Scandinavian Cardiovascular Journal

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/icdv20

Implementing screening for myocardial injury in non-cardiac surgery: perspectives of an ad-hoc interdisciplinary expert group

Dan Atar, Leiv Arne Rosseland, Ib Jammer, Kristin Moberg Aakre, Rune Wiseth, Marius Molund, Danielle M Gualandro & Torbjørn Omland

To cite this article: Dan Atar, Leiv Arne Rosseland, Ib Jammer, Kristin Moberg Aakre, Rune Wiseth, Marius Molund, Danielle M Gualandro & Torbjørn Omland (2023) Implementing screening for myocardial injury in non-cardiac surgery: perspectives of an ad-hoc interdisciplinary expert group, Scandinavian Cardiovascular Journal, 57:1, 31-39, DOI: 10.1080/14017431.2022.2112071

To link to this article: https://doi.org/10.1080/14017431.2022.2112071

Published online: 15 Dec 2022.

SCANDINAVIAN CARDIOVASCULAR JOURNAL
2023, VOL. 57, NO. 1, 31–39
https://doi.org/10.1080/14017431.2022.2112071

Taylor & Francis
Taylor & Francis Group

RESEARCH ARTICLE

OPEN ACCESS Check for updates

Implementing screening for myocardial injury in non-cardiac surgery: perspectives of an ad-hoc interdisciplinary expert group

Dan Atar[a,b], Leiv Arne Rosseland[b,c], Ib Jammer[d,e], Kristin Moberg Aakre[f,g,h], Rune Wiseth[i,j], Marius Molund[k], Danielle M Gualandro[l] and Torbjørn Omland[b,m]

[a]Department of Cardiology, Oslo University Hospital Ulleval, Oslo, Norway; [b]Institute of Clinical Medicine, University of Oslo, Oslo, Norway; [c]Department of Research and Development, Division of Emergencies and Critical Care, Oslo University Hospital, Oslo, Norway; [d]Department of Anaesthesia and Intensive Care, Haukeland University Hospital, Bergen, Norway; [e]Department of Clinical Medicine, University of Bergen, Bergen, Norway; [f]Department of Medical Biochemistry and Pharmacology, Haukeland University Hospital, Bergen, Norway; [g]Department of Heart Disease, Haukeland University Hospital, Bergen, Norway; [h]Department of Clinical Science, University of Bergen, Bergen, Norway; [i]Clinic of Cardiology, St. Olavs Hospital, Trondheim University Hospital, Trondheim, Norway; [j]Department of Circulation and Medical Imaging, NTNU, Norwegian University of Science and Technology, Trondheim, Norway; [k]Department of Orthopaedic Surgery, Østfold Hospital Trust, Grålum, Norway; [l]Department of Cardiology and Cardiovascular Research Institute Basel (CRIB), University Hospital Basel, University of Basel, Switzerland; [m]Department of Cardiology, Akershus University Hospital, Lørenskog, Norway

ABSTRACT

Objectives. Perioperative myocardial injury (PMI) is increasingly recognised as an important complication of non-cardiac surgery, with often clinically silent presentation, but detrimental prognosis. Active screening for PMI, involving the detection of dynamic and elevated levels of cardiac troponin, has recently been advocated by an increasing number of guidelines; however, active PMI screening has not been reflected in clinical practice. *Design*. As consensus on a common screening and management pathway is lacking, we synthesise the current evidence to provide suggestions on the selection of patients for screening, organisation of a screening program, and a potential management pathway, building upon a recently published perioperative screening algorithm. *Results*. Screening should be performed using high-sensitivity assays both preoperatively and postoperatively (postoperative Days 1 and 2) in patients at high-risk of experiencing perioperative complications. *Conclusion*. This expert opinion piece by an interdisciplinary group of predominantly Norwegian clinicians aims to assist healthcare professionals planning to implement guideline-recommended PMI screening at a local level in order to improve patient outcomes following non-cardiac surgery.

ARTICLE HISTORY
Received 26 July 2021
Revised 9 June 2022
Accepted 5 August 2022

KEYWORDS
Perioperative screening; myocardial injury; myocardial infarction; cardiac troponin; PMI

Introduction

Worldwide, over 300 million surgeries are performed annually [1], with over 100 million comprising non-cardiac surgery in patients aged ≥45 years [2]. Cardiac complications within 30 days of major non-cardiac surgery, including myocardial infarction, myocardial injury, and postoperative arrhythmias, occur in more than 10 million people each year [3,4]. Mortality during this period is also high [5]; in Sweden, 30-day mortality and 1-year mortality were reported to be 1.8% and 8.5% in patients undergoing non-cardiac surgery (mean age 57.4 years), respectively [6], and in Norway, 30-day mortality in patients aged ≥80 years undergoing emergency non-cardiac surgery was as high as 26% [7]. However, incidence rates of cardiac complications and mortality rates in patients undergoing non-cardiac surgery are poorly described in the wider Scandinavian region.

Myocardial infarction is an important complication of major non-cardiac surgery and is associated with a poor prognosis [5,8]. The diagnosis of acute myocardial infarction (AMI) defined by the Fourth Universal definition of Myocardial Infarction is made in the presence of a dynamic rising and/or falling pattern of cardiac troponin (cTn) with at least one measurement above the 99th percentile upper reference limit (URL), combined with clinical signs or symptoms of ischaemia or imaging evidence of loss of myocardium [9]. Myocardial infarction can be further subdivided into Type 1 myocardial infarction – caused by coronary artery disease (CAD) and precipitated by plaque disruption (rupture or erosion) – and Type 2 myocardial infarction – ischaemic myocardial injury caused by a mismatch between oxygen supply and demand [9]. In contrast to acute myocardial injury (defined by the rise and fall pattern of cTn alone, without requiring the additional ischaemic criteria), chronic myocardial injury is defined as non-dynamic elevation (no substantial change over time) of cTn above the 99th percentile URL. A visual representation of the definitions of myocardial injury and infarction is presented in Figure 1.

