Published in final edited form as:

Coron Artery Dis. 2016 June ; 27(4): 319–326. doi:10.1097/MCA.0000000000000364.

Indications, algorithms, and outcomes for coronary artery bypass surgery in patients with acute coronary syndromes

Babatunde A. Yerokun^{a,b}, Judson B. Williams^{a,b}, Jeffrey Gaca^b, Peter K. Smith^b, and Matthew T. Roe^{a,c}

^aDuke Clinical Research Institute, Duke University Medical Center, Durham, North Carolina, USA

^bDepartment of Surgery, Division of Cardiovascular and Thoracic Surgery, Duke University Medical Center, Durham, North Carolina, USA

^cDepartment of Medicine, Division of Cardiology, Duke University Medical Center, Durham, North Carolina, USA

Abstract

For patients with a non-ST-segment elevation acute coronary syndrome (NSTEMI-ACS), guideline recommendations and treatment pathways focus on revascularization for definitive treatment if the patient is an appropriate candidate. Despite the widespread use of revascularization for NSTEMI-ACS, most patients undergo a percutaneous coronary intervention, whereas a minority of patients undergo coronary artery bypass grafting. Focusing specifically on the USA, the contemporary utilization, preoperative and perioperative considerations, and outcomes of NSTEMI-ACS patients undergoing coronary artery bypass grafting have not been comprehensively reviewed.

Keywords

acute coronary syndrome; cardiac surgery; cardiology; perioperative care; revascularization

Introduction

Acute coronary syndrome (ACS) represents a spectrum of ischemic heart disease that includes ST-segment elevation myocardial infarction (STEMI), non-ST-segment elevation myocardial infarction (NSTEMI), and unstable angina (UA). Although ischemic heart disease continues to remain the leading cause of mortality worldwide [1], the frequency of type of ACS has changed over the past two decades, making non-ST-segment elevation acute coronary syndrome (NSTEMI-ACS) (NSTEMI and UA) the most prevalent type of ACS in contemporary practice [2,3]. Although the most recent practice guidelines from the American College of Cardiology and the American Heart Association (AHA) for NSTEMI-ACS recommend early invasive management and the provisional use of revascularization for patients who are acceptable candidates, the literature on the specific role of coronary artery

Correspondence to Matthew T. Roe, MD, MHS, Duke Clinical Research Institute, 2400 Pratt Street, Room 7035, Durham, NC 27705, USA, Tel: + 1 919 668 8959; fax: + 1 919 668 8665; matthew.roe@duke.edu.

Conflicts of interest

There are no conflicts of interest.

bypass graft surgery (CABG) for NSTEMI-ACS has not been comprehensively summarized nor analyzed [4]. We therefore reviewed the considerations of utilizing CABG for patients who present with NSTEMI-ACS.

Utilization of CABG for NSTEMI-ACS

Following presentation with NSTEMI-ACS, only a small proportion of patients eventually undergo CABG during their index ACS hospitalization after a series of steps. As highlighted in Fig. 1, two decisions are required for an NSTEMI-ACS patient to undergo CABG. First, a cardiologist decides whether the patient is an appropriate candidate for angiography. Following initial angiography, the angiographic findings and the patient's clinical characteristics are evaluated – both factor into the second decision relating to the use and type of revascularization procedure: CABG or percutaneous coronary intervention (PCI). These decisions play a role in the type and timing of therapies provided to the patient (Fig. 2). A previous publication from the Acute Coronary Treatment and Intervention Outcomes Network Registry – Get With The Guidelines, a registry of the National Cardiovascular Data Registry, reported that 11.5% of patients presenting with NSTEMI in 2009 underwent CABG compared with 43.6% of patients who underwent PCI (whereas 76.2% underwent angiography) [5]. Over the next few years, the use of angiography for NSTEMI patients in the Acute Coronary Treatment and Intervention Outcomes Network Registry increased slightly, whereas CABG was consistently performed in ~11% of patients [6] (Fig. 3).

Although it appears that the utilization of CABG for the overall NSTEMI population has remained relatively constant in contemporary practice, the proper patient denominator to use to assess the ultimate utilization of CABG remains uncertain. For example, among elderly NSTEMI patients included in the previous Can Rapid Risk Stratification of Unstable Angina Patients Suppress Adverse Outcomes With Early Implementation of the ACC/AHA Guidelines trial who were found to have significant coronary disease on angiography, 18.2% underwent CABG within 30 days of their index event [7]. In addition, among NSTEMI patients included in the Acute Coronary Treatment and Intervention Outcomes Network Registry in 2012 who did not have previous CABG and who were found to have three-vessel or left main coronary disease during angiography, ~40% underwent CABG, 40% underwent PCI, and 20% did not undergo revascularization (Fig. 4). Thus, utilization rates of CABG for NSTEMI can vary widely on the basis of the target population being analyzed and perceived indications for CABG (Fig. 5).

