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CORONARY ARTERY DISEASE

Clinical Decision Making

Ad Hoc Percutaneous Coronary Intervention: A Consensus Statement From the Society for Cardiovascular Angiography and Interventions

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Percutaneous coronary interventions (PCI) may be performed during the same session as diagnostic catheterization (ad hoc PCI) or at a later session (delayed PCI). Randomized trials comparing these strategies have not been performed; cohort studies have not identified consistent differences in safety or efficacy between the two strategies. Ad hoc PCI has increased in prevalence over the past decade and is the default strategy for treating acute coronary syndromes. However, questions about its appropriateness for some patients with stable symptoms have been raised by the results of recent large trials comparing PCI to medical therapy or bypass surgery. Ad hoc PCI for stable ischemic heart disease requires preprocedural planning, and reassessment after diagnostic angiography must be performed to ensure its appropriateness. Patients may prefer ad hoc PCI because it is convenient. Payers may prefer ad hoc PCI because it is cost-efficient. The majority of data confirm equivalent outcomes in ad hoc versus delayed PCI. However, there are some situations in which delayed PCI may be safer or yield better outcomes. This document reviews patient subsets and clinical situations in which one strategy is preferable over the other. © 2012 Wiley Periodicals, Inc.

Key words: stenting; percutaneous coronary intervention; angina

INTRODUCTION

Percutaneous coronary intervention (PCI) has evolved since its inception 35 years ago. Initially, PCI required cardiac surgery and anesthesiology standby, and emergency coronary artery bypass surgery (CABG) was performed in $\geq$5% of PCI patients. As PCI became safer and more predictable, it was more often performed during the same session as diagnostic catheterization (termed "ad hoc" PCI). More recently, it has been suggested that ad hoc PCI may be performed too frequently in situations in which it would be preferable to pause for additional informed consent or consideration of alternatives.1 Guidelines and appropriate use criteria for PCI are frequently being revised, adding to the factors an interventional cardiologist must consider before performing ad hoc PCI.2,3 Recommendations for the appropriate performance of ad hoc PCI were published 8 years ago by the Society for Cardiovascular Angiography and Interventions (SCAI).4 The purpose of this paper is to update those recommendations in light of recent trial results and practice trends.

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TABLE I. Studies of Ad Hoc Versus Delayed Percutaneous Coronary Intervention

Author (years enrolled)	No. patients (Ad hoc/delayed)	Angiographic success		Inpatient death		Procedural myocardial infarction		Emergent coronary bypass surgery	
		Ad hoc (%)	Delayed (%)	Ad hoc (%)	Delayed (%)	Ad hoc (%)	Delayed (%)	Ad hoc (%)	Delayed (%)
Angioplasty era									
O'Keefe et al.[8] (1985–1986)	120/404	89	91	0	1.2	0.8	1.4	1.6	3.4
O'Keefe et al.[9] (1984–1988)	73/5,351	95	95	0.5	0	0.9	0.5	2.3	0.5
Lund et al.10 (1991–1992)	124/?	92.1	88.4	NA	NA	NA	NA	NA	NA
Rozenman et al.[11] (1989–1992)	1,719/2,069	93.9	92.9	0.8	1.3	1.0	1.3	0.5	0.3
Kimmel et al.[12] (1992–1995)[a]	6,152/29,548	NA	NA	0.29	0.16	0.73	0.15	1.3	1.09
Le Feuvre et al.[13] (1990–2000)	1,809/631	92[c]	88[c]	0.9	0.4	2.2	2.3	0.6	0.9
Panchamukhi and Flaker[14] (1995–1996)	244/113	92	91	0	0	NA	NA	0.8	0
Stent era (>50% of PCI utilized stents)									
Shubrooks et al.[15] (1997)[a]	1,748/2,388	93.7[b]	93.6[b]	0.6	0.5	2.0	2.6	0.9	0.8
Goldstein et al.[16] (1995–1998)[a]	38,411/23,462	NA	NA	0.46	0.56	NA	NA	NA	NA
Krone et al.[18] (2001–2003)[a]	41,524/27,004	91.7[c]	92.5[c]	0.13	0.16	NA	NA	0.59[c]	0.34[c]
Feldman et al.[17] (2001–2002)[a]	28,904/18,116	NA	NA	0.4	0.4	NA	NA	0.2	0.3
Hannan et al.[19] (2003–2005)[a]	38,431/8,134	NA	NA	0.25[c]	0.45[c]	0.85	0.95	NA	NA
Good et al.[20] (2004)[a]	557/23	97.7	100	0.7	0	3.8[c]	8.7[c]	0.4	0

[a]Statistical analyses involved multivariate analysis.
[b]Clinical success is reported since angiographic success was not available.
[c]$P < 0.05$.
NA = not available

DEFINITIONS OF AD HOC AND DELAYED PCI

Coronary angiography followed by PCI is performed in various scenarios, including the following.

Angiography and PCI in the Same Session (Ad Hoc PCI)

Diagnostic catheterization is followed in the same session, or same sitting, by PCI.

Angiography and PCI on Separate Days (Delayed PCI)

After diagnostic catheterization, the patient is taken off the catheterization laboratory table; PCI is performed on a separate day.

Angiography and PCI on the Same Day but Separate Sessions (same-Day PCI)

After diagnostic catheterization, the patient is taken off the catheterization laboratory table and returned later in the same day for PCI. This strategy combines some of the efficiencies of ad hoc PCI while allowing for a "pause" for additional evaluation or treatment, discussion with the patient after sedation has resolved, or expert consultation. Databases usually do not distinguish between ad hoc and same-day PCI, and there are no reliable data on its prevalence or clinical impact.

EVOLUTION OF AD HOC PCI

All trials of ad hoc PCI discussed below used registry data; randomized trials of ad hoc PCI have not been conducted.

