CASE REPORT

Managing Cardiovascular Incidents in the Intra-operative Magnetic Resonance Imaging (iMRI) Environment: Lessons from Three Case Studies

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ABSTRACT

In recent years, the use of magnetic resonance imaging (MRI) has extended into the operating theatre, especially in the field of neurosurgery. By providing real-time images during surgery, intra-operative MRI (iMRI) facilitates safer and more complete brain tumour resection. However, the iMRI environment poses additional challenges to the anaesthetist when managing intra-operative cardiovascular events. Through three case examples, this article will discuss the issues of cardiovascular resuscitation, cardiac pacing and cardiovascular monitoring in the iMRI environment.

Keywords: Anaesthesia, Cardiovascular incidents, Intra-operative, Magnetic resonance imaging, Neuroanaesthesia

INTRODUCTION

Magnetic resonance imaging (MRI) is an established imaging modality that provides superior soft tissue contrast without the need for ionising radiation or nephrotoxic contrast agents. By providing real-time images during surgery, intra-operative MRI (iMRI) facilitates safer, more complete brain tumour resection and improves accuracy of neuronavigation. Multiple investigators have found that in 65% to 92% of cases in which neurosurgeons thought that they had achieved gross total resection, iMRI depicted tumour that could still be resected.[1] The first operating theatre (OT) with an MRI system was built at Brigham and Women's Hospital,[2] and since then, many iMRI units have become available worldwide. In our institution, about 30% of brain tumour resections are performed under iMRI guidance.

The MRI environment imposes many limitations on patient management, including the use of only MRI-compatible or MRI-safe equipment, electromagnetic interference on monitoring equipment, and reduced access to the patient. Patients undergoing major surgery, such as neurosurgery under iMRI, may have a higher incidence of cardiovascular events such as hypotension, cardiac arrhythmias and cardiopulmonary arrest compared to those undergoing general anaesthesia for diagnostic MRI. This poses additional challenges for the anaesthetist who has to manage these problems in the hostile iMRI environment. We describe three cases to highlight the above.

Case 1

A 68-year-old lady with hypertension and on atenolol was scheduled for an endoscopic transphenoidal resection of a pituitary macroadenoma in the iMRI OT. Induction of anaesthesia was carried out in the anaesthetic induction room adjoining the OT, outside the magnet's field. This allowed for the use of conventional, non-MRI-safe intubation equipment. During intubation, she developed severe bradycardia that rapidly deteriorated to asystole despite timely atropine administration. Cardiopulmonary resuscitation (CPR) was

immediately instituted with successful recovery of spontaneous circulation within 2 minutes.

The February 2008 issue of The Joint Commission's Sentinel Event Alert recommended never to attempt a cardiopulmonary arrest code or resuscitation within the MRI magnet room.[3] Resuscitation equipment such as the defibrillator that contains ferromagnetic materials is unsafe for use in the vicinity of the MRI scanner. There may be insufficient time to properly screen personnel entering the scan room to assist in resuscitation. Hence, it is recommended that when a patient has a medical emergency in the MRI scan room, CPR should be initiated if needed while immediately removing the patient to a designated safe location away from the magnetic field where resuscitation can be safely performed. This location should contain the necessary resuscitation equipment, such as a defibrillator, physiological monitors and a cardiac arrest trolley containing resuscitation drugs, airway equipment, oxygen source and suction.[4] To facilitate this transport, an MRI-compatible stretcher or trolley should be readily available. In the case of the iMRI OT, the adjoining anaesthetic induction room is the chosen location. Clear guidelines should dictate workflow and the roles of iMRI staff during a cardiopulmonary emergency.

Case 2

A 77-year-old man with a pituitary macroadenoma was scheduled for an endonasal endoscopic transphenoidal hypophysectomy in the iMRI OT. His medical history includes atrial fibrillation, bifascicular heart block and ischaemic heart disease. In view of these cardiac issues, temporary transvenous pacing leads were inserted preoperatively after consultation with the cardiologist. Due to the presence of pacing leads, the surgery was conducted in the intra-operative computed tomography (iCT) OT instead of in an MRI environment although iMRI would have been the preferred operating modality for transphenoidal tumour surgery.