Factors influencing the decision to perform CABG for NSTEMI

Although revascularization has superior outcomes compared with medical management alone for NSTEMI-ACS patients, the decision on the type of revascularization (CABG vs. PCI) is individualized on the basis of patient characteristics and technical features [4]. However, certain factors favor one method of revascularization over the other for these patients.

The key anatomic considerations that favor CABG are significant left main or three-vessel coronary artery disease, or significant two-vessel coronary disease with ostial or proximal left anterior descending artery stenosis [9]. The most recent NSTEMI-ACS practice guidelines provide similar anatomic recommendations to support the use of CABG for patients found to

have significant coronary disease during angiography [10]. Although anatomic considerations from the angiographic findings likely are the key decision-making point for the use of CABG versus PCI for NSTEMI-ACS patients, a recent publication reported that the use of PCI was associated with a statistically higher risk of major adverse cardiac events (death, myocardial infarction, or target lesion revascularization) through 1 year compared with CABG among patients with NSTEMI [11]. These findings likely relate to residual confounding in terms of the decision to perform PCI versus CABG, but suggest that CABG may be preferentially selected for NSTEMI-ACS patients with a lower expected long-term risk.

The SYNTAX trial randomized patients with stable ischemic heart disease who had unprotected left main or three-vessel disease to CABG or PCI [12]. The SYNTAX score, used in the trial to quantify the extent of coronary artery disease in a patient, is another tool that has been used to help determine patients with NSTEMI-ACS who may benefit from CABG as opposed to PCI. The latest follow-up of the SYNTAX trial suggests that patients with a SYNTAX score greater than 22 would benefit from CABG as opposed to PCI, although these data are not from patients with NSTEMI-ACS [13,14].

In addition to these anatomic considerations, certain key subgroups deserve further evaluation. First, older patients with NSTEMI appear to have improved outcomes with CABG compared with PCI, given that a recent publication reported lower 5-year mortality rates (24.2 vs. 33.5%) for NSTEMI patients found to have significant coronary disease on angiography who underwent CABG compared with PCI [7] (Fig. 6). Similar findings were obtained with the American College of Cardiology Foundation Society of Thoracic Surgeons Collaboration on the Comparative Effectiveness of Revascularization Strategies Comparative Effectiveness study among older patients who did not present with ACS [15]. Second, although no studies have specifically compared CABG versus PCI in patients with diabetes mellitus (DM) who present with NSTEMI-ACS, studies in the overall population of patients with significant coronary disease have shown improved survival for these patients with CABG [16,17]. In addition, the FREEDOM trial that randomized diabetic patients who had multivessel disease to PCI or CABG showed a survival advantage for the CABG cohort [18]. Given the association of DM with both chronic kidney disease and a greater burden of atherosclerosis, CABG should be preferred for NSTEMI-ACS patients with either DM or chronic kidney disease to ensure more complete and durable revascularization [4,19]. Finally, the use of CABG versus PCI for women with NSTEMI-ACS is confounded by the known smaller diameter coronary arteries of women versus men and by the older age of women versus men at the time of presentation with NSTEMI-ACS [5]. Therefore, it remains uncertain what the best type of revascularization strategy should be for female patients with NSTEMI-ACS who do have multivessel coronary disease. Although referring to the revascularization appropriate use guidelines for delineation between CABG versus PCI is beneficial in providing a reference point, these guidelines were formulated for patients with stable ischemic heart disease (Table 1). For patients with NSTEMI-ACS, the goal of adequate revascularization should be an even higher priority, given the unstable nature of NSTEMI-ACS and the potential for threatened myocardium. Despite the increased risk of stroke associated with CABG compared with PCI overall [20], this difference is reduced if not eliminated in patients with NSTEMI-ACS [7]. For these reasons, CABG may be preferred over PCI, given its

ability to provide a more adequate revascularization, although further research is needed to clearly establish the appropriate management of these patients.

Although randomized trials comparing CABG with PCI specifically for NSTEMI-ACS patients have not been conducted, two trials published in 2001 compared CABG versus PCI and included patients with UA. The Arterial Revascularization Therapy Study, which included patients with UA, had a total of 1205 patients randomized to CABG versus PCI, but did not show a difference in the rate of death, stroke, or myocardial infarction through 1 year, although the incidence of repeat revascularization was higher in the PCI cohort [21]. In addition, a randomized trial from Argentina included 450 patients, 92% of whom had UA, randomized to CABG and PCI, and showed a small increase in survival with PCI, although this trial had a higher perioperative mortality rate than reported elsewhere in the literature at the time [22]. Given the advancement of technology for both CABG and PCI procedures since those trials were conducted more than 15 years ago, these results are difficult to relate to current-day practice.

Notwithstanding guideline recommendations and clinical evidence, decisions on the method of revascularization for NSTEMI-ACS patients with multivessel coronary disease should be individualized to the patient and the clinical situation. A consistent recommendation in the more recent revascularization guidelines is the use of a Heart Team in clinical decision making [9,23]. This multidisciplinary decision-making approach originated from the SYNTAX trial, which required eligible patients to be evaluated by an interventional cardiologist and a cardiac surgeon [12]. Although not supported by data [24], an integrated, multidisciplinary decision-making approach involving both cardiologists and cardiac surgeons may be the preferred approach, but is not used widely in practice currently in the USA.