CONTACT Dan Atar dan.atar@medisin.uio.no Dept. of Cardiology, Oslo University Hospital Ulleval, Kirkeveien 166, Building 3A, Oslo, N-0450, Norway

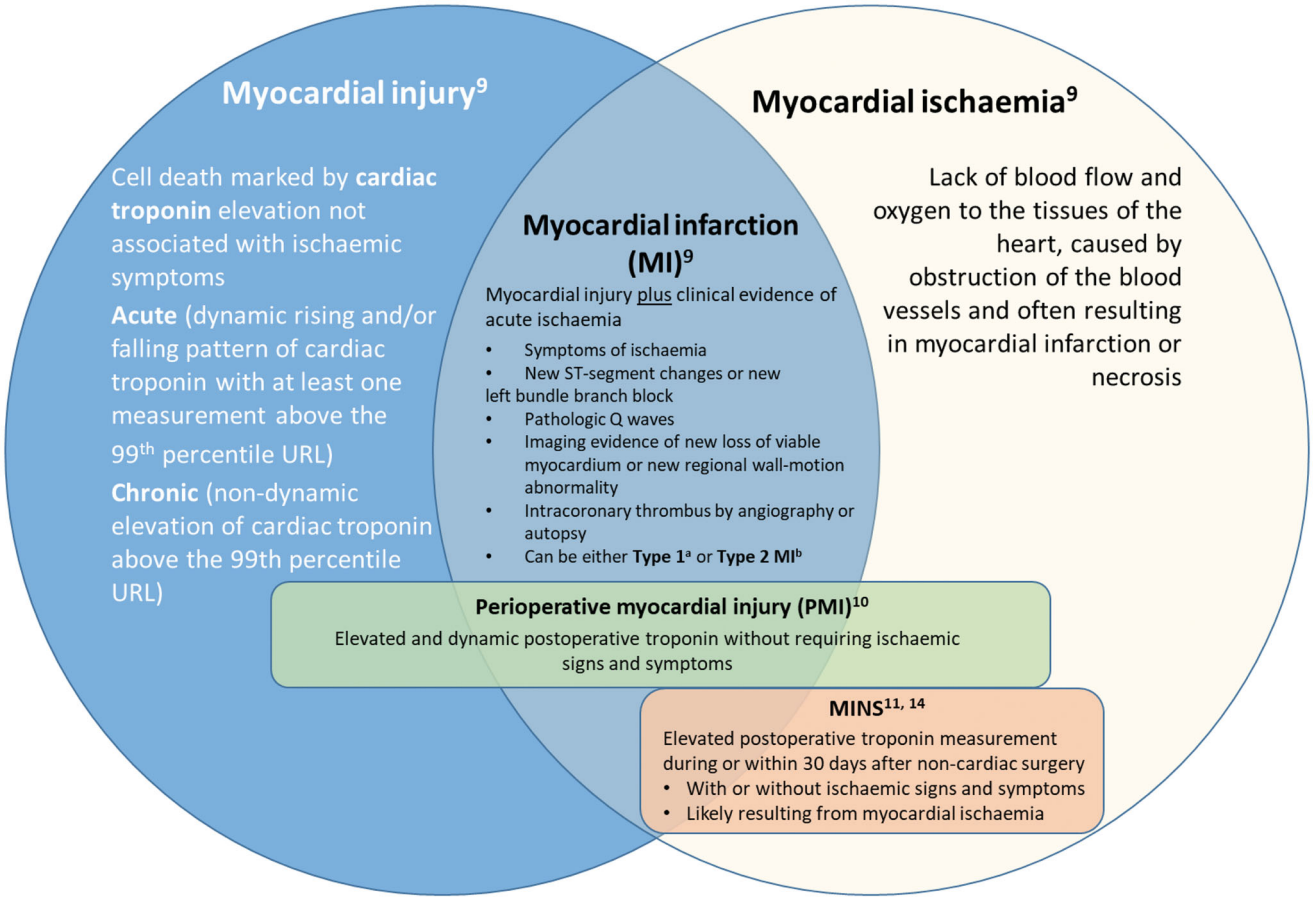

Figure 1. Conceptualisation of the definitions of myocardial infarction and myocardial injury.
Footnote: [a]Type 1 MI: Caused by coronary artery disease and precipitated by plaque disruption (rupture or erosion); [b]Type 2 MI: Ischaemic myocardial injury caused by a mismatch between oxygen supply and demand.

In the perioperative setting, identifying myocardial infarction and injury using the Universal Definition can present some difficulty. In this setting, acute myocardial injury is often clinically asymptomatic due to sedation or analgesia, resulting in prognostically important complications going undetected. Consequently, recent studies have been charged with investigating the prognostic utility of monitoring perioperative cTn levels in patients undergoing non-cardiac surgery. Perioperative myocardial injury can be detected by elevated and dynamic changes in cTn with or without additional ischaemic symptoms or signs [10]. Evidence suggests that *asymptomatic* perioperative myocardial injury is more frequent than previously thought, and as strongly associated with 30-day mortality as perioperative myocardial injury *with* ischaemic symptoms [5,8,10–12]. Indeed, in the POISE-1 trial of 8,351 patients undergoing non-cardiac surgery, 30-day mortality rate was 9.5% and 12.5% in patients with symptomatic and asymptomatic perioperative myocardial injury, respectively, compared with 2.2% in patients with no perioperative myocardial injury [8]. As the identification of events using cTn screening captures both myocardial infarctions and acute myocardial injury, for the purpose of this paper, we have used the broad term "perioperative myocardial injury," or PMI.

While PMI is generally accepted as an important complication associated with non-cardiac surgery, a single, universal definition has not been determined. The definition developed using the largest body of supporting evidence (Vascular Events in Non-cardiac Surgery Patients Cohort Evaluation [VISION] studies) is that of myocardial injury after non-cardiac surgery (MINS) [5], and is supported by the joint European Society of Anaesthesiology and Intensive Care (ESAIC) and European Society of Intensive Care Medicine (ESICM) taskforce on standard perioperative outcome definitions [13]. The VISION investigators define MINS as elevated postoperative cTn (indicative of myocardial injury) due to myocardial ischaemia, with or without ischaemic symptoms or electrocardiogram (ECG) changes during non-cardiac surgery or within 30 days' post-surgery (Figure 1) [5,11,14]. In clinical practice, it is often difficult to determine whether elevated postoperative cTn is due to myocardial ischemia, with MINS often incorrectly assumed to rely simply on elevated postoperative cTn. Moreover, the ESAIC-ESICM statement is from 2015, and further evidence and terminology has emerged since then, namely from the BASEL-PMI study. In this publication, PMI was prospectively defined as an elevated and dynamic change in cTn, irrespective of maximum postoperative values, with or without evidence of ischaemia, independent of the aetiology of the troponin elevations (Figure 1) [10].