Ad Hoc PCI in the Prestent Era

Ten studies5–14 have reported the results of ad hoc PTCA. Of these, seven compared ad hoc with delayed PTCA, and all found similar overall angiographic success and acute complication rates for ad hoc and delayed PTCA (Table I). Kimmel et al.12 reported that ad hoc angioplasty was associated with an increased risk of acute complications in patients with unstable angina, multivessel coronary artery disease (CAD), advanced age, and multilesion angioplasty. Overall, these studies provided evidence that ad hoc angioplasty, compared to delayed angioplasty, was safe in selected patients.

Ad Hoc PCI in the Stent Era

Shubrooks et al.15 reported the outcome of 4,136 PCIs performed in seven New England centers in 1997. Ad hoc PCI was performed in 42% of PCIs with similar clinical success and ischemic complication rates compared to delayed PCI. Vascular complication rates were lower in patients undergoing ad hoc PCI (0.6% vs. 1.6%, $P = 0.006$).

Goldstein et al.16 reported outcomes of 62,873 PCIs performed in 33 centers from 1995 to 1998, using data

from the New York State Department of Health PCI database. Ad hoc PCI was performed in 62% of PCIs with similar mortality as delayed PCI overall but with increased risk of mortality in "high-risk" subgroups [i.e., those with congestive heart failure (odds ratio = 1.6; $P = 0.04$) or class IV angina (odds ratio = 1.6; $P = 0.04$)].

Feldman et al.17 reported the outcome of 47,020 patients undergoing PCI from 2000 to 2001 using data from the same New York State PCI Registry analyzed by Goldstein et al. years earlier.16 Ad hoc PCI was performed in 61%. Mortality, major adverse cardiac events (death, emergency CABG, or stroke), and incidence of renal failure/dialysis during hospitalization were similar for ad hoc and delayed PCI. Patients with high-risk features (age >80 years, class IV angina, congestive heart failure on admission, renal failure, and multivessel CAD) had similar in-hospital clinical outcomes after either treatment approach.

Krone et al.18 reported the outcomes of 68,528 PCIs with stable angina from 2001 to 2003 using data from the American College of Cardiology National Cardiovascular Data Registry. Ad hoc PCI was performed in 61%. While ad hoc PCI was associated with lower success rates, and slightly more frequent unplanned CABG and emergency repeat PCIs, the differences between ad hoc and delayed PCI became nonsignificant in a multivariate analysis. Procedural mortality, cerebrovascular events, and renal failure were similar between groups.

Hannan et al.19 reported outcomes of 46,565 PCIs between 2003 and 2005 using data from the New York PCI Reporting System. Ad hoc PCI was performed in 83% of PCIs. Adjusted in-hospital mortality rates were similar for ad hoc and delayed PCI. Ad hoc PCI was associated with lower rates of renal failure (0.07% vs. 0.14%) and myocardial infarction (MI) (0.85% vs. 0.95%) compared with delayed PCI, although P values were not reported. After 36 months of follow-up, ad hoc PCI was associated with lower mortality (risk-adjusted hazard ratio 0.76, $P < 0.0001$). The mortality reduction associated with ad hoc PCI was present in "high-risk" groups (women, age $\geq$ 75 years, multivessel disease, congestive heart failure, and class IV angina). The data did not explain why delayed PCI was associated with higher mortality overall and in high-risk subgroups; the authors suggested it could be due to increased morbidity associated with a second PCI procedure or unidentified biases in their data.

Good et al.20 reported the outcomes of 580 PCIs in 2004 from a single center. Ad hoc PCI was performed in 96% of PCIs. Delayed PCI patients were older with a higher frequency of prior MI, congestive heart failure, chronic kidney disease, left ventricular systolic dysfunction, and prior CABG. Outcomes were similar for both groups except for a higher incidence of periprocedural MI in the delayed PCI group (8.7% vs. 3.8%, $P = 0.023$).

Ad Hoc PCI in the Current Era

The prevalence of ad hoc PCI has increased over the past decade.15–20 This increase is in part due to the proven efficacy of PCI (usually performed ad hoc) for acute coronary syndromes (ACS)21 and to studies suggesting that ad hoc PCI is safe and effective compared to delayed PCI.15,17,19,20

The appropriateness of ad hoc PCI has been challenged recently, particularly for patients at either end of the spectrum of CAD—those with mild CAD in whom medical therapy might be sufficient and those with extensive and complex CAD for whom the relative benefit of PCI versus CABG has been questioned.22,23 For example, it has been suggested that, for patients with stable ischemic heart disease (SIHD), delay or deferral to discuss treatment options and to intensify medical therapy may be appropriate.22,24,25 For patients with extensive (i.e., complex multivessel, or unprotected left main) CAD, it has been suggested that a "heart team" approach allowing input from both an interventional cardiologist and a cardiac surgeon may be preferable.2,23

GUIDELINES AND APPROPRIATE USE CRITERIA RELEVANT TO AD HOC PCI

PCI Guidelines

The first PCI guidelines,26 published in 1988, recommended against ad hoc balloon angioplasty. Subsequent PCI guidelines characterized ad hoc PCI as "particularly suitable" for patients with acute MI, medically refractory unstable angina, or symptomatic restenosis but advised against ad hoc PCI when "angiographic findings are unanticipated or the indication, suitability, or preferences for percutaneous revascularization are unclear."27 The 2011 PCI guidelines2 do not specifically address ad hoc PCI but recommend for ACS patients and early invasive strategy that in most cases would include ad hoc PCI, particularly for patients with ongoing ischemia (Table II) (Fig. 1).