Preoperative considerations

After deciding on CABG for NSTEMI-ACS patients, the next decision is the timing of the procedure. Multiple studies have indicated that an early invasive management strategy with prompt coronary angiography and provisional use of revascularization for patients with NSTEMI-ACS is associated with better outcomes compared with an early conservative management strategy [25–27]. However, the optimal timing of subsequent CABG for NSTEMI-ACS patients, following identification of multi-vessel coronary disease during angiography, remains uncertain.

In terms of the timing of CABG for NSTEMI-ACS, studies are conflicting. Two observational studies from 2010 both reported equivalent in-hospital mortality and 30-day mortality rates irrespective of the timing of CABG from admission for NSTEMI-ACS [28,29]. A more recent study by Davierwala *et al.* [30] analyzed 750 patients over a 5-year period and showed similar in-hospital mortality and 5-year mortality rates among NSTEMI-ACS patients who underwent CABG in less than 24, 24–72 h, versus more than 72 h after symptom onset. However, NSTEMI-ACS practice guidelines highlight certain conditions that should prompt urgent revascularization including cardiogenic shock, refractory ischemia despite optimal medical therapy, sustained ventricular arrhythmias, or dynamic ST-segment changes accompanying ischemic symptoms [4].

In addition to delineating the optimal timing of CABG for NSTEMI-ACS patients, the coordination of preoperative medications is important. Guideline-recommended acute (< 24 h) medications for NSTEMI-ACS include antiplatelet agents and anticoagulants as well as other medications such as β -blockers and statins. Because most antithrombotic medications are started acutely as soon as NSTEMI-ACS is diagnosed, perioperative decisions mainly focus on when and whether to stop particular medications before surgery, attempting to balance the risk of rethrombosis with the risk of increased bleeding during or after CABG.

NSTEMI-ACS practice guidelines recommend the use of dual antiplatelet therapy (aspirin plus an oral P2Y₁₂ inhibitor) for the acute and discharge treatment of all patients as shown in Fig. 2. Aspirin is typically started as soon as possible for patients without contraindications and is commonly continued during and after CABG without major concerns about bleeding risks [4,23]. Although NSTEMI-ACS guidelines recommend the upstream use of a P2Y₁₂ inhibitor for the acute (<24 h) treatment of NSTEMI-ACS irrespective of the intended revascularization strategy, not all patients are receiving early P2Y₁₂ inhibitor therapy in accordance with guideline recommendations. A recent analysis of the Acute Coronary Treatment and Intervention Outcomes Network Registry – Get With The Guidelines showed that only 57% of NSTEMI patients are receiving a P2Y₁₂ inhibitor within 24 h in current US practice [31]. Clopidogrel, prasugrel, and ticagrelor are commonly used P2Y₁₂ inhibitors with different bleeding risks as well as different pharmacokinetic and pharmacodynamic profiles for drug offset following discontinuation [32,33]. Current guidelines recommend that prasugrel should be discontinued for at least 7 days before elective CABG to decrease CABG-related major bleeding risks compared with at least 5 days of discontinuation for clopidogrel and ticagrelor [9]. A paper by Hansson *et al.* [34] supplies new evidence that waiting for 5 days may not be necessary. In this analysis, they show that waiting 3 days as opposed to 5 days did not increase the rate of CABG-related major bleeding for patients on ticagrelor. The necessary waiting periods for drug offset before CABG may drive the inclination to withhold the loading dose of a P2Y₁₂ inhibitor until after identification of the coronary anatomy with early coronary angiography, but treatment pathways vary considerably across US hospitals in the preferred timing of the start of P2Y₁₂ inhibitors. More precise decision making for the timing of CABG following discontinuation of a P2Y₁₂ inhibitor may be supported by serial platelet function testing to identify the threshold for recovery of platelet function to prompt CABG (on the basis of diminished concerns about bleeding risk), but no large, prospective studies have been completed as yet to reliably test this strategy [35]. Our institutional experience is to treat patients with a P2Y₁₂ inhibitor upstream of angiography. If the postprocedural plan is for CABG, the P2Y₁₂ inhibitor is discontinued and the patient undergoes surgery 4–5 days after angiography irrespective of the P2Y₁₂ inhibitor that was used. In the time between angiography and surgery, the patient is anticoagulated with unfractionated heparin (UFH) or bivalirudin if there is a contraindication to heparin (Fig. 2). Our institutional practice is to start/restart dual antiplatelet therapy after surgery.

