Postoperative Troponin Screening
A Cardiac Cassandra?

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The cardiovascular management of the patient undergoing noncardiac surgery has been in evolution for the last 35 years. Over this time frame, 2 secular trends have advanced in parallel but provided contrary practice implications for the care of the surgical patient. First, cardiovascular event rates have been dropping significantly over time. In 1977, Goldman et al.1 created a risk evaluation system that predicted a 22% rate of life-threatening cardiovascular events and >50% mortality in the highest-risk group in 1001 patients undergoing surgery. These rates of events have dropped significantly each decade since. Finks et al2 reported 2 years ago a mere 2.8% national mortality rate for open abdominal aortic aneurysm repair, the exemplar of routine, high-risk surgery. These numbers were recapitulated worldwide for high-risk patients undergoing noncardiac surgery in the Perioperative Ischemic Evaluation (POISE) trial.3 Improvements in surgical and anesthetic techniques, perioperative medical therapy, and intensive care have contributed to the significant improvement in outcomes.

Second, the sensitivity of testing to detect evidence of cardiovascular disease or ischemia has increased dramatically. In this same time frame, risk assessment has evolved from stress testing to nuclear-vasodilator testing, inotropic echocardiographic assessment, cardiac magnetic resonance imaging, and positron emission tomographic scanning. Counterintuitively, the ability to accurately detect smaller and smaller amounts of disease has not improved postoperative cardiovascular event prognostication. Indeed, the positive predictive value for each of these modalities in predicting a cardiovascular event remains <20%.4 The poor performance may be attributed to 2 components. First, improvements in disease detection foster inclusion of patients previously deemed healthy by less sensitive modalities. Indeed, it is the specific coronary heart disease detection improvement that undermines its prognostic value in the stable patient by diminishing the risk of the group with a positive study. Second, ever-dropping event rates largely render the prognostic value of these tests moot. A 3-fold hazard ratio in the setting of a 1% to 3% surgical mortality provides little insight into patient selection for higher-level therapies beyond medical therapy. Because of the overall low mortality and the limited value of noninvasive testing to clarify outcome and need for preoperative coronary artery revascularization,5 there has been an increase in efforts to find patients at heightened risk postoperatively to stave off severe adverse events. Over the last decade, much of this effort has focused on biomarkers of myocardial injury, the cardiac troponins.

The troponin complex is colocated with tropomyosin on the actin filament and participates in cardiac muscle contraction. The complex consists of 3 peptide components, T, I, and C. The first 2 components have been used in the measurement of myocardial injury, whereas troponin C, the calcium binding site, is not used because of its shared location in skeletal muscle. Measurement of troponin T was approved by the Food and Drug Administration in 1996, and its uptake into medical practice was rapid. Just 4 years later, the cardiology community made troponin the preferred biomarker to diagnose myocardial infarction6 as part of the guideline process. By 2007, troponin measurement became the de facto global standard when the first universal definition of myocardial infarction was published.7 Over the last decade, the use of troponin has skyrocketed beyond the limited use for determining the presence or absence of an acute coronary syndrome, and troponin has become a nonspecific marker of illness. Indeed, the value of troponin in the diagnosis of myocardial infarction may have reached its apex in 2001 with the publication of the Treat Angina With Aggrastat and Determine Cost of Therapy With An Invasive or Conservative Strategy (TACTICS) study. The investigators showed that early invasive therapy was superior to a conservative approach in patients presenting to the hospital with chest pain with a troponin T of >0.01 ng/mL but not without this troponin T elevation.8 This led to the wide adoption of troponin in the standard evaluation of patients with chest pain or thought to be at risk of myocardial infarction. Subsequently, troponin has been measured in a wide variety of settings to provide prognostic information in diseases that do not originate in the coronary arteries. Prognostic information has been generated for diseases that originate with the heart, affect the heart, are remote from the heart and has extended to patients who are not acutely ill. Elevations in troponin are associated with worse outcomes in patients with myocarditis,9 congestive heart failure,10,11 and cardiac contusions,12 showing the value of this biomarker in a broad range of cardiac disease. Troponin release provides significant prognostic information for pulmonary disease, presumably because of its direct vascular coupling with the right ventricle. For example, many studies have shown that troponin release during pulmonary embolism is a marker of severity and adverse prognosis.13-15 Similarly, elevations in troponin during chronic obstructive
pulmonary disease exacerbation are associated with a greater need for ventilator support and worse long-term survival.\textsuperscript{16} The release of troponin is thought to result from a direct increase in right ventricular overload and strain in the right side of the heart.

Perhaps more impressively, release of cardiac troponin has become sensitive enough to act as a barometer of the severity of illness unrelated to the heart. Patients with septicemia who have measurable troponin levels experience worse outcomes than those who do not, even after adjustment for other prognostic markers.\textsuperscript{17} Similarly, the release of troponin predicts poorer outcomes in patients admitted with subarachnoid hemorrhage.\textsuperscript{18–20} More recently, investigators have shown that troponin release may occur in the absence of overt illness and provide prognostic data for outcomes in the nonhospitalized person. Using a high-sensitivity troponin T assay, investigators in the Dallas Heart Study have shown that among 3546 individuals aged 30 to 65 years enrolled between 2000 and 2002, 25\% of the cohort had detectable troponin T.\textsuperscript{21} Moreover, when the troponin level was >0.0014 ng/mL, the hazard ratio for all-cause death over the 6.4 years of follow-up was nearly 5-fold higher despite adjustment for age, race/ethnicity, sex, diabetes mellitus, hypertension, hypercholesterolemia, low high-density lipoprotein cholesterol level, current smoking, log-transformed values of high-sensitivity C-reactive protein, and chronic kidney disease categories. Moreover, the troponin elevation across the range predicted all-cause mortality and cardiovascular mortality similarly. And therein lies the problem. Although certainly originating in the heart, when used to provide prognostic data beyond cardiac-in-origin diseases, troponin elevation no longer provides cardiovascular outcome-specific information. It becomes a nonspecific test of illness that requires interpretation by setting. Indeed, the screening measurement of troponin postoperatively most resembles the use of troponin in the Dallas Heart Study as a screening tool.