While there is a high medical need for effective PMI screening and management strategies to potentially improve

postoperative mortality, global consensus and clinical guidance are lacking. In this opinion paper, we discuss the available evidence regarding approaches for screening and management of PMI after non-cardiac surgery, with the hope to assist physicians with implementing guideline-recommended cTn screening at a local level.

Implementing PMI screening

Identifying who should be screened

Routine screening for myocardial injury in the perioperative setting is recommended to varying degrees in current guidelines and expert reviews and should be performed in patients considered to be at increased risk of experiencing perioperative complications following non-cardiac surgery [9,15–21]. The definition of what constitutes a 'high-risk' patient has been a point of contention between guidelines and in the current literature [9–11,15,17,18]. It is important to identify a population of patients to screen whereby the detection of cTn elevations will be of significant clinical value. In a recently published expert opinion paper, Puelacher and colleagues aimed to develop a comprehensive PMI screening and care algorithm recommended for use in clinical practice when assessing and screening patients undergoing non-cardiac surgery. In this algorithm, they supported the criteria for high-risk patients undergoing non-cardiac surgery requiring ≥24-hour hospital stay posited by the Canadian Cardiovascular Society; that is: patients aged ≥45 years with known significant cardiovascular disease (e.g. CAD, cerebral vascular disease, peripheral arterial disease or congestive heart failure); OR patients aged >45 years with a Revised Cardiac Risk Index (RCRI) score ≥1; OR patients aged 18–64 years with significant cardiovascular disease who are scheduled for urgent/emergent or semi-urgent surgery; OR aged ≥65 years (Figure 2a). This Canadian Cardiovascular Society recommendation was supported by a recent cost-consequence analysis of VISION, which found that in patients undergoing non-cardiac surgery, conducting cTn screening in those that were aged ≥65 years, or those with a history of cardiovascular disease, was considerably more cost-effective than screening unselected patients aged ≥45 years [22]. While we generally support the recommendations from Puelacher et al., contrary to the algorithm (Figure 2a), we advocate that patients undergoing urgent or emergent surgery should be considered for PMI screening, but only if they are aged ≥50 years with cardiovascular risk factors or with established cardiovascular disease. Other important modifications that the expert group recommend to the Puelacher et al. algorithm are summarised in Table 1.

It is also important to state that the decision to screen a patient is ultimately at the discretion of the physician based on the presenting individual. The type of non-cardiac surgery that the patient is undergoing may also impact PMI prevalence and PMI aetiology, and would thus impact the clinicians decision of whether or not to screen the patient; however, future studies are needed to shed further light on this [23]. Identifying patients to be screened can be automated to some degree if well-established criteria for assessing automated screening results are implemented. Although some debate exists as to which medical discipline should be responsible for identifying patients and ordering screening, the decision should be based upon a combination of both automated screening and an assessment by a medical professional. This could be by an anaesthesiologist, for example, as they are involved in assessing patient safety during the operative and perioperative period. Surgeons are also well placed to identify patients for screening, due to their involvement in systematic post-operative review.

The screening programme

Once high-risk patients have been identified following preoperative assessment prior to non-cardiac surgery, the PMI screening pathway developed by Puelacher et al. recommends that clinicians should obtain pre- and postoperative hs-cTn measurements in these patients (Figure 2a) [20]. Preoperative cTn may provide information for risk stratification, but it is mainly necessary as a baseline value for perioperative myocardial injury screening. Indeed, the Fourth Universal Definition of Myocardial Infarction recommends postoperative cTn monitoring for high-risk individuals [9], which along with preoperative measurement, can help to differentiate between acute and chronic myocardial injury. However, comparison of acute and chronic myocardial injury during the perioperative period has shown a similar clinical impact on postoperative mortality [24]. Moreover, a systematic review reported that dynamic changes between cTn before and after non-cardiac surgery may be a predictor of postoperative cardiac events [25], a finding also reported in the BASEL-PMI study [10], although further studies are still needed to confirm this. When preoperative hs-cTn is available, in the primary and secondary care settings, we recommend hs-cTn measurements be taken on postoperative Day 1 and Day 2. However, in the tertiary care setting, we advocate that only one postoperative hs-cTn measurement is required during routine clinical practice on postoperative Day 1 (or Day 2 if not feasible) (Table 1), with back-referrals (to primary/secondary care) usual in this setting. Repeated measurements should only be performed in the event of hs-cTn elevation, as repeat testing in all patients is likely redundant and may have significant cost implications. The authors also favour the use of absolute rather than relative (%) delta hs-cTn for the diagnosis of PMI, as in the non-operative setting, the diagnostic accuracy of absolute changes are reportedly higher than relative changes for the detection of AMI [26].

Identifying PMI and MINS

The type of assay and cTn cut-offs used for PMI screening have differed between studies. While literature exists on the use of contemporary cTn assays for PMI screening [5,14,27–29], two landmark studies reported the diagnostic superiority of high-sensitivity cTn (hs-cTn) assays; early diagnosis of AMI and risk stratification were improved with hs-cTn assays versus contemporary assays [30,31]. Given