The management of anticoagulation is less complicated because of the shorter half-lives of these parenteral/subcutaneous medications compared with oral P2Y₁₂ inhibitors. UFH, enoxaparin, bivalirudin, and fondaparinux are the medications recommended for anticoagulation after NSTEMI-ACS presentation, although UFH is predominantly used in the

USA [6]. These medications can usually be discontinued between 6 and 24 h before CABG depending on the particular medication and UFH is restarted during initiation of cardiopulmonary bypass.

Although the data for a relationship between the pre-operative use of β blockers and perioperative mortality rates are controversial, the role of perioperative and postoperative β -blockers in this setting for reducing the risk of postoperative atrial fibrillation has been established [36,37]. Current CABG guidelines recommend the continuation of β -blocker medications in the perioperative setting for patients who are on a β -blocker pre-operatively [9].

Statin therapy is also important in the perioperative setting. In addition to cholesterol-lowering properties, statins are increasingly being recognized as a useful anti-inflammatory adjunct for cardiac surgery patients [38–40]. Current guidelines recommend the early initiation and continuation of high-intensity statin therapy after NSTEMI-ACS and continuation in the perioperative setting with a goal of an LDL-C less than 100 mg/dl with further titration to 70 mg/dl if possible [4,9,10,23]. A previous cohort study by Collard *et al.* [41] reported that pre-operative statin was associated with reduced cardiac mortality, whereas discontinuation postoperatively was associated with increased in-hospital mortality.

Postoperative considerations

Medication management in the postoperative setting following CABG for NSTEMI-ACS is more straightforward. The reduction in mortality associated with aspirin following CABG is well established and it should be continued without interruption [42]. The role of P2Y₁₂ inhibitor therapy after CABG in patients with NSTEMI-ACS is more controversial. Although NSTEMI-ACS guidelines are clear in recommending dual antiplatelet therapy (aspirin plus a P2Y₁₂ inhibitor) for 12 months for all patients irrespective of the in-hospital use and type of revascularization procedure on the basis of consistent results across patient groups in the pivotal trials for the currently used P2Y₁₂ inhibitors [4,23], the 2011 American College of Cardiology Foundation/AHA Guidelines for CABG do not specifically recommend P2Y₁₂ inhibitors after CABG for NSTEMI-ACS patients [9]. Although a small, underpowered trial of dual anti-platelet therapy versus aspirin after elective CABG showed no difference in saphenous vein graft intimal hyperplasia, the role of dual antiplatelet therapy after CABG is currently still being investigated [43,44].

Angiotension converting enzyme inhibitors or angiotensin receptor blockers are also indicated after CABG for NSTEMI-ACS, especially for patients with DM and those with left ventricular systolic dysfunction [4]. These medications should either be reinitiated or added after CABG. Long-term outcomes are improved in patients on angiotension converting enzyme inhibitors or angiotensin receptor blockers following CABG [45], although there are less adverse events when starting 7 days or greater after surgery [46].

Postoperative statins and β -blocker should be administered as soon as possible following CABG for NSTEMI-ACS. The long-term mortality benefit associated with statin therapy [41,47] and the benefit in prevention of postoperative atrial fibrillation associated with β -

blocker therapy [36,37] have been discussed already. Data further suggest that postoperative β -blocker use is associated with decreased long-term mortality after CABG [48].

Conclusion

Although only a minority of NSTEMI-ACS patients undergo CABG as a definitive treatment for their index ACS event, there are many complex decision-making steps following hospital presentation that occur before the decision to perform CABG is confirmed. The timing of CABG for NSTEMI-ACS is strongly influenced by the upstream use of oral P2Y₁₂ inhibitors (which need to be discontinued for 5–7 days after angiography to allow for recovery of platelet function before CABG) and is individualized on the basis of patient clinical characteristics. Therefore, integrated decision making with cardiologists and cardiac surgeons is needed to optimize the concomitant medical treatments and the preoperative, peri-operative, and postoperative outcomes for NSTEMI-ACS patients who undergo CABG.

Acknowledgments

B.A.Y., J.B.W., and P.K.S. are supported by the NIH funded Cardiothoracic Surgery Trials Network 5U01HL088953-05.

