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Case Report

CASE REPORT

Visualising myocardial injury after noncardiac surgery: a case series using postoperative cardiovascular MRI

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Abstract

Myocardial injury after noncardiac surgery (MINS) and perioperative myocardial injury are associated with increased morbidity and mortality. Both are diagnosed by a perioperative increase in troponin, yet there is controversy if MINS is a genuine myocardial insult. We applied postoperative cardiovascular magnetic resonance T2 mapping techniques to visualise acute myocardial injury (i.e. oedema) in six patients with multiple cardiovascular risk factors who underwent aortic surgery. The burden of myocardial oedema was substantially higher in four patients with elevated troponin qualifying for MINS, compared with patients without MINS. The data and images suggest that MINS represents genuine myocardial injury.

Keywords: cardiovascular magnetic resonance; MINS; myocardial injury after noncardiac surgery; myocardial oedema; perioperative myocardial injury; T2 mapping

Brief report

Myocardial injury after noncardiac surgery (MINS) and perioperative myocardial injury (PMI) have gained interest in the fields of anaesthesiology and cardiology. MINS is typically defined by a perioperative increase in high-sensitive troponin T (hsTnT) of 5 ng L^{-1} with the absolute hsTnT >20 ng L^{-1} after operation or a postoperative hsTnT >65 ng L^{-1}, independent of the relative increase, after 24 h post-surgery.[1] PMI has an overlap with MINS as both are defined by cardiac troponins. PMI can be classified as cardiac or extracardiac as the increase in hsTnT can occur as a result of sepsis, atrial fibrillation, or stroke, while the definition of MINS excludes extracardiac causes and is believed to be the result of myocardial ischaemia.[2,3] In most cases, a leading cause of MINS is thought to be an oxygen demand and supply mismatch (type II injury) while a minority present with obstructed coronary epicardial vessels (type I injury).[1,2] In the VISION study, 21% of patients with MINS fulfilled the universal definition of myocardial infarction. In total, 93% of patients with MINS did not experience any symptoms of ischaemia and might have as such remained undetected without troponin monitoring.[1] MINS can be as frequent as 40% in high-risk patients with known coronary artery disease (CAD) or with a high risk thereof.[4] Importantly, MINS and PMI are known independent predictors of 30-day, mid- and long-term mortality and morbidity.[1,3,4] Retrospective studies looking into triggers of an oxygen supply/demand mismatch have identified some suspected culprits, such as anaemia, tachycardia, and hypotension as contributors to PMI/MINS.[4] Further, a case report applying perioperative cardiovascular magnetic resonance (CMR) has shown that myocardial oxygenation and function rapidly fluctuate throughout the induction of general anaesthesia, especially in

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patients with CAD.[5] Yet, results of randomised controlled studies trying to optimise the myocardial oxygen demand/supply balance have so far been disappointing.[6,7] Moreover, there is still controversy on whether the perioperative troponin increase (often referred to as troponitis) defined as MINS/PMI, is just a result of a generally more vulnerable patient and is not a specific sign of an acute myocardial injury. Not only is there heterogeneity in the diagnostic criteria applied to detect PMI, but an increase in troponin can reflect a variety of pathophysiological mechanisms.[3]

