Prevention of periprocedural myocardial infarction (MI) has been the target of substantial research effort.\textsuperscript{1,2} Even routine, elective, uncomplicated percutaneous coronary intervention (PCI) has been demonstrated to produce embolization.\textsuperscript{3} The greater the patient acuity is, such as with ST-segment elevation myocardial infarction, the larger is the degree of embolization and the more apparent the clinical consequences. Although the exact threshold of PCI-related myonecrosis that is clinically relevant remains a matter of debate, few would challenge the central concept that myonecrosis is best avoided if possible.\textsuperscript{1,2}

Detection of periprocedural MI rests largely on the use of creatine kinase myocardial isoenzyme (CK-MB) measurement. The problem with this approach is that by the time the myonecrosis is detected, the proverbial horse is out of the barn. Troponin measurements are more sensitive though less validated in this setting and still give information regarding myonecrosis only after the fact, though, at least in some study populations, have been shown to provide incremental information.\textsuperscript{4} Newer imaging modalities such as cardiac magnetic resonance imaging are able to detect microinfarctions,\textsuperscript{5} though, once more, the diagnosis is being made after the damage is done.

Biomarkers, particularly those associated with inflammation, also seem to predict subsequent myonecrosis.\textsuperscript{6} Diminished response to antiplatelet therapy has also been linked to increased degrees of post-PCI myonecrosis, including in elective PCI.\textsuperscript{7–9} Although heightened inflammatory status or relative antiplatelet resistance may predispose to plaque embolization and subsequent platelet aggregatory response during PCI, other procedural factors that predispose to embolization such as plaque burden caused by lesion length and severity or that predispose to ischemia such as prolonged balloon inflation time would not be expected to be fully factored in by any combination of preprocedural tests.

In this issue of \textit{Circulation}, Balian and colleagues\textsuperscript{10} describe a technique for predicting periprocedural myocardial injury much earlier than previously possible. By connecting the proximal end of a standard coronary guide wire to a multichannel ECG recorder and obtaining tracings before and after PCI, the authors were able to determine the degree of ST-segment elevation or depression compared with baseline—the intracoronary ST-segment shift. This technique is far more sensitive than surface ECG recordings. Intracoronary ST-segment shift is not a new concept; the technology has been studied previously, is easy to use, and is inexpensive.\textsuperscript{11} The authors found that those patients who had a significant ST-segment shift of at least 1 mm were more likely to have myonecrosis, as measured either by troponin or CK-MB. In fact, intracoronary ST-segment shift after PCI was the only independent predictor of periprocedural MI, with an odds ratio of $>50$. Furthermore, patients with ST-segment shift had a trend ($P=0.06$) toward a greater number of hard clinical events, though in this elective PCI population of 114 patients, the number of events was expectedly quite low, limiting the statistical power of an examination of the most relevant clinical outcomes. Nevertheless, 4 of 5 of the occurrences of fatal or nonfatal MI were in those patients who had an ST-segment shift of at least 1 mm.

This finding creates the very exciting possibility of altering therapy to mitigate the ultimate impact of any clinically silent periprocedural event detected by ST-segment shift. Because more than one third of patients had ST-segment shifts in this study of elective PCI, however, this test may not ideally discriminate between the patients at highest and lowest risk of complications because many patients who will not ultimately have clinical events might still be identified as higher risk. An additional caveat to the interpretation of this study other than the small sample size is the possibility that intracoronary ST-segment shift is an epiphenomenon and is associated with worse clinical outcomes for some other reason that portends unfavorable clinical outcome and is not truly causative—the same argument that has been made against any causative role of periprocedural CK-MB increase. For example, if ST-segment shift occurs as the result of microcirculatory dysfunction, it may be this underlying dysfunction or associated conditions that predispose to the future clinical event. Still, if the majority of patients with clinical events have an abnormal intracoronary electrogram for whatever reason, this could be potentially valuable as a risk stratification tool.

An obvious potential use for this type of information would be subsequent allocation of potent pharmacotherapy on a “bail-out” basis to patients with abnormal intracoronary ECG recordings.\textsuperscript{12} This approach would have the potential to limit bleeding complications and costs associated with agents such as glycoprotein IIb/IIIa inhibitors that are now less often used prophylactically for routine, elective PCI but may have specific use in patients who have demonstrated significant

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The opinions expressed in this article are not necessarily those of the editors or of the American Heart Association.