References

1. Lozano R, Naghavi M, Foreman K, Lim S, Shibuya K, Aboyans V, et al. Global and regional mortality from 235 causes of death for 20 age groups in 1990 and 2010: a systematic analysis for the Global Burden of Disease Study 2010. *Lancet*. 2012; 380:2095–2128. [PubMed: 23245604]
2. Rogers WJ, Frederick PD, Stoeck E, Canto JG, Ornato JP, Gibson CM, et al. Trends in presenting characteristics and hospital mortality among patients with ST elevation and non-ST elevation myocardial infarction in the National Registry of Myocardial Infarction from 1990 to 2006. *Am Heart J*. 2008; 156:1026–1034. [PubMed: 19032996]
3. Yeh RW, Sidney S, Chandra M, Sorel M, Selby JV, Go AS. Population trends in the incidence and outcomes of acute myocardial infarction. *N Engl J Med*. 2010; 362:2155–2165. [PubMed: 20558366]
4. Amsterdam EA, Wenger NK, Brindis RG, Casey DE Jr, Ganiats TG, Holmes DR Jr, et al. ACC/AHA Task Force Members, Society for Cardiovascular Angiography and Interventions and the Society of Thoracic Surgeons. 2014 AHA/ACC guideline for the management of patients with non-ST-elevation acute coronary syndromes: executive summary: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines. *Circulation*. 2014; 130:2354–2394.
5. Clemmensen P, Roe MT, Hochman JS, Cyr DD, Neely ML, McGuire DK, et al. TRILOGY ACS Investigators. Long-term outcomes for women versus men with unstable angina/non-ST-segment elevation myocardial infarction managed medically without revascularization: insights from the TaRgeted platelet Inhibition to cLarify the Optimal strateGy to medically manage Acute Coronary Syndromes trial. *Am Heart J*. 2015; 170:695.e5–705.e5. [PubMed: 26386793]
6. Masoudi FA, Ponirakis A, Yeh RW, Maddox TM, Beachy J, Casale PN, et al. Cardiovascular care facts: a report from the national cardiovascular data registry: 2011. *J Am Coll Cardiol*. 2013; 62:1931–1947.
7. Roe MT, Li S, Thomas L, Wang TY, Alexander KP, Ohman EM, Peterson ED. Long-term outcomes after invasive management for older patients with non-ST-segment elevation myocardial infarction. *Circ Cardiovasc Qual Outcomes*. 2013; 6:323–332. [PubMed: 23652734]
8. Harskamp RE, Wang TY, Bhatt DL, Wiviott SD, Amsterdam EA, Li S, et al. Hospital patterns of medical management strategy use for patients with non-ST-elevation myocardial infarction and 3-vessel or left main coronary artery disease. *Am Heart J*. 2014; 167:355.e3–362.e3. [PubMed: 24576520]

9. Hillis LD, Smith PK, Anderson JL, Bittl JA, Bridges CR, Byrne JG, et al. 2011 ACCF/AHA Guideline for Coronary Artery Bypass Graft Surgery: executive summary: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines. *Circulation*. 2011; 124:2610–2642. [PubMed: 22064600]
10. Anderson JL, Adams CD, Antman EM, Bridges CR, Califf RM, Casey DE Jr, et al. ACC/AHA 2007 guidelines for the management of patients with unstable angina/non-ST-Elevation myocardial infarction: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Writing Committee to Revise the 2002 Guidelines for the Management of Patients With Unstable Angina/Non-ST-Elevation Myocardial Infarction) developed in collaboration with the American College of Emergency Physicians, the Society for Cardiovascular Angiography and Interventions, and the Society of Thoracic Surgeons endorsed by the American Association of Cardiovascular and Pulmonary Rehabilitation and the Society for Academic Emergency Medicine. *J Am Coll Cardiol*. 2007; 50:e1–e157. [PubMed: 17692738]
11. Caggegi A, Capodanno D, Capranzano P, Chisari A, Ministeri M, Mangiameli A, et al. Comparison of one-year outcomes of percutaneous coronary intervention versus coronary artery bypass grafting in patients with unprotected left main coronary artery disease and acute coronary syndromes (from the CUSTOMIZE Registry). *Am J Cardiol*. 2011; 108:355–359. [PubMed: 21545992]
12. Serruys PW, Morice MC, Kappetein AP, Colombo A, Holmes DR, Mack MJ, et al. Percutaneous coronary intervention versus coronary-artery bypass grafting for severe coronary artery disease. *N Engl J Med*. 2009; 360:961–972. [PubMed: 19228612]
13. Head SJ, Davierwala PM, Serruys PW, Redwood SR, Colombo A, Mack MJ, et al. Coronary artery bypass grafting vs. percutaneous coronary intervention for patients with three-vessel disease: final five-year follow-up of the SYNTAX trial. *Eur Heart J*. 2014; 35:2821–2830. [PubMed: 24849105]
14. Mohr FW, Morice MC, Kappetein AP, Feldman TE, Stähle E, Colombo A, et al. Coronary artery bypass graft surgery versus percutaneous coronary intervention in patients with three-vessel disease and left main coronary disease: 5-year follow-up of the randomised, clinical SYNTAX trial. *Lancet*. 2013; 381:629–638. [PubMed: 23439102]
15. Weintraub WS, Grau-Sepulveda MV, Weiss JM. Comparative effectiveness of revascularization strategies. *N Engl J Med*. 2012; 366:1467–1476. [PubMed: 22452338]
16. Weintraub WS, Stein B, Kosinski A, Douglas JS Jr, Ghazzal ZM, Jones EL, et al. Outcome of coronary bypass surgery versus coronary angioplasty in diabetic patients with multivessel coronary artery disease. *J Am Coll Cardiol*. 1998; 31:10–19. [PubMed: 9426011]
17. BARI Investigators. Seven-year outcome in the Bypass Angioplasty Revascularization Investigation (BARI) by treatment and diabetic status. *J Am Coll Cardiol*. 2000; 35:1122–1129. [PubMed: 10758950]
18. Farkouh ME, Domanski M, Sleeper LA, Siami FS, Dangas G, Mack M, et al. Strategies for multivessel revascularization in patients with diabetes. *N Engl J Med*. 2012; 367:2375–2384. [PubMed: 23121323]
19. Patel MR, Dehmer GJ, Hirshfeld JW, Smith PK, Spertus JA. ACCF/SCAI/STS/AATS/AHA/ASNC/HFSA/SCCT 2012 Appropriate use criteria for coronary revascularization focused update: a report of the American College of Cardiology Foundation Appropriate Use Criteria Task Force, Society for Cardiovascular Angiography and Interventions, Society of Thoracic Surgeons, American Association for Thoracic Surgery, American Heart Association, American Society of Nuclear Cardiology, and the Society of Cardiovascular Computed Tomography. *J Am Coll Cardiol*. 2012; 59:857–881. [PubMed: 22296741]
20. Palmerini T, Biondi-Zoccai G, Reggiani LB, Sangiorgi D, Alessi L, De Servi S, et al. Risk of stroke with coronary artery bypass graft surgery compared with percutaneous coronary intervention. *J Am Coll Cardiol*. 2012; 60:798–805. [PubMed: 22917004]
21. Serruys PW, Unger F, Sousa JE, Jatene A, Bonnier HJ, Schönberger JP, et al. Comparison of coronary-artery bypass surgery and stenting for the treatment of multivessel disease. *N Engl J Med*. 2001; 344:1117–1124. [PubMed: 11297702]
22. Rodriguez A, Bernardi V, Navia J, Baldi J, Grinfeld L, Martinez J, et al. Argentine randomized study: coronary angioplasty with stenting versus coronary bypass surgery in patients with