CMR imaging may be able to shed light on acute postoperative myocardial injury. Imaging studies have investigated regional wall motion abnormalities by echocardiography and CMR after MINS.[8] This previous CMR study used different cut-offs for hsTnT. There was no difference in the prevalence of scar quantified with late gadolinium enhancement (LGE) in patients positive for MINS *vs* controls (28% *vs* 30%) within the first month after hospital discharge. Importantly, LGE is positive if fibrotic tissue/scar has already formed and is thus usually not an acute marker. It is therefore unclear if fibrotic tissue was a result of MINS/PMI itself or just a feature of the preexisting CAD. A key feature of acute myocardial injury is myocardial oedema, an insult where the myocardium is prone to the accumulation of water in the intracellular or interstitial compartments. Myocardial oedema is typically an acute event that is often attributed to myocardial ischaemia or inflammation and is observed before permanent myocardial injury occurs.[9] T2 mapping is a quantitative imaging technique that interrogates the water content of the tissue per cubic millimetre voxel. T2 mapping measures the transverse relaxation time of the tissue and expresses this as the time during which the transverse relaxation has decayed to 37% of the original magnetisation, which is measured in milliseconds (ms). A longer T2 represents a higher water content of the tissue, indicative of myocardial oedema if it exceeds the normal values for a given tissue. This technique is already being used for the assessment of acute myocardial injury for a variety of cardiovascular events including myocardial infarction and inflammatory cardiomyopathies such as myocarditis, and has found its way into diagnostic recommendations.[10] In COVID-19 patients, T2 mapping was shown to be correlated with hsTnT.[11] While hsTnT is a marker for cell necrosis, T2 mapping can define whether and where myocardial injury occurs, yet it has not yet been applied to investigate MINS/PMI.

Therefore, we performed postoperative CMR in a small subset of patients undergoing major noncardiac surgery to assess if there is a potential link between troponin defined MINS and acute myocardial injury. In this brief report, six patients from an ongoing clinical trial investigating MINS (clinicaltrials.gov, NCT04808401) are described.[12] Male patients aged between 60 and 84 yr underwent open abdominal aortic surgery (tubular conduit prosthesis or Y-prosthesis) with aortic cross-clamping for 70–90 min. All had diagnosed CAD or at least two risk factors for CAD according to the revised cardiac risk index[13] (Supplementary Table S1). HsTnT was acquired before surgery, 2 and 24 h after surgery, and the established criteria for MINS were used (Fig. 1a). Subsequently, these patients had a postoperative CMR examination performed during their hospitalisation (median 6 days after surgery [6–13 days]). CMR was either clinically indicated based on the increase of troponins and postoperative symptoms, or patients consented to undergo imaging as an additional substudy. Four patients had MINS detected 24 h after surgery by hsTnT, while two patients did not have a relevant hsTnT increase (Fig. 1b).

In the CMR examination, standard function cine sequences and T2 maps were acquired in short- and long-axis views of the heart (Supplementary Fig. S1). A T2 <41 ms is considered normal, based on local cut-offs of healthy controls older than 50 yr of age acquired from the same scanners, identical sequences, and analysis techniques. Figure 1c depicts the global T2, which is an average of the left ventricle from patients with and without MINS. The two patients without MINS had the lowest T2 that were below the cut-off and thus had a normal global myocardial water content. The four patients with MINS had higher T2 indicating myocardial oedema due to acute myocardial injury. There was a good correlation between the global T2 values and change in hsTnT after 24 h (r=0.84, P=0.04). There was no correlation of either T2 or hsTnT to brain natriuretic peptide changes or aortic cross-clamp time. From the function cines, left ventricular longitudinal strain was assessed as a marker of wall motion abnormalities, and regional ventricular systolic dysfunction was weakly correlated with regional T2 (r=0.24, P=0.03, Supplementary Fig. S2).

The T2 mapping of a surgical patient negative for MINS (Fig. 1d) shows a normal water content (green, global T2=39.7 ms). By contrast, in a MINS-positive patient, higher T2 across the myocardium can be observed by the orange colour overlay (global T2=44.5 ms). It can also be seen that there are regions with a higher burden of injury (red and purple, T2 >50 ms), especially in the apical septum. Based on the combination with other CMR diagnostic data, this patient was subsequently referred to cardiology for an invasive coronary intervention, where an occlusion of the right coronary artery, and a haemodynamically significant lesion (fractional flow reserve of 0.75) in the left anterior descending coronary artery were found, both of which are responsible for perfusing the septum. Regional distribution of both T2 and wall motion abnormalities quantified by feature tracking strain of the MINS patients according to coronary perfusion are displayed in Supplementary Table S2. Two of the four MINS patients showed myocardial scar detected by LGE. However, scar is unlikely to have developed in this short time and was therefore likely pre-existing. It should be noted that preoperative CMR examinations were not performed.

