T-segment elevation myocardial infarction (STEMI) has the highest mortality rate of all of the acute coronary syndromes. Because acute thrombosis is central to STEMI pathogenesis, treatment modalities have focused on rapid resolution of the obstruction, either by pharmacological or mechanical means. This article reviews the current status of thrombus aspiration (TA) as part of a mechanical reperfusion strategy.

RATIONALE FOR USING TA TO TREAT STEMI

Immediate or “primary” percutaneous coronary intervention (PCI) is a central treatment for STEMI.1-3 When PCI is performed, it may be expected that the less-adherent elements of the obstructive lesion may embolize downstream (Figure 1). Thus, although the epicardial vessel may appear to be angiographically acceptable, the embolized material may prevent satisfactory nutritive flow to areas of the myocardium. It has previously been shown that despite restoring epicardial vessel patency, PCI may achieve optimal myocardial perfusion (based on myocardial blush grade [MBG]) in only one-third of cases.4 Furthermore, it has been demonstrated that patients with TIMI grade 3 flow and suboptimal myocardial perfusion (MBG < 3) have worse clinical outcomes, including a larger amount of irreversible myocardial injury, a higher incidence of adverse left ventricular remodeling leading to heart failure, and consequently increased early and late mortality.5 Thus, preventing microembolization may improve outcomes secondary to decreasing the extent of myocardial injury. This concept provides the rationale for TA prior to definitive vessel recanalization.

In some instances, TA alone yields excellent angiographic results, with little or no residual lesions. TA alone may be particularly beneficial in instances when STEMI is related to embolism, hypercoagulable states, endothelial dysfunction, and plaque erosion. Furthermore, in such instances when TA alone yields satisfactory angiographic results, balloon angioplasty and stenting may be avoided and obviate the need for long-term dual-antiplatelet therapy. Escaned et al recently demonstrated the safety and efficacy of such an approach in selected patients.6

CLINICAL EVIDENCE

TA can be performed by simple manual aspiration using specially designed catheters or by mechanical aspiration (AngioJet, Bayer HealthCare, Indianola, PA). Murakami et al were among the first to demonstrate that TA could be safely performed in STEMI patients using a probing intracoronary catheter.7 With the currently available TA catheters, intracoronary aspirations are frequent during STEMI (Figure 1), even if there is no obvious thrombus on angiography.8 As one might expect, aspiration analyses predominantly show clots, but other plaque debris elements have also been found.9
The clinical value of manual TA has been assessed in several randomized clinical trials (RCTs); however, there are conflicting results regarding the value of TA in relation to clinical outcomes. The largest RCT (n = 1,071) with the longest follow-up (up to 1 year) was the TAPAS trial, which is considered a landmark trial for TA. TAPAS showed both short- and long-term benefits in “hard” and “soft” event endpoints with use of the Export aspiration catheter (Medtronic, Inc., Minneapolis, MN) before stenting. TA resulted in a higher MBG (46% vs 32%; \( P < .001 \)), a higher proportion of ST-segment resolution (\( P < .001 \)), and fewer pathological Q waves (\( P = .001 \)). These benefits also translated into improved clinical outcomes, including lower rates of mortality, reinfarction, and major adverse cardiac events (MACE) at 1 year. The TAPAS trial had the limitations of being performed at a single center and being underpowered to study mortality.

Noman et al recently reported “real-world” results in an observational study in which 1,095 of 2,567 STEMI patients underwent manual TA before PCI. They reported significant reductions in all-cause in-hospital mortality and 1-year mortality, as well as improved TIMI grade 3 flow as compared with patients who underwent PCI with no TA.23

The recently published INFUSE-AMI randomized trial failed to demonstrate a benefit either on infarct size, as measured by cardiac MRI at 30 days, or MACE at 30 days between the TA and no TA groups.21 It is important to note that more than 20% of patients had nonevaluable cardiac magnetic resonance studies.