- multiple-vessel disease (ERACI II): 30-day and one-year follow-up results. ERACI II Investigators. *J Am Coll Cardiol*. 2001; 37:51–58. [PubMed: 11153772]
23. Roffi M, Patrono C, Collet J-P, Mueller C, Valgimigli M, Andreotti F, et al. ESC Guidelines for the management of acute coronary syndromes in patients presenting without persistent ST-segment elevation: task force for the management of acute coronary syndromes in patients presenting without persistent st-segment elevation of the European Society of Cardiology (ESC). *Eur Heart J*. 2015; 2015 Epub ahead of print.
 24. Rosenschein U, Nagler RM, Rofe A. The heart team approach to coronary revascularization – have we crossed the lines of evidence-based medicine? *Am J Cardiol*. 2013; 112:1516–1519. [PubMed: 23993117]
 25. Bhatt DL, Roe MT, Peterson ED, Li Y, Chen AY, Harrington RA, et al. CRUSADE Investigators. Utilization of early invasive management strategies for high-risk patients with non-ST-segment elevation acute coronary syndromes: results from the CRUSADE Quality Improvement Initiative. *JAMA*. 2004; 292:2096–2104. [PubMed: 15523070]
 26. Mehta SR, Granger CB, Boden WE, Steg PG, Bassand JP, Faxon DP, et al. TIMACS Investigators. Early versus delayed invasive intervention in acute coronary syndromes. *N Engl J Med*. 2009; 360:2165–2175. [PubMed: 19458363]
 27. Neumann FJ, Kastrati A, Pogatsa-Murray G, Mehilli J, Bollwein H, Bestehorn HP, et al. Evaluation of prolonged antithrombotic pretreatment ('cooling-off' strategy) before intervention in patients with unstable coronary syndromes: a randomized controlled trial. *JAMA*. 2003; 290:1593–1599. [PubMed: 14506118]
 28. Deyell MW, Ghali WA, Ross DB, Zhang J, Hemmelgarn BR. Alberta Provincial Project for Outcome Assessment in Coronary Heart Disease (APPROACH) Investigators. Timing of nonemergent coronary artery bypass grafting and mortality after non-ST elevation acute coronary syndrome. *Am Heart J*. 2010; 159:490–496. [PubMed: 20211314]
 29. Parikh SV, de Lemos JA, Jessen ME, Brilakis ES, Ohman EM, Chen AY, et al. CRUSADE and ACTION Registry-GWTG Participants. Timing of in-hospital coronary artery bypass graft surgery for non-ST-segment elevation myocardial infarction patients results from the National Cardiovascular Data Registry ACTION Registry-GWTG (Acute Coronary Treatment and Intervention Outcomes Network Registry-Get With The Guidelines). *JACC Cardiovasc Interv*. 2010; 3:419–427. [PubMed: 20398870]
 30. Davierwala PM, Verevkin A, Leontyev S, Misfeld M, Borger MA, Mohr FW. Does timing of coronary artery bypass surgery affect early and long-term outcomes in patients with non-ST-segment-elevation myocardial infarction? *Circulation*. 2015; 132:731–740. [PubMed: 26304664]
 31. Sherwood MW, Wiviott SD, Peng SA, Roe MT, Delemos J, Peterson ED, Wang TY. Early clopidogrel versus prasugrel use among contemporary STEMI and NSTEMI patients in the US: insights from the National Cardiovascular Data Registry. *J Am Heart Assoc*. 2014; 3:e000849. [PubMed: 24732921]
 32. Wiviott SD, Braunwald E, McCabe CH, Montalescot G, Ruzyllo W, Gottlieb S, et al. Prasugrel versus clopidogrel in patients with acute coronary syndromes. *N Engl J Med*. 2007; 357:2001–2015. [PubMed: 17982182]
 33. Becker RC, Bassand JP, Budaj A, Wojdyla DM, James SK, Cornel JH, et al. Bleeding complications with the P2Y₁₂ receptor antagonists clopidogrel and ticagrelor in the PLATelet inhibition and patient Outcomes (PLATO) trial. *Eur Heart J*. 2011; 32:2933–2944. [PubMed: 22090660]
 34. Hansson EC, Jidéus L, Åberg B, Bjursten H, Dreifaldt M, Holmgren A, et al. Coronary artery bypass grafting-related bleeding complications in patients treated with ticagrelor or clopidogrel: a nationwide study. *Eur Heart J*. 2016; 37:189–197. [PubMed: 26330426]
 35. Gurbel PA, Mahla E, Tantry US. Peri-operative platelet function testing: the potential for reducing ischaemic and bleeding risks. *Thromb Haemost*. 2011; 106:248–252. [PubMed: 21505715]
 36. Arsenault KA, Yusuf AM, Crystal E, Healey JS, Morillo CA, Nair GM, Whitlock RP. Interventions for preventing post-operative atrial fibrillation in patients undergoing heart surgery. *Cochrane Database Syst Rev*. 2013; 1:CD003611.
 37. Khan MF, Wendel CS, Movahed MR. Prevention of post-coronary artery bypass grafting (CABG) atrial fibrillation: efficacy of prophylactic beta-blockers in the modern era: a meta-analysis of latest