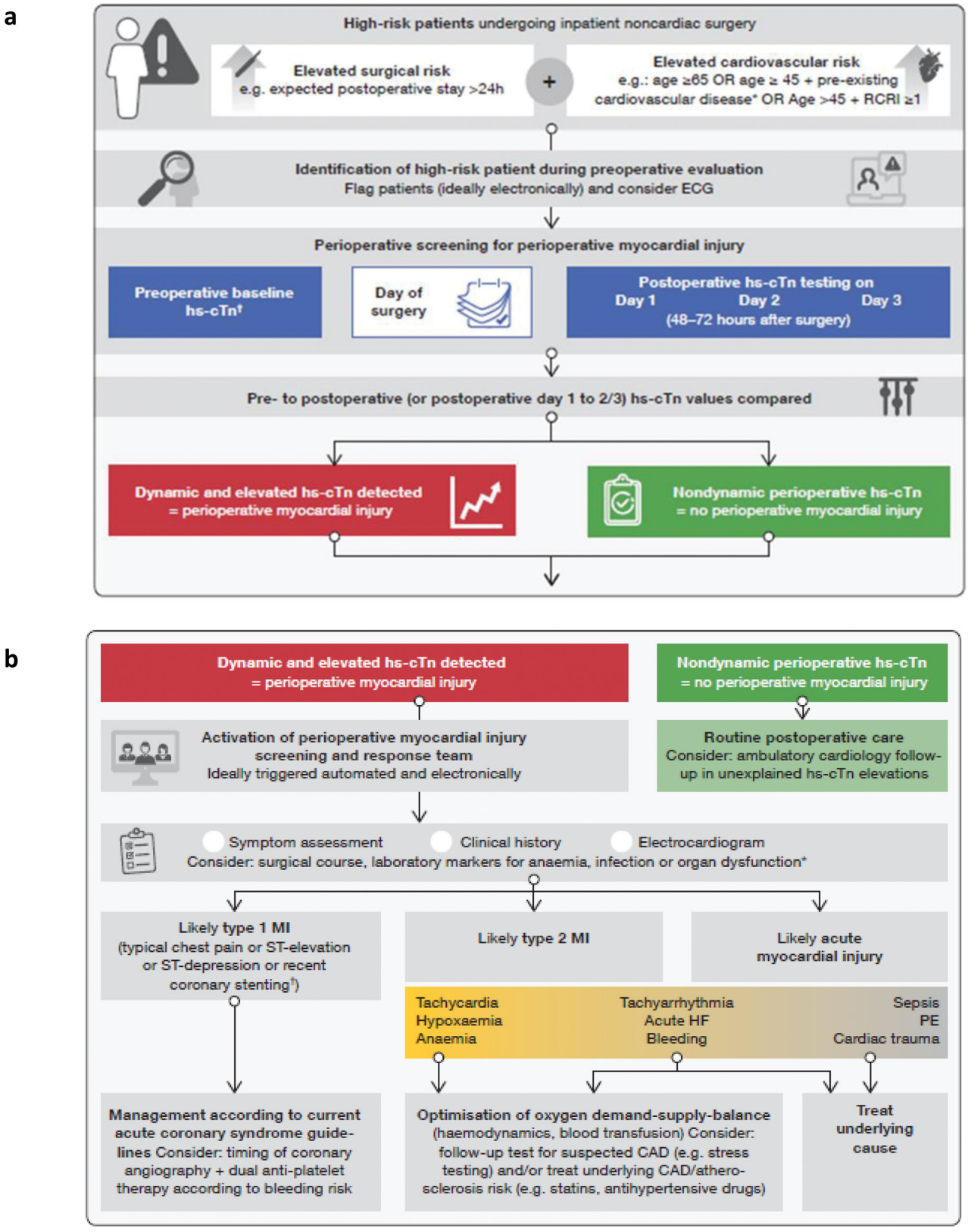

Figure 2. Example of a potential perioperative cTn screening and management pathway.

Footnote: Algorithm published in European Journal of Anaesthesia by Puelacher et al. [20]. (a) Details the perioperative screening pathway, including how to define high risk patients. (b) Depicts a perioperative management and care pathway.

*Known significant cardiovascular disease, such as coronary artery disease, cerebral vascular disease, peripheral arterial disease, congestive heart failure.

†Preoperative cTn may provide information for risk stratification, but it is mainly necessary as a baseline value for perioperative myocardial injury screening.

cTn: cardiac troponin; ECG: electrocardiogram; hs: high-sensitivity; RCRI: Revised Cardiac Risk Index

Table 1. Proposed changes to the Puelacher et al. [20] EJA algorithm recommendations by the expert panel.

Puelacher et al. EJA algorithm [20]	Proposed changes by the expert panel
High-risk patients undergoing non-cardiac surgery are defined as those aged ≥45 years with known significant cardiovascular disease (e.g. CAD, cerebral vascular disease, peripheral arterial disease or congestive heart failure); OR patients aged >45 years with a RCRI score ≥1; OR patients aged 18–64 years with significant cardiovascular disease who are scheduled for urgent/emergent or semi-urgent surgery; OR aged ≥65 years	Patients undergoing urgent or emergent surgery should be considered for PMI screening only if they are aged ≥50 years with cardiovascular risk factors or with established cardiovascular disease
Postoperative hs-cTn measurements should be taken on postoperative Day 1, Day 2 and Day 3 (48–72 h after surgery)	In primary and secondary care, hs-cTn measurements should be taken on postoperative Day 1 and Day 2 In tertiary care, only one postoperative hs-cTn measurement is required during routine clinical practice on postoperative Day 1 (or Day 2 if not feasible)

CAD: coronary artery disease; EJA: European Journal of Anaesthesia; hs-cTn: high-sensitivity cardiac troponin; PMI: perioperative myocardial injury; RCRI: Revised Cardiac Risk Index.

this evidence, guidelines express a clear preference for the use of hs-cTn assays [9,18], so we present here screening approaches using high-sensitivity assays only.

The BASEL-PMI study, documenting the local screening approach employed at University Hospital Basel, investigated the incidence of PMI in high-risk patients (aged ≥65 years, or aged ≥45 years with history of CAD, peripheral artery disease, or stroke) undergoing non-cardiac surgery, and due to have an inpatient stay >24 h post-surgery [10,12]. Hs-cTn screening was conducted preoperatively (within 30 days before surgery) and on postoperative days 1 and 2. PMI was diagnosed on detection of an absolute delta of the respective URL of the hs-cTn assay used (14 ng/L for hs-cTnT [Elecsys, Roche Diagnostics, Rotkreuz, Switerland] and 26 ng/L for hs-cTnI [ARCHITECT High Sensitive STAT Troponin I assay, Abbott Laboratories, Illinois, USA]) above preoperative concentrations (or between two postoperative concentrations if the preoperative value was missing). These values were selected as they represent the 99th percentile of healthy individuals, meaning all PMIs would fulfill the change and the absolute cTn criteria required for the diagnosis of spontaneous AMI [9,10,12]. The reported incidence rates of overall PMI were 15% with hs-cTnT and 9% with hs-cTnI, respectively [12].