Several meta-analyses of RCTs have evaluated clinical outcomes with TA. Sobieraj et al analyzed 17 RCTs and concluded that TA using manual devices decreased the risk of “hard” endpoints of MACE by 27% versus PCI alone.24 TA also significantly improved the “soft” endpoints of ST-segment resolution (+49%), MBG = 3 (+39%), TIMI grade 3 flow (+8%), distal embolization (-44%), no reflow (-48%), and coronary dissection (-70%) versus PCI alone. The other three meta-analyses reached similar conclusions.25-27 In the most recent meta-analysis of 25 trials comprising 5,534 patients, including the INFUSE-AMI trial, Kumbhani et al demonstrated that manual TA was associated with a 24% relative risk reduction of MACE and a 29% relative risk reduction in mortality at a median follow-up of 6 months.28

MECHANICAL THROMBECTOMY

There are very few data, particularly in RCTs, that any motor-driven mechanical aspiration device improves clinical outcomes. In fact, RCTs using mechanical thrombectomy systems have suggested worse outcomes. There have been seven trials comprising 1,598 patients comparing mechanical thrombectomy during primary PCI to conventional PCI, the largest two being the AIMI and JETSTENT trials.28-30 A meta-analysis of all of these studies showed no difference in MBG, final infarct size, or ejection fraction.28 The incidence of ST-segment resolution was higher with mechanical thrombectomy compared to conventional PCI alone (75% vs 64%; \( P = .007 \)); however, there was significant heterogeneity among the studies for this endpoint. There was no difference noted in the incidence of MACE or mortality; however, there was a strong trend toward an increased stroke risk with mechanical thrombectomy (1.3% vs 0.4%; risk ratio, 2.74; \( P = .07 \)).28

TREAT-MI trial is the only head-to-head comparison of manual aspiration (with the Export catheter) versus mechanical thrombectomy (with the X-Sizer system, formerly manufactured by ev3 Inc., Plymouth, MN) evaluat-
ing acute efficacy and long-term clinical outcomes in 201 patients. Manual thrombus aspiration was associated with a higher success rate and greater ST resolution, but the long-term outcomes were similar. Although routine mechanical thrombectomy cannot be recommended, it may have a role in selected cases in which there is a large thrombus burden that cannot be cleared by manual TA alone.

**OTHER MODALITIES TO PREVENT NOREFLOW**

The concept of preventing distal embolization using embolic protection devices seems attractive but has failed to yield any superior outcomes compared to conventional PCI in multiple RCTs and meta-analyses. A novel polyethylene terephthalate micronet mesh-covered bare-metal stent (MGuard, InspireMD, Inc., Tel Aviv, Israel) has been designed to trap and hence prevent distal embolization of thrombus, and the associated debris has recently been tested in an RCT (MASTER trial). The primary endpoint of the trial was percentage ST resolution, which was achieved in a higher proportion of patients who were randomized to the MGuard stent. There was no difference in cardiac magnetic resonance indices of myocardial damage nor MACE events at 30-day follow-up between the MGuard stent and the conventional stenting arms. Of note, the MGuard stent was unable to reach or cross the lesion in nine of 217 patients (4.1%), and there were two cases of MGuard stent embolization. The current design of this stent is bulky, with very specific lesion subsets in which it can be used. Future well-powered RCTs assessing hard endpoints are required to define a specific role (or not) for this stent in the percutaneous approach to STEMI.

Nonrandomized studies suggested a potential benefit to intracoronary abciximab in improving outcomes. The Infuse AMI study suggested somewhat smaller infarct size by MR imaging, but the results cannot be considered definitive, as more studies are required to determine the value of this strategy.

**CURRENT GUIDELINES FOR TA**

The 2011 ACCF/AHA/SCAI PCI, 2013 ACCF/AHA STEMI, and 2012 ESC STEMI guidelines have concluded that manual TA is reasonable for patients undergoing primary PCI (class IIa). The American STEMI guidelines specifically recommend manual TA only as a class IIa indication. The other two guidelines recommend “thrombus aspiration,” but the text of both docu-
ments imply that manual TA specifically, as opposed to mechanical thrombectomy, should be used.

**FUTURE STUDIES**

There are two ongoing RCTs that address the long-term clinical outcomes of manual TA with PCI versus PCI alone. The TOTAL trial will enroll 4,000 patients with the endpoints of cardiovascular death, recurrent myocardial infarction, cardiogenic shock, or new or worsening New York Heart Association Class IV heart failure at 180 days. The TASTE trial is a multicenter, prospective, randomized, controlled, open-label, 5,000-patient study embedded in the Swedish Coronary Angiography and Angioplasty Registry platform, with blinded evaluation of the primary endpoint of 30-day all-cause mortality.

**CONCLUSION**

Manual TA has evolved as an adjunctive therapy during mechanical reperfusion of an infarct-related artery. A TA strategy before PCI, regardless of visible angiographic thrombus, should be considered because it results in improved “soft” endpoints, including microvascular perfusion. Definitive evidence on the value of TA on “hard” endpoints, including mortality, awaits the completion of future studies.

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