Appropriate Use Criteria

The 2012 Appropriate Use Criteria (AUC)3 classified PCI as appropriate, inappropriate, or of uncertain appropriateness in a wide range of clinical scenarios based on four variables: clinical presentation [ST-segment elevation MI (STEMI), non-ST elevation ACS (NSTE-ACS), or SIHD], extent and degree of ischemia suggested by

TABLE II. Clinical Scenarios Favoring Delayed Percutaneous Coronary Intervention

1. High-risk/complex anatomic stable coronary disease (e.g., unprotected left main, complex multivessel coronary artery disease, chronic total occlusion).
2. Excessive contrast or radiation during diagnostic procedure or anticipated during percutaneous coronary intervention.
3. Site of service (e.g., facility without onsite surgery in which the patient risk or lesion risk is high or facility lacking necessary interventional equipment).
4. Inadequate informed consent (e.g., diagnostic catheterization identifies anatomy for which the risk of PCI is significantly higher than was discussed before percutaneous coronary intervention).
5. Uncertainty regarding extent of symptoms in patients with stable ischemic heart disease.
6. Lack of evidence of ischemia and unavailability of fractional flow reserve or intravascular ultrasound.
7. Complication during diagnostic catheterization (e.g., stroke and access site bleeding).
8. Operator or patient fatigue after diagnostic catheterization.
9. Scheduling problems (e.g., if a new patient presents with ST-elevation as ad hoc PCI is being considered for a patient with stable ischemic heart disease).
10. Inadequate pretreatment (e.g., no aspirin before diagnostic catheterization, inadequate trial of antianginal therapy, and inadequate hydration).

noninvasive testing before coronary angiography, adequacy of medical therapy, and extent of anatomic CAD. The document makes no explicit statement about ad hoc PCI but implies several principles. The AUC imply that ad hoc PCI is appropriate for many patients with ACS, particularly those with ongoing ischemia. The AUC also suggest that patients with stable moderate/severe angina who are optimally treated medically and have moderate/high-risk findings on ischemic testing are generally suitable candidates for PCI, although they do not specify timing. In contrast, the AUC suggest that, for patients without severe symptoms, prior functional testing confirming ischemia, and/or an attempt to provide optimal medical therapy, PCI is generally inappropriate. The AUC note that fractional flow reserve (FFR) or intravascular ultrasound (IVUS) are acceptable substitutes for noninvasive testing before angiography to confirm that a target lesion is sufficiently severe to warrant PCI if a functional test was not performed before angiography.2,28,29 The AUC do not discuss timing of PCI, but a logical extension of the concept of appropriateness is that, when appropriateness of a procedure is uncertain, it should be delayed until indications are clarified.

AD HOC PCI FOR SPECIFIC PATIENT SUBSETS

ST-Segment Elevation Myocardial Infarction

Ad hoc PCI of the infarct-related artery within 12 hr in symptomatic patients with STEMI has a class I indication in the 2011 PCI guidelines.2 The 2011 PCI guidelines rate PCI of nonculprit lesions at the time of primary PCI as a class III recommendation2 due to evidence that the strategy increases adverse events.30

Cardiogenic Shock

Revascularization decreases the mortality of STEMI patients with cardiogenic shock complicating ACS.31 Ad hoc PCI of the infarct artery is appropriate. Ad hoc PCI of more than one lesion may be appropriate if the culprit cannot be identified with certainty. Among patients with hemodynamic stabilization after PCI of the infarct artery, ad hoc PCI of noninfarct artery stenoses correlates with poorer outcomes.32 If shock persists despite PCI of the culprit lesion, ad hoc PCI of nonculprit lesions may be helpful if they are flow limiting at rest and supply a large risk region.33

NSTE-ACS

The 2011 PCI guidelines give a class I recommendation for an early invasive strategy defined as diagnostic angiography with the intention to perform PCI for patients with NSTE-ACS who are at increased risk for clinical events or who have refractory angina, hemodynamic compromise, or electrical instability.2 While these guidelines do not specifically advocate ad hoc PCI in these situations, it is commonly used to provide the revascularization as recommended in these guidelines. Plaque rupture apparent on angiography or IVUS may occur in multiple sites,34 warranting PCI of multiple lesions if the culprit cannot be identified or if more than one is suspected to be a culprit. Routine ad hoc PCI of nonculprit arteries in ACS may be of benefit.35–37 In a survey of 411 interventional cardiologists regarding PCI of nonculprit lesions in patients with ACS, 42% recommended ad hoc PCI, 37% recommended delayed PCI, and 14% recommended PCI of nonculprit lesions only if the patient experienced recurrent ischemia after PCI of the culprit lesion.38

Stable Ischemic Heart Disease

The 2011 PCI guidelines and 2012 AUC provide guidance for PCI in SIHD.2,3 In general, either ad hoc or delayed PCI is appropriate for symptom relief when patients are on optimal medical therapy, have symptoms limiting their quality of life, have evidence of ischemia in the target artery by stress testing or FFR, and have undergone informed consent. Among patients with SIHD, the AUC give the highest ratings of appropriateness (8 or 9 on a scale of 1 to 9) to those with the most severe symptoms and largest areas of myocardium at risk. These patients are the most likely to benefit from PCI,25 and indications to perform ad hoc PCI