van Waes et al\textsuperscript{22} are to be commended for reporting in this issue of \textit{Circulation} the largest single-center study of postoperative troponins yet published. The investigators studied 2232 consecutive intermediate- to high-risk noncardiac surgery patients >60 years of age who underwent surgery in 2011. In the total surgical population, all-cause mortality was 3\%, troponin T release was detected in 19\%, and elevations predicted death in a dose-related manner, consistent with past work. Also consistent with past work and similar to the Dallas Heart Study was a stronger association with all-cause mortality than myocardial infarction. In this cohort, myocardial infarction (based on the universal definition) was diagnosed in 10 subjects or 0.6\% of the total.

Other studies have demonstrated both a similar relationship between troponin elevation and mortality after surgery and the relative infrequency of myocardial infarction by the universal definition in this setting.\textsuperscript{23} However, it is the Vascular Events in Noncardiac Surgery Patients Cohort Evaluation (VISION) Study that puts the whole picture in perspective.\textsuperscript{24} The VISION investigators measured troponin T levels 6 to 12 hours after surgery and on days 1, 2, and 3 after surgery in 15133 patients aged >45 years who required at least a 1-night stay in the hospital. Overall, the 30-day mortality rate was 1.9\%, and troponin T was measurable in 11.6\% of the patients.

Across a narrow range of troponin T elevation, the hazard for mortality rose quickly, with a 10-fold mortality risk noted in patients with troponin elevations ≥0.30 ng/mL. Despite the fact that the vascular death category included nontraditional elements like pulmonary embolism, hemorrhage, and death resulting from unknown causes, the number of vascular deaths remained smaller than the number of nonvascular deaths. The VISION investigators reported that increases in troponin T predicted cardiovascular and nonvascular death equivalently. Thus, postoperative troponin elevation has become a nonspecific marker of hazard.

In my opinion, practitioners underappreciate this lack of specificity of postoperative troponin testing. For example, the authors of the third universal definition of myocardial infarction\textsuperscript{25} recommend “routine monitoring of cardiac biomarkers in high-risk patients, both prior to and 48 to 72 h after major surgery” because “most patients who have a perioperative MI [myocardial infarction] will not experience ischemic symptoms. Nevertheless, asymptomatic perioperative MI is as strongly associated with 30-day mortality, as is symptomatic MI.” They then go on to recommend close clinical scrutiny but without any specific recommendation for care. I favor an approach to testing as advocated by Laine\textsuperscript{26} in posing certain questions before ordering a test. First, will the test change the care of my patient? In the asymptomatic patient without ECG changes, a troponin elevation does not predict any specific kind of death; thus, the test provides no direction for care, and clinicians should continue to treat patients individually. Second, what are the probability and potential adverse consequences of a false-positive result? For this, I would refer to the vanishingly small number of type 1 myocardial infarctions diagnosed and worry that management for plaque rupture events (antiplatelet therapy, anticoagulation, and possibly catheterization) would be provided for patients with hemodynamic (type 2 myocardial infarction) events. None of these interventions is likely beneficial for the vast majority of patients, particularly early after major surgery when troponin is likely to be elevated. As noted by van Waes and the VISION investigators, the majority of troponin T release occurs by the end of postoperative day 1, a high-risk period for bleeding. Third, is the patient in potential danger over the short term if I do not perform this test? Although it is certainly true that an elevation in troponin portends adverse outcome, the lack of specificity concerning the mechanism of adverse outcome suggests that the test will not foster a change in or modification of therapy. In a small study of patients aged >60 years undergoing emergency orthopedic surgery, the addition of cardiovascular care to troponin-positive patients did not affect in-hospital cardiovascular complications or 1-year mortality.\textsuperscript{27} Most telling, however, is that the cardiologists did little to alter care. No coronary angiography was performed, and only 1 in 6 patients seen by cardiologists had the addition of aspirin, β-blockers, or both.

It is my opinion that improvements in troponin T assay sensitivity have created a condition in which the biomarker is so easily measured that it now calls out patients at higher risk for any adverse event more than diagnoses cardiaspecific events. Indeed, one may suggest that the results are similar to the Dallas Heart Study, but instead of free-living individuals, the perioperative patient population represents...
an asymptomatic group exposed to surgical stress, and the elevation in troponin similarly indicates a high-risk group for all-cause death. In the absence of any demonstrated beneficial treatment strategy, the possibility of harm in applying the standard treatment for type 1 myocardial infarction, and the potential to divert attention from a true cause of adverse event (nonvascular morbidity) to a false one (myocardial infarction), I believe that routine measurement of troponin is more likely to cause harm than to provide benefit and should not be used as a screening modality.

Currently, low rates of overall perioperative mortality in the setting of guidelines-based care have made risk prediction difficult and largely limited the task of risk assessment to ferreting out patients with active cardiac conditions, severe pulmonary disease, or severe underlying medical illness. These factors may or may not be related to the features seemingly most predictive of troponin release such as intraoperative hypotension, preoperative hypertension, and the presence of atherosclerosis. Studies are ongoing to determine response strategies to elevations of troponin postoperatively, but until a specific strategy or treatment is identified, the ontogeny of troponin testing makes it unlikely that patients will benefit from its routine measurement after noncardiac surgery.

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References

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