MRI is currently contraindicated in patients with implanted pacemakers. Strong magnetic and radiofrequency forces generated by the MRI scanner may have potential adverse effects on pacemakers, resulting in pacemaker inhibition, reprogramming, conversion to an inappropriate mode, dislodgement, disconnection, and heating of the leads. Reports of morbidity and mortality attributed to MRI and pacemaker interactions exist. In recent years, a number of small prospective human studies examining the issue of MRI and pacemaker interactions and safety seem to suggest that MRI may not be as harmful to pacemaker function as once thought,[5-6] especially with newer MRI-conditional pacemaker models that have improved resistance to external interference.

However, significant controversy still exists over safety issues, and the presence of a pacemaker is still a strong relative contraindication to routine MRI examination. MRI in such patients should only be considered if potential benefits clearly outweigh risks. In such cases, risks should be discussed clearly with the patient and scanning performed only at extremely experienced centres. During scanning, a physician with pacemaker expertise should be present, resuscitation equipment available, and cardiac rhythm and vital signs monitored. Pacemaker interrogation should be carried out before and after the procedure.[6]

MRI scanning in patients with temporary transvenous pacing leads (with or without the external pulse generator) is not recommended.[6] Although these pacing leads are non-ferromagnetic, they may incorporate electrically conductive materials that can result in thermal injury to myocardial tissue as a result of voltage induction during MRI scanning. Furthermore, the transvenous pacemaker external pulse generator cannot be reliably used during MRI as the harsh electromagnetic environment can damage it or alter its function.

Case 3

A 36-year-old lady with no known medical problems underwent resection of an oligodendroglioma in the iMRI OT. During an intra-operative scan, an episode of hypotension resulted in interruption of scanning to allow the anaesthetist (who had been monitoring the patient via a remote physiological monitor from an adjoining control room) to enter the iMRI OT to institute corrective measures.

Interruption of MRI scanning could have been avoided had the anaesthetist remained in the iMRI OT during scanning. The American Society of Anesthesiologists' (ASA) Standards for Basic Anesthetic Monitoring[7] requires qualified anaesthesia personnel to be present in the room throughout the conduct of all general anaesthetics, regional anaesthetics and monitored anaesthesia

care. This is for direct patient observation and to facilitate rapid response to any changes in the patient's condition.

However, ASA also states that intermittent remote observation of the patient is justified if there is a direct known hazard to anaesthesia personnel. Short-term effects of MRI magnetic fields on personnel include nausea, vertigo and seeing flashing lights, resulting from induced electrical currents in the inner ear and retina. Although long-term health effects of cumulative magnetic field exposure from MRI scanning are still unknown, the current lack of evidence of harm does not exclude such a finding in future. Indeed, the Medical Devices Agency (MDA) of the United Kingdom advises that it is prudent not to perform MRI in patients in the first trimester of pregnancy until further evidence of its safety is available.[8] Furthermore, during scanning in the iMRI, high levels of noise, sometimes up to 95db, poses risk of hearing damage to personnel within the scan room. Moreover, the use of ear protection makes patient monitoring difficult, limits auditory sense as a monitoring tool and interferes with communication.[9]

The Association of Anaesthetists of Great Britain and Ireland (AAGBI) recommends that workers should minimise the risk of personal exposure to magnetic fields as far as is reasonably achievable, and that a remote monitoring facility be available to allow the anaesthetic team to remain outside the scanning room should they wish to do so.[8] Our practice allows for the anaesthetist to monitor the patient from the adjoining control room where there is an unobstructed view of the patient, monitors and anaesthesia machine during MRI scanning, with the caveat that scanning ceases if needed, to alter drugs or assess the patient. More importantly, potentially unstable patients are not listed to be operated on under iMRI.

CONCLUSION

These cases have been used to highlight potential cardiovascular issues and their management in a unique operating environment. The iMRI OT is a hostile environment in view of its isolation, specialty equipment and requirement for staff trained to function in it. Patient selection is essential and any clinically or potentially unstable patients should not be listed to be operated there. This will require a careful discussion of risks versus benefits for each patient. If any doubt exists about patient suitability, whether clinically or because of unsuitable equipment such as the presence of pacemakers, it is reasonable to err on the side of safety and use a conventional operating room.

Neurosurgery and neuroanaesthesia can result in cardiovascular changes, for example arrhythmias during brainstem irritation. Anaesthetists must know how to respond to cardiovascular emergencies during iMRI, including how to conduct CPR and where to transfer the patient for immediate treatment. The neuroanaesthetist must be prepared to interrupt MRI scanning if changes in the patient's condition warrant it, or if alterations are required to equipment.

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