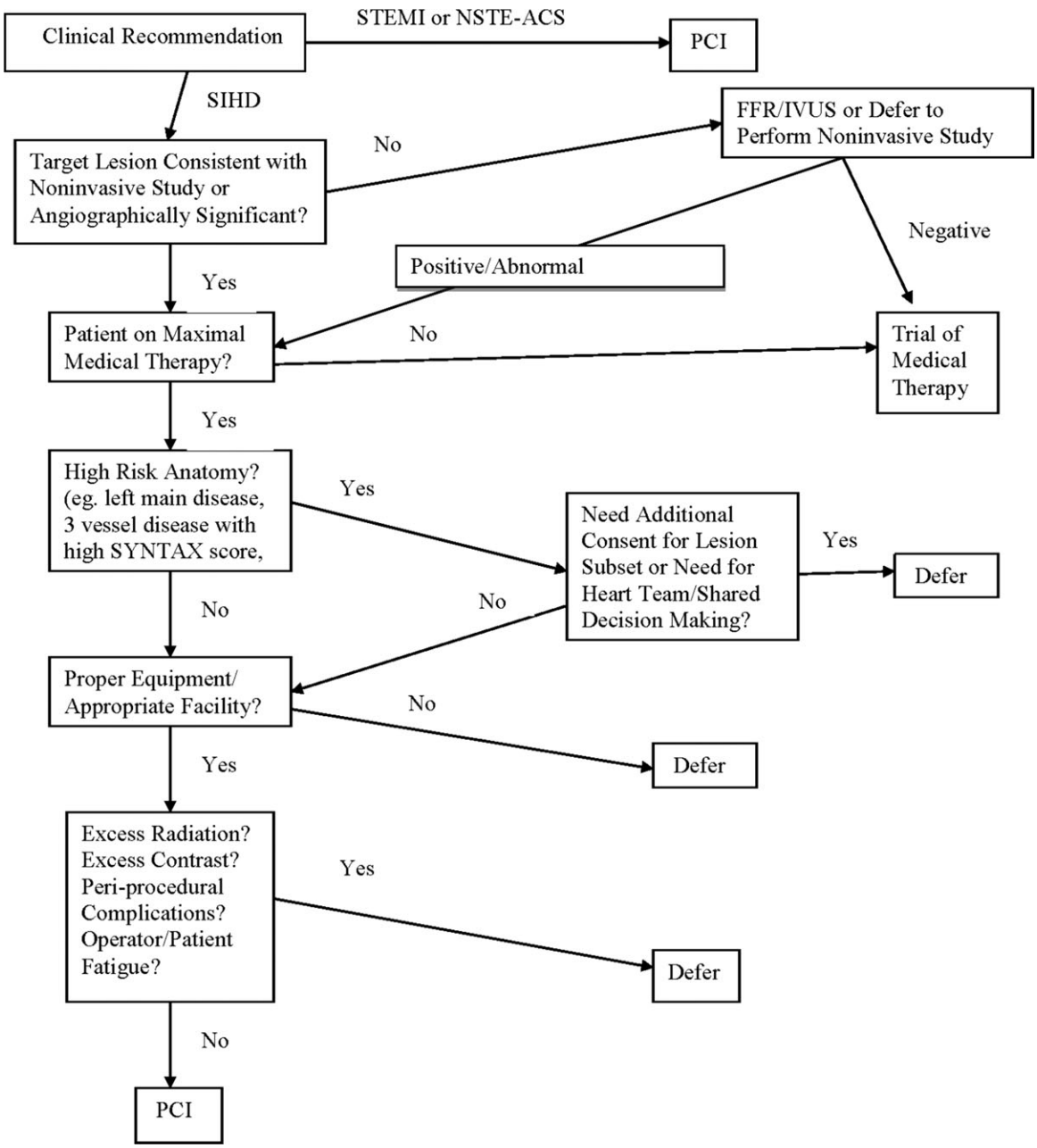

Fig. 1. Decision flow chart for ad hoc PCI. STEMI, ST elevation myocardial infarction; NSTE-ACS, non-ST elevation acute coronary syndrome; PCI, percutaneous coronary intervention.

are clearer than in patients with less severe symptoms or ischemia. Ad hoc PCI may be inappropriate if complications have occurred during the diagnostic catheterization, excessive radiation or contrast were used, the significance of a lesion cannot be determined, or a heart team approach is indicated to identify the best strategy for treatment of complex coronary disease.

FFR performed immediately after diagnostic angiography can help distinguish lesions that are hemodynamically significant and, therefore, appropriate for ad hoc PCI.29 IVUS may be useful in assessing the severity of coronary lesions, but it is not able to assess functional or hemodynamic significance, and there is no consensus on the criteria that define a hemodynamically significant lesion.2,39,40

Decisions about ad hoc PCI for multivessel CAD are complex since angiography may overestimate28 and stress imaging may underestimate41 the number of significant lesions. FFR-guided PCI produces better outcomes than angiographically guided PCI for multivessel CAD.28 A strategy of partial revascularization with ad hoc PCI followed by a repeat procedure targeting

other lesions if clinically indicated is reasonable for some patients.42

Patients Requiring Complex PCI Techniques

PCI involving complex techniques (e.g., requiring left ventricular support devices or involving unprotected left main lesions) is relatively uncommon (i.e., <5% of cases) in most interventional practices. It is appropriate only if the patient has undergone informed consent specifically addressing the increased risks usually associated with these procedures. For anatomically complex PCI [e.g., moderate-high SYNTAX score patients, chronic total occlusions, or complex bifurcation stenting (e.g., Medina class 1,1,1 lesions)], ad hoc PCI is less likely to be appropriate than for simpler lesions.43 Ad hoc PCI should not be performed if there is a reasonable likelihood of needing adjunctive therapy not available onsite (e.g., rotational atherectomy, percutaneous left ventricular support device, or CABG).

Contrast and Radiation Dose

Contrast-induced nephropathy correlates with contrast dose, may be predicted,44 and should be considered before proceeding with ad hoc PCI. It is prudent to limit total contrast dose to less than 3.7 times the estimated glomerular filtration rate.45 Excessive radiation may cause injuries46 and should be avoided.47 Total radiation dose for 1 day should not exceed 4–6 grays, particularly in patients at high risk of radiation injury. If ad hoc PCI is likely to exceed these limits of contrast or radiation, delayed PCI may be preferable.

REQUIREMENTS FOR AD HOC PCI

Ad hoc PCI should be performed only as part of a comprehensive, multidisciplinary institutional program that ensures (1) an informed consent process that involves the patient in shared decision making; (2) availability of data to determine the appropriateness of PCI; (3) tools for the assessment of periprocedural patient risk; (4) capability of administering appropriate adjunctive pharmacotherapy; and (5) flexibility in scheduling of patients and the physician operator.

Patient Consent

Informed consent for ad hoc PCI must be obtained before conscious sedation for cardiac catheterization. It should include discussions with the patient about advance directives and the goals, risks, alternatives, and risks of the alternatives to PCI. The discussion as well as the patient's wishes regarding ad hoc PCI should be documented. Patients tend to overestimate the benefits of procedures and underestimate the success of medical therapy.48 It is the operator's responsibility to ensure that the patient has an accurate understanding of the benefits of alternative therapies. Operators who perform ad hoc PCI for multivessel CAD, high-risk anatomy, or high-risk clinical situations must include the increased risk of these situations in the informed consent discussion. However, since patients cannot give informed consent on the table under sedation, any circumstances not anticipated in preprocedural informed consent discussions should lead to termination of the diagnostic procedure without proceeding to ad hoc PCI.