Discussion

To our knowledge this is the first publication showing myocardial oedema in relation to MINS detected by hsTnT. All our patients were scanned within their hospital stay at a median of 6 days after surgery, therefore, although oedema can be transient, we expect that if present, the oedema would have been observed during this timeframe. In swine, T2 mapping detected myocardial injury as soon as 2 h after an ischemia/reperfusion injury, with just as high T2 observed at 7 days after insult,[14] and in humans, T2 can remain elevated for up to 3 months postinfarction.[15] Perioperative myocardial ischaemia is a key culprit for MINS, however, remote stressors may also trigger myocardial injury.[16] Systemic inflammatory responses have been associated with increased risk of postoperative cardiac events and even decreased contractility as a result of myocardial injury.[4] Importantly, prolonged aortic cross-clamping is known to trigger pronounced ischaemia/reperfusion injury and can lead to remote organ injury as well. Although the myocardial injury observed in this case series can be of ischaemic origin, reperfusion injury after aortic

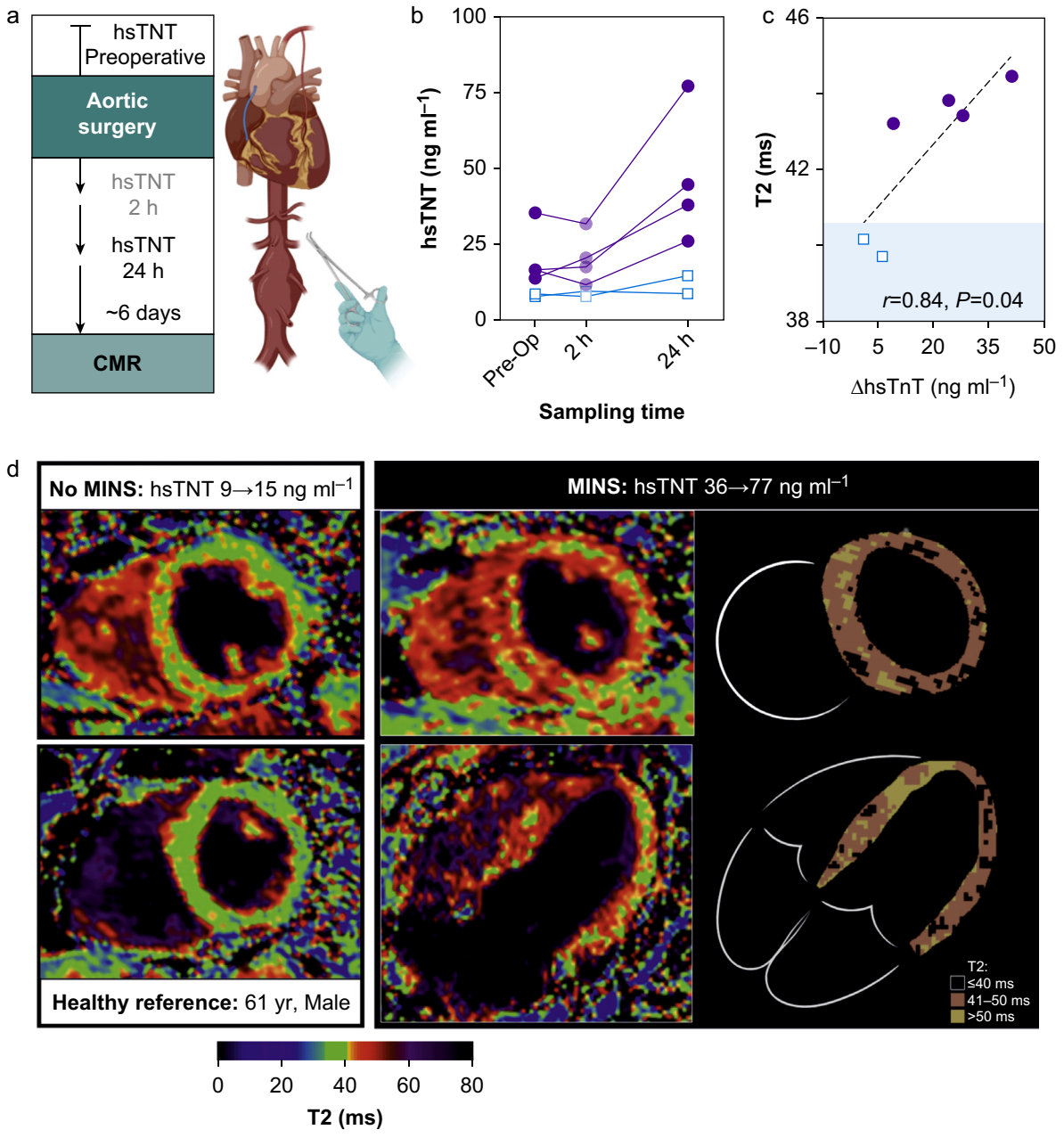

Fig 1. Perioperative myocardial injury and cardiovascular magnetic resonance (CMR) imaging. (a) Sequence of troponin measurements and postoperative CMR. (b) In comparison to preoperative high-sensitive troponin T (hsTnT) measurements, four patients had a significant increase in hsTnT after 24 h (purple circles), while two patients did not have an hsTnT-defined MINS after major aortic surgery (blue squares). (c) Postoperative CMR demonstrated that myocardial T2, reflecting myocardial injury with oedema, was higher in patients with MINS than in those without MINS with a relationship between higher T2 and hsTnT assessed by a Pearson's correlation. (d) *Top left:* a T2 map of a 74-yr-old male patient (patient B in Supplementary Table S1) who did not have MINS showed relatively normal T2 across the left ventricular myocardium (green, average T2=39.7 ms). *Bottom left:* a 61-yr-old healthy control is shown for reference (cut-off for normal T2 is <40.6 ms, depicted by green voxels). *Middle:* T2 mapping of a 