- randomized controlled trials. *Ann Noninvasive Electrocardiol.* 2013; 18:58–68. [PubMed: 23347027]
38. Martínez-Comendador JM, Alvarez JR, Mosquera I, Sierra J, Adrio B, Carro JG, et al. Preoperative statin treatment reduces systemic inflammatory response and myocardial damage in cardiac surgery. *Eur J Cardiothorac Surg.* 2009; 36:998–1005. [PubMed: 19581104]
39. Castaño M, González-Santos JM, López J, García B, Centeno JE, Aparicio B, et al. Effect of preoperative oral pravastatin reload in systemic inflammatory response and myocardial damage after coronary artery bypass grafting. A pilot double-blind placebo-controlled study. *J Cardiovasc Surg (Torino).* 2015; 56:617–629.
40. Sodha NR, Sellke FW. The effect of statins on perioperative inflammation in cardiac and thoracic surgery. *J Thorac Cardiovasc Surg.* 2015; 149:1495–1501. [PubMed: 25791954]
41. Collard CD, Body SC, Shernan SK, Wang S, Mangano DT. Multicenter Study of Perioperative Ischemia (MCSPI) Research Group, Inc., Ischemia Research and Education Foundation (IREF) Investigators. Preoperative statin therapy is associated with reduced cardiac mortality after coronary artery bypass graft surgery. *J Thorac Cardiovasc Surg.* 2006; 132:392–400. [PubMed: 16872968]
42. Mangano DT. Aspirin and mortality from coronary bypass surgery. *N Engl J Med.* 2002; 347:1309–1317. [PubMed: 12397188]
43. Kulik A, Le May MR, Voisine P, Tardif JC, Delarochelliere R, Naidoo S, et al. Aspirin plus clopidogrel versus aspirin alone after coronary artery bypass grafting: the clopidogrel after surgery for coronary artery disease (CASCADE) Trial. *Circulation.* 2010; 122:2680–2687. [PubMed: 21135365]
44. Bomb R, Oliphant CS, Khouzam RN. Dual antiplatelet therapy after coronary artery bypass grafting in the setting of acute coronary syndrome. *Am J Cardiol.* 2015; 116:148–154. [PubMed: 25933730]
45. Oostergera M, Voors AA, Pinto YM, Buikema H, Grandjean JG, Kingma JH, et al. Effects of quinapril on clinical outcome after coronary artery bypass grafting (The QUO VADIS Study). *QUinapril on Vascular Ace and Determinants of Ischemia. Am J Cardiol.* 2001; 87:542–546. [PubMed: 11230836]
46. Rouleau JL, Warnica WJ, Baillot R, Block PJ, Chocron S, Johnstone D, et al. IMAGINE (Ischemia Management with Accupril post-bypass Graft via Inhibition of the coNverting Enzyme) Investigators. Effects of angiotensin-converting enzyme inhibition in low-risk patients early after coronary artery bypass surgery. *Circulation.* 2008; 117:24–31. [PubMed: 18071079]
47. Knatterud GL, Rosenberg Y, Campeau L, Geller NL, Hunninghake DB, Forman SA, et al. Long-term effects on clinical outcomes of aggressive lowering of low-density lipoprotein cholesterol levels and low-dose anticoagulation in the post coronary artery bypass graft trial. *Post CABG Investigators. Circulation.* 2000; 102:157–165. [PubMed: 10889125]
48. Zhang H, Yuan X, Zhang H, Chen S, Zhao Y, Hua K, et al. Efficacy of long-term β -blocker therapy for secondary prevention of long-term outcomes after coronary artery bypass grafting surgery. *Circulation.* 2015; 131:2194–2201. [PubMed: 25908770]