The ideal informed consent process should (1) precede the procedure by enough time for the patient to ask questions and consult with family and caregivers and should be confirmed immediately before the procedure; (2) be patient centered, using a shared decision-making model involving a two-way exchange of all relevant medical and personal information between the physician and patient (and potentially others) in a collaborative approach; and (3) be patient specific, with estimates of risk and benefit based on the patient's unique characteristics.25,49 Validated prediction models have been developed to assist clinicians in estimating procedural risk and PCI outcome before PCI.50 Tools are available to help evaluate the appropriateness of PCI prior to diagnostic catheterization so that when the anatomy becomes known, the appropriateness of PCI can easily be ascertained.49

Data Needed to Determine Appropriateness of PCI

Programs performing ad hoc PCI should ensure that information critical for determining the appropriateness of PCI is available, including (1) clinical presentation and severity of angina or angina equivalent symptoms; (2) extent and severity of myocardial ischemia assessed by noninvasive testing or FFR; (3) extent of antianginal medical therapy; (4) coronary anatomy; and (5) knowledge of the patient's wishes obtained during the informed consent discussion.

Patient Risk Assessment

Comprehensive patient risk assessment is a fundamental component of ad hoc PCI programs. The procedural risks (short-term and long-term) must be anticipated while obtaining informed consent and should be discussed with the patient during the shared decision-making process. These risks also must be reassessed when new data emerge (e.g., after diagnostic angiography). Examples of risks that should be considered include major complications of intervention including death, MI, stroke, contrast nephropathy, radiation skin burns, restenosis, stent thrombosis, and early and late bleeding. This assessment should

TABLE III. Payments to Physicians for Ad Hoc Diagnostic Catheterization/PCI Versus Diagnostic Catheterization and Delayed PCI in 2012

		Physician reimbursement			Hospital/facility reimbursement	
Procedure	CPT codes	Physician work RVUs	Total RVUs[a]	Physician medicare payment[b]	APC payment	DRG payment
Separate-session/separate day diagnostic catheterization and PCI						
Coronary angiography and left heart catheterization	93458	5.85	9.28		(APC 0080) $2,718.42	DRG 248: $16,553 or DRG 249: $10,210
Coronary stent	92980	14.82	24.61		(APC 0104) $5,689.41	
Total		20.67	33.89	$1153.53	$8,407.83	
Same-session diagnostic catheterization and PCI (reimbursement for catheterization/arteriography is reduced by 50%)						
Coronary angiography and left heart catheterization	93458	5.85	9.28 @ 50% = 4.63		(APC 0080) $2,718.42 @ 50% = $1,359.21	DRG 248: $16,553 or DRG 249: $10,210
Coronary Stent	92980	14.82	24.61		(APC 0104) $5,689.41	
Total		20.67	29.24	$995.26	$7,048.62	

New codes for PCI to be implemented January 1, 2013, will render these projections obsolete, but the magnitudes of differences among various scenarios are expected to remain similar. Data are from the 2012 National Physician Fee Schedule Relative Value File (RELEASED 12/21/2011) and Addendum B.-OPPS Payment by HCPCS Code for CY 2012.

[a]Includes physician work relative value units (RVUs), practice expense RVUs, and malpractice insurance RVUs.

[b]National Average Based on 2012 Conversion factor $34.0376.DRG 248, diagnosis-related group for drug eluting stents; DRG 249, diagnosis-related group for bare metal stents; APC, ambulatory payment classifications; PCI, percutaneous coronary intervention.

also include the risks of alternative treatments (medical therapy and CABG). SCAI supports the use of validated tools for these assessments,23,51 which should be available to patient caregivers.50

Pretreatment

Patients considered for ad hoc PCI should be administered aspirin before diagnostic catheterization. Pretreatment with $P2Y_{12}$ inhibitors hours to days before PCI is ideal,52 although they can be also administered at the time of PCI, particularly if they are among those that act rapidly.53 Adequate hydration with normal saline should be provided before diagnostic catheterization if ad hoc PCI is to be considered,54 and lack of adequate hydration may be a relative contraindication to ad hoc PCI.

Scheduling

Ad hoc PCI after diagnostic catheterization will prolong the procedure and should be anticipated when the diagnostic procedure is scheduled. This requires flexibility in the catheterization laboratory schedule and operator schedules. If the invasive cardiologist performing diagnostic catheterization is not an interventionist, ad hoc PCI requires the availability of an interventionist. Ad hoc PCI should not be rushed because of scheduling issues.

CODING, COST, AND REIMBURSEMENT FOR AD HOC PCI

Coding

American Medical Association Current Procedural Terminology (CPT) coding guidelines indicate that, when diagnostic angiography is followed on a different day by delayed PCI, diagnostic angiography may not be coded again along with the PCI. Only if the patient's condition has changed such that repeat diagnostic angiography is necessary (e.g., interim MI), can diagnostic angiography be coded again before the PCI.

Cost and Reimbursement

Two studies have studied cost of ad hoc PCI versus diagnostic angiography with delayed PCI. Panchamukhi and Flaker found that ad hoc PCI reduced total costs by 16% ($P < 0.0001$) and Adele et al.55 found that ad hoc PCI with stents reduced cost by 19% ($P < 0.05$).

Medicare payment policies reduce payment for diagnostic catheterization by 50% when it is performed on the same day as PCI by the same physician or by a member of the same physician's group (Table III). Diagnostic catheterization performed on a separate day from PCI is not discounted. Total Medicare reimbursement to hospitals and physicians is greater when PCI is performed on a different day than diagnostic catheterization (Table III). Reimbursement should not influence the timing of PCI. The patient's interests should drive decisions on whether and when to perform PCI.