The criteria for MINS were derived from a large observational study of 21,842 patients aged ≥45 years undergoing non-cardiac surgery with a postoperative inpatient stay of ≥24 h [11]. MINS was defined as postoperative hs-cTnT >20 ng/L combined with an absolute change of ≥5 ng/L, or postoperative hs-cTnT ≥65 ng/L. As the definition of MINS requires elevated hs-cTnT to be the result of ischaemic causes, non-ischaemic cardiac causes (e.g. non-ischaemic heart failure, pulmonary embolism, direct myocardial trauma, or pericarditis), and extra-cardiac causes (e.g. sepsis, pulmonary embolism, or severe renal failure), were excluded; tachyarrhythmia aetiology was also excluded. Another important distinction was that the VISION study measured postoperative hs-cTnT (6–12 h post-surgery and on postoperative days 1–3), and preoperative cTn measurements were not taken in all of the patients. The incidence rate of MINS was 17.9%, and a crude 30-day mortality of 4.1% was observed [11].

While BASEL-PMI and VISION provide compelling evidence for use of these cut-offs in clinical practice, several other studies have utilised different high-sensitivity assays and assay-specific cut-offs (e.g. ≥6 ng/L increase in hs-cTnT [Elecsys, Roche Diagnostics] and peak postoperative hs-cTnI ≥26 ng/L [ARCHITECT High Sensitive STAT Troponin I assay] for PMI and ≥60 ng/L [ARCHITECT High Sensitive STAT Troponin I assay] for MINS) [32–36]. It is not surprising that confusion exists as to which cut-offs should be used in clinical practice, given that a universal cut-off has not been defined. However, a one-size-fits-all cut-off would not be prudent due to lack of standardisation between assays manufacturers and variations in precision at the URL [37]. Moreover, age- and sex-specific cut-offs should be considered. Evidence suggests that men generally have higher cTn levels than women, and consequently disparities between men and women in diagnosis and management of myocardial injury are observed [9,38,39]. Circulating concentrations of cTn are also known to rise with increasing age [40,41]. While an increasing number of studies report a relevant diagnostic and prognostic benefit of age- and sex-specific cuts offs, many report that these cut-offs have only a minor influence [42,43]. A sub-analysis of TRAPID-AMI found that age-specific hs-cTnT cut-offs had a significant impact on diagnostic and prognostic reclassification in patients with suspected AMI, while the influence of gender specific cut-offs was only modest [44]. Given this ambiguity in the literature, more data are required to confirm the clinical utility of age- and sex-specific cut-offs.

Management

The importance of postoperative monitoring and management in high-risk patients should be stressed, as evidence suggests that the majority of PMI events are likely to occur in the first 48 h–72h post-surgery [9–11]. In their recent opinion paper, Puelacher and colleagues also developed a management pathway that we believe serves as a good basis for which healthcare professionals in Scandinavia could assess their patients following perioperative screening (Figure 2b) [20].

Both during surgery and in the postoperative period, various preventive measures can be taken to reduce the risk of PMI. First, the authors advocate blood pressure monitoring starting during surgery (and continuing into the post anesthesia care unit and postoperative period) in patients undergoing non-cardiac surgery, as evidence suggests that even short durations of intraoperative hypotension are

associated with myocardial injury [45,46] and 30-day mortality [47]. Therefore, treatment with intravenous vasoactive medication should be considered to ensure high-risk patients have a mean arterial pressure >60 mmHg at all times. In addition, the following preventive steps may also be beneficial; avoiding perioperative hypotension through stable induction, increased use of vasopressor, restrictive fluid therapy, and avoiding postoperative tachycardia. Despite these recommendations, it is important to note that randomised controlled trials (RCTs) are needed to determine whether PMI outcomes improve following these types of interventions. Importantly, recent studies highlight that high intraoperative blood pressure does not reduce adverse cardiovascular events after non-cardiac surgery [48,49]. Although less studied, postoperative hypertension has been identified is a risk marker for perioperative myocardial injury and morbidity [50,51].

Following surgery, it is essential that clinicians follow the guideline recommendations for patients thought to have type 1 myocardial infarction, tachyarrhythmia, AHF, sepsis or pulmonary embolism [52]. For other types of cardiac PMI, making recommendations for prescribing treatment remains difficult as limited evidence from RCTs exists, but there are some potential candidates. In POISE-1 patients who experienced a perioperative myocardial infarction, multivariable logistic regression analysis revealed that risk of 30-day mortality was lower among patients receiving acetylsalicylic acid (ASA) treatment (adjusted hazard ratio [aHR] 0.54; 95% CI 0.24–0.99) and those receiving statins (aHR 0.26; 95% CI 0.13–0.54) during the study [8]. In a large RCT of patients with CAD, patients with perioperative myocardial infarction had improved 30-day mortality when treated with long-term secondary prophylactic treatment (ASA, statins, beta-blockers or angiotensin-converting enzyme inhibitors) versus those without treatment intervention [53]. Furthermore, a recent study found that in patients recently discharged after a MINS diagnosis, those receiving statins had significantly lower 1-year and overall mortalities than those receiving no statins [54]. These results should be viewed with caution due to the observational nature of the studies; while statins are generally considered to be safe to administer in the postoperative period, particular attention has to be paid to ASA due to its risk of adverse bleeding events.

The most compelling evidence for PMI treatment in the postoperative setting comes from MANAGE, a RCT investigating dabigatran treatment in patients with MINS aged ≥45 years [55]. A total of 1,754 patients were randomised to dabigatran 110 mg bid or placebo within 35 days of non-cardiac surgery and a MINS diagnosis. Compared with placebo, patients randomised to dabigatran had reduced risk of a major vascular complication (11% vs 15%; HR 0.72; 95% CI 0.55–0.93; $p = 0.0115$), non-haemorrhagic stroke, peripheral arterial thrombosis, amputation, and symptomatic venous thromboembolism at 16 months (mean) follow-up [55]. Although major bleeding risk was not increased by treatment, some patients had increased risk of minor bleeding and lower gastrointestinal bleeding, but these were not clinically significant. Despite these promising results, the study was limited by a high drop-out rate (dabigatran prematurely discontinued in 46% of patients), and preoperative troponin measurements were not performed.

