complete heart block with escape rhythm or with successful transcutaneous pacing: for a temporary pacemaker lead. Then transfer tot CCU until implantation of permanent cardiac device.
3. Coronary artery injury: for coronary angiography.

If the above mentioned situation cannot be solved in the fluoroscopy EP lab, then the cardiothoracic surgeon will be consulted immediately. When indicated the patient will be transferred to the OR for treatment.

Treatment Categories based on where and when treatment is needed.

E. Complications after procedure.

All the potential adverse events mentioned in this category are well described after electrophysiological studies in general and do not need special attention or protocol for iCMR procedures.

MRI RAMP-DOWN (i.e. quench procedure)

Quench procedure: according to hospital protocol

In the event that a magnetic object becomes pinned to the MRI, the procedure should be immediately discontinued.

- If the patient is trapped or in danger due to the object, then immediately ramp-down the MRI and begin emergency evacuation procedure.
- If the patient is not in danger and can be removed safely in from the MR, then evacuate the patient and contact appropriate staff to remove the object or begin a controlled MRI ramp-down.

EVACUATION PLAN

- 1) Preparation for patient removal (disconnect system cabling)
- 2) Emergency bed release / removal
- 3) Removal of imaging coils
- 4) Transfer beyond the 5 Gauss line

Equipment required outside of the iCMR scanner room (i.e. outside zone 4):

- Automatic External Defibrillator
- Echocardiography
- Emergency crash car
- Electrophysiology portable car

Treatment Categories based on where and when treatment is needed.

REFERENCES

1. Expert Panel on MR Safety, Kamal E, Barkovich AJ, Bell C, Borgstede JP, Bradley WG Jr, Froelich JW, et al. ACR guidance document on MR safe practices: 2013. *J Magn Reson Imaging*. 2013 Mar;37(3):501-30
2. Tsang TS, Enriquez-Sarano M, Freeman WK, Barnes ME, Sinak LJ, Gersh BJ, et al. Consecutive 1127 therapeutic echocardiographically guided pericardiocenteses: clinical profile, practice patterns, and outcomes spanning 21 years. *Mayo Clin Proc* 2002; 77:429–436.
3. Cardona V, Ansotegui IJ, Ebisawa M, et al. World Allergy Organization anaphylaxis guidance 2020. *World Allergy Organ J*, 13 (2020), Article 100472