RELEVANT ETHICAL PRINCIPLES

The three important principles of medical ethics are beneficence (doing what is best for the patient and avoiding harm), autonomy (respecting and facilitating the patient's right and ability to make informed decisions about their own care), and justice (considering how the patient's treatment will affect others in the healthcare system).

Beneficence

Decisions on whether to perform ad hoc versus delayed PCI should be made keeping the patient's welfare foremost. For example, convenience for the patient may favor the performance of ad hoc PCI when PCI is clearly indicated and can be performed quickly and safely. In contrast, safety may dictate delayed PCI when ad hoc PCI would require dangerous levels of radiation or contrast.44–47 The heart team approach may require delayed revascularization when diagnostic catheterization identifies complex multivessel CAD.2

Autonomy

Decisions for ad hoc versus delayed PCI should involve the patient through the informed consent process described above.49 The principles of autonomy and beneficence may conflict when patients prefer a convenient strategy (e.g., ad hoc PCI) rather than a safer or more effective strategy (e.g., delayed PCI or even CABG for complex multivessel CAD).48 In such cases, the physician should use clinical judgment combined with insightful communication with the patient to reach consensus on a course that is best for the patient.

Justice

Decisions for ad hoc versus delayed PCI should include consideration of how the patient's treatment might affect others. For example, delaying PCI may be more appropriate than forcing other scheduled patients to wait long periods while ad hoc PCI is performed. Care of acutely ill patients may dictate delays in care for stable patients (e.g., PCI of a STEMI patient taking precedence over an ad hoc PCI).

RECOMMENDATIONS AND CONCLUSIONS

PCI for ACSs

Ad hoc PCI should be the default strategy for patients with STEMI and with NSTE-ACS. Ad hoc PCI of nonculprit lesions should not be performed routinely during primary PCI, may be appropriate in cardiogenic shock if these conditions are contributing to ischemia, and may be appropriate in ACS.

PCI for SIHD

Ad hoc PCI for SIHD should be considered, and has the greatest benefit, when optimal medical therapy for CAD has failed to adequately control patients' symptoms and large areas of myocardium are potentially ischemic. For patients who have not failed a trial of optimal medical therapy before diagnostic catheterization, the benefits of ad hoc PCI should be compared with the benefits of a trial of optimal medical therapy. It should be recognized that PCI in these patients may be rated as inappropriate by the AUC. Ad hoc PCI is appropriate when indications for PCI are present and other requirements for ad hoc PCI described above are met.

PCI for Multivessel Complex and/or Unprotected Left Main SIHD

Ad hoc PCI for complex multivessel or unprotected left main SIHD should be reserved for unusual circumstances in which surgical consultation has already occurred or is clearly not an appropriate consideration due to comorbidities or other factors, and the patient has been fully informed regarding benefits and above-normal risks.

Informed Consent

Ad hoc PCI should be considered only if informed consent included the risks and benefits of PCI appropriate for the patient and for the extent of CAD identified, as well as the risks and benefits of alternative treatments.

Regulatory and Reimbursement Status

Third-party payers and quality auditors should recognize that ad hoc PCI is appropriate in many situations, and delayed PCI is more appropriate in other situations.

Patient Autonomy

When patient preference (e.g., for ad hoc PCI) conflicts with optimal efficacy/safety (e.g., favoring delayed PCI), the physician should use clinical judgment combined with insightful communication with the patient to reach consensus on a course that is best for the patient.

Future Research

The trends, guidelines, and appropriate use criteria discussed in this article may change the incidence of ad hoc versus delayed PCI and may change the characteristics of patients in these groups. Analyses of large databases should be undertaken in the future to assess changes in practice and outcomes associated with these strategies.