Imperatively, as evidence-based treatment recommendations are lacking, treatment should be tailored to the specific patient, taking into account their presentation and medical history. In summary, it is reasonable to recommend that treatment should be tailored to the aetiology of the PMI. Patients with extra-cardiac causes of PMI, such as sepsis or pulmonary embolism, should receive the guideline recommended therapy for these conditions. Patients with PMI due to arrhythmias or acute heart failure should also be treated accordingly. The remaining patients with a presumed ischaemic cause, which include all patients with MINS, may benefit from ASA, statins, additional cardiac testing, optimal management of cardiac risk factors and, in selected cases, dabigatran.

Responsibility

In the postoperative setting, while the anaesthesiologist should have responsibility for assessing the patient up to postoperative Day 1, cardiologist involvement at this stage would have significant benefit. Cardiologist consultation could detect otherwise undiagnosed complications and additional cTn elevations after postoperative Day 1. Indeed, it has recently been reported that in a study of MINS patients, those evaluated by a cardiologist had significantly lower mortality than those who were not [56]. Ultimately, the success of PMI screening programme depends on the collaboration of a multidisciplinary perioperative team, with the involvement of these disciplines agreed before a perioperative screening programme is initiated. In an ideal situation, an interdisciplinary team of nurses and physicians would draw upon the knowledge of various perioperative specialists, including anaesthesiologists, surgeons, cardiologists, intensive care specialists, internists, and experts from laboratory medicine. The notion of a dedicated perioperative department is gaining traction, as evidence in a survey of behaviours towards perioperative medicine in UK anaesthesiologists. While 64% of respondents considered themselves a 'perioperative doctor,' many described significant barriers to the development of perioperative medicine, including insufficient time and inadequate training [57]. At present, this ideal scenario with shared responsibility between multiple specialities may not be feasible in many institutions that have an already overstretched healthcare system. Increased governmental and health leadership focus on patient safety would support the implementation of perioperative screening and care programmes in high-risk patients.

Follow-up

It is our belief that specific PMI-related follow-up should be scheduled for patients considered to have cardiac PMI in

the acute phase, while those with PMI of other causes (e.g. sepsis, pulmonary embolism) should be treated for the underlying disease and transferred to primary healthcare. In patients with cardiac PMI, evidence suggests that preventable events such as hypotension and/or arrhythmias (tachycardia) occur in the first month after surgery, so scheduling follow-up within this period is paramount. Patients should be monitored in the acute phase, adjusting medications if appropriate, and outpatient coronary perfusion imaging and/or consultation with a cardiologist or internal medicine physician within 1-month post-surgery should be organised. There is currently limited information as to what patient follow-up after discharge should include, as it is still unclear if PMI is a sole cardiac problem or an indicator of a global hypoxemic event. As previously discussed, interdisciplinary collaboration to enable the best outcomes for patients would be preferable, and we encourage hospitals to put in place a dedicated perioperative team to be involved in patient follow-up.

Future direction and conclusions

Clinical practice in the field of PMI is currently limited by significant evidence gaps, and further research into the effectiveness of PMI screening in patients undergoing non-cardiac surgery is required to change practice. We advocate further risk reduction and cost effectiveness analyses, and suggest researchers conduct large RCTs in order to a) optimise perioperative handling of patients; and b) show the benefit of screening (pre- and postoperatively) by assessing outcomes before and after its implementation to avoid push-back from surgeons/anaesthesiologists/cardiologists against the additional work-up. We also propose development of a Scandinavian perioperative registry, based on the example that has been implemented in Sweden [58], to capture pre- and postoperative events and provide a comprehensive database from which a robust standard operative procedure for Scandinavian institutions could be based. Finally, we believe further studies on the interpretation of hs-cTn should be conducted to optimise assay performance and encourage consensus on both cut-offs used and diagnostic criteria for PMI.

In summary, while guidelines recommend perioperative screening in high-risk patients undergoing non-cardiac surgery, this has not yet been reflected in local clinical practice. Here we synthesise the current evidence and advocate the implementation of the perioperative screening algorithm developed by Puelacher and colleagues to improve patient outcomes in this setting. Further studies providing evidenced-based support of a PMI screening and care programme are imperative to shift the current attitudes of healthcare providers in favour of this approach.

Disclosure statement

All authors participated in an advisory board organised by Roche Diagnostics (chair: DA). DA has received honoraria from Amgen, AstraZeneca, Bayer, Boehringer-Ingelheim, BMS/Pfizer, MSD, Novartis, Roche-Diagnostics, Sanofi, and Vifor, outside the submitted work. He has also received grants to the institution from BMS/Pfizer, Roche-Diagnostics, and Medtronics, outside the submitted work. LAR has received honorarium as a member of a scientific advisory board from Ferring Pharmaceutical, Roche Diagnostics, and from an expert input meeting hosted by MDS, Norway. IJ reports research grants from the European Society of Anaesthesiology and Intensive Care (ESAIC) and Roche, speaker honoraria from Orion and is chair of the Perioperative Medicine and Management (PoMM) program from the Scandinavian Society of Anaesthesia and Intensive Care (SSAI). KMA has served on advisory boards for Roche Diagnostics and received personal fees from Siemens Healthineers. RW reports no conflicts of interest. MM reports no conflicts of interest. DMG reports grants from the Swiss Heart Foundation and consulting fees from Roche. TO has received speaker fees, consulting honoraria, and research funding *via* Akershus University Hospital from manufacturers of cardiac troponin assays (Roche Diagnostics, Abbott Diagnostics, Siemens Healthineers).

Funding

Editorial support was provided by Samantha Blakemore of inScience Communications, Springer Healthcare Ltd, Chester, UK, and was funded by Roche Diagnostics who initiated and sponsored the advisory board meeting where discussions on this topic were held. While Roche Diagnostics provided funding for the article, they were not involved in the development or review of the manuscript.