Fig. 1.

Decision tree for patients who present with NSTEMI-ACS. For patients who present with NSTEMI-ACS, two decision points exist for them to receive CABG. angio, angiography; CABG, coronary artery bypass graft surgery; cath, catheterization; D1, first decision on whether to pursue angiography; D2, second decision on revascularization method; MM, medical management; NSTEMI-ACS, non-ST-segment elevation acute coronary syndrome; PCI, percutaneous coronary intervention; revasc, revascularization.

Fig. 2.

Summary of antiplatelet medication and anticoagulation management after presentation with NSTEMI-ACS. Careful management of antiplatelet medications and anticoagulation is imperative after a patient presents with NSTEMI-ACS. Prompt initiation of DAPT and anticoagulation after the diagnosis is made. If the decision is to proceed with angiography, these medications are continued. (a) If the decision is to proceed with CABG, anticoagulation is continued and DAPT is discontinued until surgery. DAPT is then restarted before discharge. (b) If the decision is to proceed with PCI, anticoagulation is discontinued after intervention. DAPT is continued through discharge. (c, d) If noninvasive management or no revascularization is pursued, then anticoagulation is discontinued during the hospitalization. DAPT is continued through discharge. angio, angiography; ASA, aspirin; CABG, coronary artery bypass graft surgery; cath, left-heart catheterization; DAPT, dual antiplatelet therapy; NSTEMI-ACS, non-ST-segment elevation acute coronary syndrome; PCI, percutaneous coronary intervention; P2Y12, P2Y12 inhibitor; revasc, revascularization.

Fig. 3. ACTION Registry-GWTG processes of care metrics: cardiac procedures and revascularization strategies among eligible patients. ACTION Registry-GWTG, Acute Coronary Treatment and Intervention Outcomes Network Registry – Get With The Guidelines; CABG, coronary artery bypass grafting; cath, catheterization; NSTEMI, non-ST-segment elevation myocardial infarction; PCI, percutaneous coronary intervention; STEMI, ST-segment elevation myocardial infarction. Reproduced with permission [6].

Fig. 4.

Trends in the use of medical management, PCI, and CABG. This figure shows the percentage of patients treated with a medical management strategy, PCI, and CABG for each quarter between 1 January 2007 and 31 March 2012, at 423 hospitals in the US. Cochran–Armitage Trend test for medical management one-sided P : 0.11, for PCI: $P < 0.001$, for CABG: $P < 0.001$. CABG, coronary artery bypass grafting; MMS, medical management strategy; PCI, percutaneous coronary intervention. Reproduced with permission [8].

Fig. 5. Hospital-level variation of medical management use among hospitals in the ACTION Registry-GWTG. Hospital-level variation of medical management use (%) with 95% CI over the 5-year analysis time period (2007–2012) in 316 hospitals with an adequate volume of NSTEMI patients. The remaining percentage of patients can be used as a proxy for the percentage of patients undergoing revascularization. ACTION Registry-GWTG, Acute Coronary Treatment and Intervention Outcomes Network Registry – Get With The Guidelines; CI, confidence interval; NSTEMI, non-ST-segment elevation myocardial infarction. Reproduced with permission [8].

Fig. 6.

Kaplan–Meier curves showing long-term mortality cumulative incidence from 30 days after hospital discharge through 5 years for patients stratified by treatment group: medical management versus percutaneous coronary intervention (PCI) versus coronary artery bypass grafting (CABG) – $P < 0.0001$ for three-way comparisons among groups. Reproduced with permission [7].

Table 1

Summary of the appropriate use guidelines on the type of revascularization for stable ischemic heart disease

Stable ischemic heart disease recommendations	
2v-Disease with proximal LAD	Both are reasonable
2v-Disease with proximal LAD and DM	CABG is preferred over PCI
3v-Disease with low CAD burden	Both are reasonable
3v-Disease with intermediate/high CAD burden	CABG is preferred over PCI
3v-Disease and DM	CABG is preferred over PCI
Left main disease	CABG is preferred over PCI

CABG, coronary artery bypass grafting; CAD, coronary artery disease; DM, diabetes mellitus; LAD, left anterior descending coronary artery disease; PCI, percutaneous coronary intervention; 2v, two vessel; 3v, three vessel.