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REFERENCES

1. Redberg RF. Informed strategies for treating coronary disease. Arch Intern Med 2012;172:321.
2. Levine GN, Bates ER, Blankenship JC, Bailey SR, Bittl JA, Cercek B, Chambers CE, Ellis SG, Guyton RA, Hollenberg SM, Khot UN, Lange RA, Mauri L, Mehran R, Moussa ID, Mukherjee D, Nallamothu BK, Ting HH. 2011 ACCF/AHA/SCAI Guideline for percutaneous coronary intervention: executive summary: A report of the American College of Cardiology Foundation/American Heart Association Task Force on practice guidelines and the society for cardiovascular angiography and interventions. Circulation 2011;124:2574–2609.
3. 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.
4. Blankenship JC, Klein LW, Laskey WK, Krone RJ, Dehmer GJ, Chambers C, Cowley M. SCAI statement on ad hoc versus the separate performance of diagnostic cardiac catheterization and coronary intervention. Catheter Cardiovasc Interv 2004;63:444–451.
5. Feldman RL, Macdonald RG, Hill JA, Conti R, Pepine CJ, Carmichael MJ, Knauff DG, Alexander JA. Coronary angioplasty at the time of initial cardiac catheterization. Cathet Cardiovasc Diagn 1986;12:219–222.
6. Myler RK, Stertzer SH, Clark DA, Shaw RE, Fishman-Rosen J, Murphy MC. Coronary angioplasty at the time of initial cardiac catheterization. Cathet Cardiovasc Diagn 1986;12:213–214.
7. Breisblatt WM, Ruffner RJ, Uretsky BF, Reddy PS. Same-day angioplasty and diagnostic catheterization: safe and effective but riskier in unstable angina. Angiology 1991;8:607–613.
8. O'Keefe JH, Reeder GS, Miller GA, Bailey KR, Holmes DR. Safety and efficacy of percutaneous transluminal coronary angioplasty performed at time of diagnostic catheterization compared with that performed at other times. Am J Cardiol 1989; 63:27–29.
9. O'Keefe JH, Gernon C, McCallister BD, Ligon RW, Hartzler GO. Safety and cost effectiveness of ad hoc coronary angiography and angioplasty. Am Heart J 1991;122:50–54.
10. Lund GK, Nienaber CA, Hamm CW, Terres W, Kuck KH. One session diagnostic heart catheterization and balloon dilatation ("prima-vista"-PTCA): Results and risks. Dtsch Med Wochenschr 1994;119:169–174.
11. Rozenman Y, Gilon D, Zelingher J, Lotan C, Mosseri M, Geist M, Weiss AT, Hasin Y, Gotsman MS. One-stage coronary angiography and angioplasty. Am J Cardiol 1995;75:30–33.
12. Kimmel SE, Berlin JE, Hennessy S, Strom BL, Krone RJ, Laskey WK. Risk of major complications from coronary angioplasty performed immediately after diagnostic coronary angiography: Results from the Registry of the Society for Cardiac Angiography and Interventions. J Am Coll Cardiol 1997;30:193–200.
13. Le Feuvre C, Helft G, Beygui F, Zerah T, Fonseca E, Catuli D, Batisse JP, Metzger JP. Safety, efficacy, and cost advantages of combined coronary angiography and angioplasty. J Interv Cardiol 2003;16:195–199.
14. Panchamukhi V, Flaker GC. Should interventional cardiac catheterization procedures take place at the time of diagnostic procedures? Clin Cardiol 2000;23:332–334.
15. Shubrooks SJ, Malenka DJ, Piper WD, Bradley WA, Watkins MW, Ryan TJ, Hettleman BD, VerLee PN, O'Meara JR, Robb JF, Kellett MA, Hearne MA, McGrath PD, Wennberg DE, O'Rourke DJ, Silver TM. Safety and efficacy of percutaneous coronary interventions performed immediately after diagnostic catheterization in northern New England and comparison with similar procedures performed later. Am J Cardiol 2000;86:41–45.
16. Goldstein CL, Racz M, Hannan EL. Impact of cardiac catheterization-percutaneous coronary intervention timing on in-hospital mortality. Am Heart J 2002;144:561–567.
17. Feldman DN, Minutello RM, Gade CL, Wong SC. Outcomes following immediate (ad hoc) versus staged percutaneous coronary interventions (Report from the 2000 to 2001 New York State Angioplasty Registry). Am J Cardiol 2007;99:446–449.
18. Krone RJ, Shaw RE, Klein LW, Blankenship JC, Weintraub WS; American College of Cardiology. Ad hoc percutaneous coronary interventions in patients with stable coronary artery disease—a study of prevalence, safety, and variation in use from the American College of Cardiology National Cardiovascular Data Registry (ACC-NCDR). Catheter Cardiovasc Interv 2006;68:696–703.
19. Hannan EL, Samadashvili Z, Walford G, Holmes DR, Jacobs A, Sharma S, Katz S, King SB. Predictors and outcomes of ad hoc versus non-ad hoc percutaneous coronary interventions. JACC Cardiovasc Interv 2009;2:350–356.
20. Good CW, Blankenship JC, Scott TD, Skelding KA, Berger PB, Wood GC. Feasibility and safety of ad hoc percutaneous coronary intervention in the modern era. J Invasive Cardiol 2009; 21:194–200.
21. Fox KA, Clayton TC, Damman P, Pocock SJ, de Winter SJ, Tijssen SGP, Lagerqvist B, Wallentin L. Long-term outcome of a routine versus selective invasive strategy in patients with non-ST-segment elevation acute coronary syndrome a meta-analysis of individual patient data. J Am Coll Cardiol 2010;55: 2435–2445.
22. Boden WE, O'Rourke RA, Teo KK, Hartigan PM, Maron DJ, Kostuk WJ, Knudtson M, Dada M, Casperson P, Harris CL, Chaitman BR, Shaw L, Gosselin G, Nawaz S, Title LM, Gau G, Blaustein AS, Booth DC, Bates ER, Spertus JA, Berman DS, Mancini GB, Weintraub WS; COURAGE Trial Research Group. Optimal medical therapy with or without PCI for stable coronary disease. N Engl J Med 2007;356:1503–1516.
23. Serruys PW, Morice MC, Kappetein AP, Colombo A, Holmes DR, Mack MJ, Stahle E, Feldman TE, van den Brand M, Bass EJ, Van Dyck N, Leadley, K, Dawkins KD, Mohr FW. SYNTAX Investigators. Percutaneous coronary intervention versus coronary-artery bypass grafting for severe coronary artery disease. N Engl J Med 2009;360:961–972.
24. Nallamothu B, Krumholz HM. Putting ad hoc PCI on pause. JAMA 2010;304:2059–2060.
25. Blankenship JC, Marshall JJ, Pinto DS, Lange RA, Bates ER, Holper EM, Grines CL, Chambers CE. Effect of percutaneous coronary intervention on quality of life: A consensus statement from the Society for Cardiovascular Angiography and Intervention. Cathet Cardiovasc Interv 2012;DOI: 10.1002/ccd.24376.
26. Guidelines for percutaneous transluminal coronary angioplasty. A report of the American College of Cardiology/American