ORCID

Dan Atar http://orcid.org/0000-0003-1513-8793
Torbjørn Omland http://orcid.org/0000-0002-6452-0369

References

[1] Weiser TG, Haynes AB, Molina G, et al. Size and distribution of the global volume of surgery in 2012. Bull World Health Organ. 2016;94(3):201–209F.
[2] Weiser TG, Regenbogen SE, Thompson KD, et al. An estimation of the global volume of surgery: a modelling strategy based on available data. Lancet. 2008;372(9633):139–144.
[3] Sellers D, Srinivas C, Djaiani G. Cardiovascular complications after non-cardiac surgery. Anaesthesia. 2018;73(Suppl 1):34–42.
[4] Smilowitz NR, Gupta N, Ramakrishna H, et al. Perioperative major adverse cardiovascular and cerebrovascular events associated with noncardiac surgery. JAMA Cardiol. 2017;2(2):181–187.
[5] Devereaux PJ, Chan MT, Alonso-Coello P, et al. Association between postoperative troponin levels and 30-day mortality among patients undergoing noncardiac surgery. JAMA. 2012;307(21):2295–2304.
[6] Jawad M, Baigi A, Oldner A, et al. Swedish surgical outcomes study (SweSOS): an observational study on 30-day and 1-year mortality after surgery. Eur J Anaesthesiol. 2016;33(5):317–325.
[7] Aakre EK, Ulvik A, Hufthammer KO, et al. Mortality and complications after emergency laparotomy in patients above 80 years. Acta Anaesthesiol Scand. 2020;64(7):913–919.
[8] Devereaux PJ, Xavier D, Pogue J, et al. Characteristics and short-term prognosis of perioperative myocardial infarction in patients undergoing noncardiac surgery: a cohort study. Ann Intern Med. 2011;154(8):523–528.
[9] Thygesen K, Alpert JS, Jaffe AS, et al. Fourth universal definition of myocardial infarction. J Am Coll Cardiol. 2018;72(18):2231–2264.
[10] Puelacher C, Lurati Buse G, Seeberger D, et al. Perioperative myocardial injury after noncardiac surgery: incidence, mortality, and characterization. Circulation. 2018;137(12):1221–1232.

[11] Devereaux PJ, Biccard BM, Sigamani A, et al. Association of postoperative high-sensitivity troponin levels with myocardial injury and 30-Day mortality among patients undergoing noncardiac surgery. JAMA. 2017;317(16):1642–1651.
[12] Gualandro DM, Puelacher C, Lurati Buse G, et al. Incidence and outcomes of perioperative myocardial infarction/injury diagnosed by high-sensitivity cardiac troponin I. Clin Res Cardiol. 2021;110(9):1450–1463.
[13] Jammer I, Wickboldt N, Sander M, et al. Standards for definitions and use of outcome measures for clinical effectiveness research in perioperative medicine: European perioperative clinical outcome (EPCO) definitions: a statement from the ESA-ESICM joint taskforce on perioperative outcome measures. Eur J Anaesthesiol. 2015;32(2):88–105.
[14] Botto F, Alonso-Coello P, Chan MT, et al. Myocardial injury after noncardiac surgery: a large, international, prospective cohort study establishing diagnostic criteria, characteristics, predictors, and 30-day outcomes. Anesthesiology. 2014;120(3):564–578.
[15] Duceppe E, Parlow J, MacDonald P, et al. Canadian cardiovascular society guidelines on perioperative cardiac risk assessment and management for patients who undergo noncardiac surgery. Can J Cardiol. 2017;33(1):17–32.
[16] De Hert S, Staender S, Fritsch G, et al. Pre-operative evaluation of adults undergoing elective noncardiac surgery: updated guideline from the European Society of Anaesthesiology. Eur J Anaesthesiol. 2018;35(6):407–465.
[17] Kristensen SD, Knuuti J, Saraste A, et al. ESC/ESA guidelines on non-cardiac surgery: cardiovascular assessment and management: the joint task force on non-cardiac surgery: cardiovascular assessment and management of the European Society of Cardiology (ESC) and the European Society of Anaesthesiology (ESA). Eur Heart J. 2014;35(35):2383–2431.
[18] Gualandro DM, Yu PC, Caramelli B, et al. 3rd guideline for perioperative cardiovascular evaluation of the Brazilian society of cardiology. Arq Bras Cardiol. 2017;109(3 Supl 1):1–104.
[19] Szczeklik W, Fronczek J. Myocardial injury after noncardiac surgery – an update. Curr Opin Anaesthesiol. 2021;34(3):381–386.
[20] Puelacher C, Bollen Pinto B, Mills NL, et al. Expert consensus on peri-operative myocardial injury screening in noncardiac surgery: a literature review with expert consensus. Eur J Anaesthesiol. 2021;38(6):600–608.
[21] Borges FK, Devereaux PJ. Physicians should obtain perioperative cardiac troponin measurements in at-risk patients undergoing noncardiac surgery. Clin Chem. 2021;67(1):50–53.
[22] Buse GL, Manns B, Lamy A, et al. Troponin T monitoring to detect myocardial injury after noncardiac surgery: a cost-consequence analysis. Can J Surg. 2018;61(3):185–194.
[23] Zarinsefat A, Henke P. Update in preoperative risk assessment in vascular surgery patients. J Vasc Surg. 2015;62(2):499–509.
[24] Park J, Yang K, Lee SH, et al. Comparison of acute and chronic myocardial injury in noncardiac surgical patients. PLOS ONE. 2020;15(7):e0234776.
[25] Humble CAS, Huang S, Jammer I, et al. Prognostic performance of preoperative cardiac troponin and perioperative changes in cardiac troponin for the prediction of major adverse cardiac events and mortality in noncardiac surgery: a systematic review and meta-analysis. PLOS ONE. 2019;14(4):e0215094.
[26] Reichlin T, Irfan A, Twerenbold R, et al. Utility of absolute and relative changes in cardiac troponin concentrations in the early diagnosis of acute myocardial infarction. Circulation. 2011;124(2):136–145.
[27] Chong CP, Lam QT, Ryan JE, et al. Incidence of post-operative troponin I rises and 1-year mortality after emergency orthopaedic surgery in older patients. Age Ageing. 2008;38(2):168–174.
[28] Nagele P, Rao LK, Penta M, et al. Postoperative myocardial injury after major head and neck cancer surgery. Head Neck. 2011;33(8):1085–1091.
[29] van Waes JA, Nathoe HM, de Graaff JC, et al. Myocardial injury after noncardiac surgery and its association with short-term mortality. Circulation. 2013;127(23):2264–2271.
[30] Keller T, Zeller T, Peetz D, et al. Sensitive troponin I assay in early diagnosis of acute myocardial infarction. N Engl J Med. 2009;361(9):868–877.
[31] Reichlin T, Hochholzer W, Bassetti S, et al. Early diagnosis of myocardial infarction with sensitive cardiac troponin assays. N Engl J Med. 2009;361(9):858–867.
[32] Duceppe E, Patel A, Chan MTV, et al. Preoperative N-Terminal Pro-B-Type natriuretic peptide and cardiovascular events after noncardiac surgery: a cohort study. Ann Intern Med. 2020;172(2):96–104.
[33] Gillies MA, Shah AS, Mullenheim J, et al. Perioperative myocardial injury in patients receiving cardiac output-guided haemodynamic therapy: a substudy of the OPTIMISE trial. Br J Anaesth. 2015;115(2):227–233.
[34] Gillmann HJ, Meinders A, Grohennig A, et al. Perioperative levels and changes of high-sensitivity troponin T are associated with cardiovascular events in vascular surgery patients. Crit Care Med. 2014;42(6):1498–1506.
[35] Liem VGB, Hoeks SE, Grune F, et al. Prognostic value of postoperative high-sensitivity troponin T in patients with different stages of kidney disease undergoing noncardiac surgery. Br J Anaesth. 2018;120(1):84–93.
[36] Mol KHJM, Hoeks SE, Liem VGB, et al. Postoperative troponin release is associated with major adverse cardiovascular events in the first year after noncardiac surgery. Int J Cardiol. 2019;280:8–13.
[37] Ungerer JP, Tate JR, Pretorius CJ. Discordance with 3 cardiac troponin I and T assays: implications for the 99th percentile cutoff. Clin Chem. 2016;62(8):1106–1114.
[38] Mehta LS, Beckie TM, DeVon HA, et al. Acute myocardial infarction in women: a scientific statement from the American Heart Association. Circulation. 2016;133(9):916–947.
[39] Lee KK, Ferry AV, Anand A, et al. Sex-Specific thresholds of high-sensitivity troponin in patients with suspected acute coronary syndrome. J Am Coll Cardiol. 2019;74(16):2032–2043.
[40] Kuster N, Monnier K, Baptista G, et al. Estimation of age- and comorbidities-adjusted percentiles of high-sensitivity cardiac troponin T levels in the elderly. Clin Chem Lab Med. 2015;53(5):691–698.
[41] Eggers KM, Lind L, Venge P, et al. Factors influencing the 99th percentile of cardiac troponin I evaluated in community-dwelling individuals at 70 and 75 years of age. Clin Chem. 2013;59(7):1068–1073.
[42] Mueller-Hennessen M, Giannitsis E. Do we need to consider age and gender for accurate diagnosis of myocardial infarction? Diagnosis. 2016;3(4):175–181.
[43] Romiti GF, Cangemi R, Toriello F, et al. Sex-specific cut-offs for high-sensitivity cardiac troponin: is less more? Cardiovasc Ther. 2019;2019:9546931.
[44] Mueller-Hennessen M, Lindahl B, Giannitsis E, et al. Diagnostic and prognostic implications using age- and gender-specific cut-offs for high-sensitivity cardiac troponin T – Subanalysis from the TRAPID-AMI study. Int J Cardiol. 2016;209:26–33.
[45] Walsh M, Devereaux PJ, Garg AX, et al. Relationship between intraoperative mean arterial pressure and clinical outcomes after noncardiac surgery: toward an empirical definition of hypotension. Anesthesiology. 2013;119(3):507–515.
[46] Salmasi V, Maheshwari K, Yang D, et al. Relationship between intraoperative hypotension, defined by either reduction from baseline or absolute thresholds, and acute kidney and myocardial injury after noncardiac surgery: a retrospective cohort analysis. Anesthesiology. 2017;126(1):47–65.
[47] Monk TG, Bronsert MR, Henderson WG, et al. Association between intraoperative hypotension and hypertension and 30-day postoperative mortality in noncardiac surgery. Anesthesiology. 2015;123(2):307–319.