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intra coronary ST-segment shift. Drugs that vasodilate or limit myocardial oxygen demand given either systemically or through intracoronary injection may also serve to limit myocardial damage in the patient who displays shifts in the intracoronary ECG. Future antiinflammatory drugs may also have a role in patients identified as having significant ST-segment changes.

Clinically, lack of ST-segment shift may identify an extremely low-risk cohort after elective PCI. In the study by Balian et al, of the patients without ST-segment shift, only 1 had a nonfatal MI. This may be a population that would be most appropriate to consider same-day discharge after low-risk elective PCI, assuming there were no concerning issues with arterial site access. This strategy of early discharge would need to be tested prospectively, but it holds the potential to improve catheterization laboratory throughput, enhance patient satisfaction, and decrease healthcare costs.

Although the study by Balian et al involved patients with elective PCI, this technology could be applied in other settings, such as acute coronary syndromes, including ST-segment elevation MI. For example, in a patient with an occluded artery, resolution of intracoronary ST-segment changes might predict reperfusion success. Indeed, if validated by future study, such an approach may once again rekindle excitement in the study of reperfusion injury and agents to limit such damage. In another small study, Balian and colleagues demonstrated that intracoronary ST-segment resolution of at least 50% predicted significantly higher left ventricular ejection fraction and improved wall motion 6 months after primary PCI. In patients with prior MI undergoing PCI, intracoronary electrograms have also been shown to correlate well with assessments of myocardial viability by low-dose dobutamine echocardiography. Older studies had examined the value of intracoronary electrograms in establishing the existence and mechanisms behind ischemic preconditioning.

Surprisingly, embolic protection devices (EPDs) studied to date have not been demonstrated to have a beneficial impact in PCI of acute MI. Potentially, evaluation of future embolic protection devices before phase 3 studies could first determine their impact on ST-segment shift. For example, using a standard wire connected to the ECG recorder, an EPD could be passed down the artery, and the degree of ST-segment shift that occurs could be monitored. A bulky EPD of the sort that has been evaluated thus far in the coronary circulation may lead to a nontrivial degree of embolization with initial wire passage, and this may overwhelm the benefit that may have been realized from subsequent capture of embolic material by the EPD. Newer-generation, low-profile EPDs may not have these limitations, but an objective comparison could be made by using intracoronary ECG tracings.

Therefore, both for the real-time evaluation of interventional devices and pharmacotherapy, intracoronary ST-segment shift may allow a refined estimate of success before proceeding with definitive phase 3 testing. In a manner akin to how intravascular ultrasound is currently being used to assess the effect of antiatherosclerotic compounds on plaque progression in phase 2 trials, intracoronary ST-segment shift could be incorporated into trials of EPDs and antithrombotic and antiinflammatory agents given before or at the time of PCI. Devices or compounds with minimal beneficial effect on ST-segment shift could be abandoned early in their development, and promising therapies could move on to phase 3 testing to ensure safety and positive impact on clinical events. From a clinical trialist’s perspective, this may be the most appealing niche for intracoronary ST-segment measurement.

It is hoped that the study by Balian et al will encourage further investigation of this inexpensive and easy technique. The amount of incremental work and time that it might add to the procedure would be minimal, even in a busy catheterization laboratory environment. If future studies validate intracoronary ST-segment shift as an early marker of myocardial infarction and of subsequent clinically important events, it will have succeeded in shifting the diagnosis of periprocedural MI to a time point when we can do something about it that actually matters in terms of improving patient outcomes.

Disclosures

Dr Bhatt has served on advisory boards and previously received honoraria from Astra Zeneca, Bristol Myers Squibb, Centocor, Eisai, Eli Lilly, Glaxo Smith Kline, Millennium, Paringenix, PDL, Sanofi Aventis, Schering Plough, and The Medicines Company and has previously served on the speaker’s bureau for Bristol Myers Squibb, Sanofi Aventis, and The Medicines Company.

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