75-yr-old male patient (patient C in Supplementary Table S1) who had a significant increase in hsTnT, defined as MINS, demonstrates significantly higher T2 (orange, red and purple colours), representing higher water content/myocardial oedema. *Right:* in the patient with MINS, voxels were categorised as normal (black), prolonged T2 (41–50 ms, mauve) or significantly prolonged T2 (>50 ms, gold). In this patient with MINS, 16% of the myocardium had normal T2, 67% showed prolonged T2, with significant myocardial injury in 17% of the myocardium. In both patients, CMR was performed 6 days after the operation. CMR, cardiovascular magnetic resonance; MINS, myocardial injury after noncardiac surgery.

cross-clamping or associated inflammatory responses cannot be ruled out as a co-contributor. Potential injury to the thinner right ventricular wall should not be overlooked, however our analysis could only focus on left ventricular myocardial injury because of the limitations of the voxel size of the T2 sequence used in this analysis.

Conclusions

In this case series we show for the first time that MINS is associated with myocardial injury visualised and quantified by T2 mapping cardiovascular magnetic resonance imaging. These results corroborate the findings of myocardial injury detected by the increase in hsTnT according to the MINS criteria. As downstream complications of MINS and PMI remain unacceptably high, more studies that identify triggers of MINS/PMI and strategies to prevent or alleviate this injury are needed. Cardiovascular magnetic resonance imaging has the potential to shed light on the mechanisms of MINS/PMI.

Authors' contributions

Contributed to the conception and design: DPG, JOF, KF
Acquired data: DPG, JOF, SS, SW, GE, MN, ATH, CG, KF
Interpreted data: DPG, JOF, SS, MN, CG, KF
Drafted the article: DPG, JOF, KF
Critically revised the article: SS, SW, GE, MN, ATH, CG
Gave final approval of the manuscript and agree to be accountable for all aspects of the work: all authors

Declaration of interest

The authors declare they have no conflicts of interest.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.bja.2024.07.012.

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