[48] Shimada T, Mascha EJ, Yang D, et al. Intra-operative hypertension and myocardial injury and/or mortality and acute kidney injury after noncardiac surgery: a retrospective cohort analysis. Eur J Anaesthesiol. 2022;39(4):315–323.
[49] Wanner PM, Wulff DU, Djurdjevic M, et al. Targeting higher intraoperative blood pressures does not reduce adverse cardiovascular events following noncardiac surgery. J Am Coll Cardiol. 2021;78(18):1753–1764.
[50] Liem VGB, Hoeks SE, Mol K, et al. Postoperative hypotension after noncardiac surgery and the association with myocardial injury. Anesthesiology. 2020;133(3):510–522.
[51] Sessler DI, Meyhoff CS, Zimmerman NM, et al. Period-dependent associations between hypotension during and for four days after noncardiac surgery and a composite of myocardial infarction and death: a substudy of the POISE-2 trial. Anesthesiology. 2018;128(2):317–327.
[52] Puelacher C, Gualandro DM, Lurati Buse G, et al. Etiology of peri-operative myocardial infarction/injury after noncardiac surgery and associated outcome. J Am Coll Cardiol. 2020;76(16):1910–1912.
[53] Gualandro DM, Campos CA, Calderaro D, et al. Coronary plaque rupture in patients with myocardial infarction after noncardiac surgery: frequent and dangerous. Atherosclerosis. 2012;222(1):191–195.
[54] Park J, Kim J, Lee SH, et al. Postoperative statin treatment may be associated with improved mortality in patients with myocardial injury after noncardiac surgery. Sci Rep. 2020;10(1):11616.
[55] Devereaux PJ, Duceppe E, Guyatt G, et al. Dabigatran in patients with myocardial injury after non-cardiac surgery (MANAGE): an international, randomised, placebo-controlled trial. Lancet. 2018;391(10137):2325–2334.
[56] Park J, Oh AR, Lee S-H. Association between cardiologist evaluation and mortality in myocardial injury after non-cardiac surgery. Heart. 2022;108(2):155–155.
[57] Partridge JSL, Rogerson A, Joughin AL, et al. The emerging specialty of perioperative medicine: a UK survey of the attitudes and behaviours of anaesthetists. Perioper Med. 2020;9:3.
[58] Chew MS, Mangelus C, Enlund G, et al. Surgery was successful–but how did it go for the patient? Experiences from and hopes for the Swedish perioperative register. Eur J Anaesthesiol. 2015;32(7):453–454.