Heart Association Task Force on Assessment of Diagnostic and Therapeutic Cardiovascular Procedures (Subcommittee on Percutaneous Transluminal Coronary Angioplasty). J Am Coll Cardiol 1988;12:529–545.
27. Smith SC Jr, Dove JT, Jacobs AK, Kennedy JW, Kereiakes D, Kern MJ, Kuntz RE, Popma JJ, Schaff HV, Williams DO, Gibbons RJ, Alpert JP, Eagle KA, Faxon DP, Fuster V, Gardner TJ, Gregoratos G, Russel RO. ACC/AHA guidelines of percutaneous coronary interventions (revision of the 1993 PTCA guidelines). J Am Coll Cardiol 2001;37:2215–2239.
28. Tonino P, De Bruyne B, Pijls N, Siebert U, Ikeno F, van't Veer M, Klauss V, Manoharan G, Engstrom T, Oldroyd K, Ver Lee P, MacCarthy P, Fearon W. Fractional flow reserve versus angiography for guiding percutaneous coronary intervention. N Engl J Med 2009;360:213–224.
29. Pijls NH, van Schaardenburgh P, Manoharan G, Boersma E, Bech JW, van't Veer M, Bar F, Hoorntie J, Koolen J, Wijns W, de Bruyne B. Percutaneous coronary intervention of functionally non-significant stenosis: 5-year follow-up of the DEFER study. J Am Coll Cardiol 2007;49:2105–2111.
30. Vlaar PJ, Mahmoud KD, Holmes DR, van Valkenhoef G, Hillege HL, van der Horst ICC, Zilstra F, de Smet BJGL. Culprit vessel only versus multivessel and staged percutaneous coronary intervention for multivessel disease in patients presenting with ST-segment elevation myocardial infarction: a pairwise and network meta-analysis. J Am Coll Cardiol 2011;58:692–703.
31. Hochman JS, Sleeper LA, Webb JG, Dzavik V, Buller CE, Aylward P, Col J, White HD. Early revascularization and long-term survival in cardiogenic shock complicating acute myocardial infarction. JAMA 2006;295:2511–2515.
32. Webb JG, Lowe AM, Sanborn TA, Sleeper LA, Carere RG, Buller CE, Slater JN, Baran KW, Koller PT, Talley D, Porway M, Hochman JS. Percutaneous coronary intervention for cardiogenic shock in the SHOCK trial. J Am Coll Cardiol 2003;42:1380–1386.
33. Reynolds HR, Hochman JS. Cardiogenic shock: current concepts and improving outcomes. Circulation 2008;117:686–697.
34. Rioufol G, Finet G, Ginon I, Andre-Fouet X, Rossi R, Vialle E, Desjoyaux E, Convert G, Huret JF, Tabib A. Multiple atherosclerotic plaque rupture in acute coronary syndrome: A three--vessel intravascular ultrasound study. Circulation 2002;106:804–808.
35. Shishehbor MH, Lauer MS, Singh IM, Chew DP, Karha J, Brener SJ, Moliterno DJ, Ellis SG, Topol EJ, Bhatt DL. In unstable or non-ST-segment acute coronary syndrome, should patients with multi-vessel coronary artery disease undergo multi-vessel or culprit-only stenting? J Am Coll Cardiol 2007;49:849–854.
36. Ijsselmuiden AJ, Ezechiels J, Westendorp ICD, Tijssen JGP, Kiemeneij F, Slagboom T, van der Wieken R, Tangelder G, Serruys PW, Laarman G. Complete versus culprit vessel percutaneous coronary intervention in multivessel disease: A randomized comparison. Am Heart J 2004;148:467–474.
37. Palmer ND, Causer JP, Ramsdale DR, Perry RA. Effect of completeness of revascularization on clinical outcome in patients with multivessel disease presenting with unstable angina who undergo percutaneous coronary intervention. J Invasive Cardiol 2004;16:185–188.
38. Dangas GD, George JC, Weintraub W, Popma JJ. Timing of staged percutaneous coronary intervention in multivessel coronary artery disease. JACC Cardiovasc Interv 2010;3:1096–1099.
39. Ahn JM, Kang SJ, Mintz GS, Oh JH, Kim WJ, Lee JY, Park DW, Lee SW, Kim YH, Lee CW, Park SW, Moon DH, Park SJ. Validation of minimal luminal area measured by intravascular ultrasound for assessment of functionally significant coronary stenosis comparison with myocardial perfusion imaging. JACC Cardiovasc Interv 2011;4:665–671.
40. Kang SJ, Lee JY, Ahn JM, Mintz GS, Kim WJ, Park DW, Yun SC, Lee SW, Kim YH, Lee CW, Park SW, Park SJ. Validation of intravascular ultrasound-derived parameters with fractional flow reserve for assessment of coronary stenosis severity. Circ Cardiovasc Interv 2011;4:65–71.
41. Melikian N, De Bondt P, Tonino P, De Winter O, Wyffels E, Bartunek J, Heyndrickx GR, Fearon WF, Pijls NH, Wijns W, De Bruyne B. Fractional flow reserve and myocardial perfusion imaging in patients with angiographic multivessel coronary artery disease. JACC Cardiovasc Interv 2010:307–314.
42. Blankenship JC, Moussa I, Brilakis ES, Chambers CE, Dehmer G, Morrison D. Staging of multi-vessel percutaneous coronary interventions. A consensus statement from the Society for Cardiovascular Angiography and Interventions. Cathet Cardiovasc Interv 2012;79:1138–1152.
43. de Labriolle A, Bonello L, Roy P, Lemesle G, Steinberg DH, Xue Z, Kaneshige K, Suddath WO, Satler LF, Kent KM, Pichard AD, Lindsay J, Waksman R. Comparison of safety, efficacy, and outcome of successful versus unsuccessful percutaneous coronary intervention in "true" chronic total occlusions. Am J Cardiol 2008;102:1175–1181.
44. Mehran R, Aymong ED, Nikolsky E, Lasic Z, Iakovou I, Fahy M, Mintz GS, Lansky AJ, Moses JW, Stone GW, Leon MB, Dangas G. A simple risk score for prediction of contrast-induced nephropathy after percutaneous coronary intervention: Development and initial validation. J Am Coll Cardiol 2004;44:1393–1399.
45. Laskey WK, Jenkins C, Selzer F, Marroquin OC, Wilensky RL, Glaser R, Cohen HA, Holmes DR. A pharmacokinetically-based risk factor for prediction of early creatinine increase after percutaneous coronary intervention. J Am Coll Cardiol 2007;50:584–590.
46. Frazier TH, Richardson JB, Fabre VC, Callen JP. Fluoroscopy-induced chronic radiation skin injury: A disease perhaps often overlooked. Arch Dermatol 2007;143:637–640.
47. Chambers CE, Fetterly KA, Holzer R, Lin PJP, Blankenship JC, Balter S, Laskey WK. Radiation safety program for the cardiac catheterization laboratory. Catheter Cardiovasc Interv 2011;77:546–556.
48. Blankenship JC. Progress towards doing the right thing. JACC Cardiovasc Interv 2012;5:236–237.
49. Arnold SV, Decker C, Ahmad H, Olabiyi O, Mundluru S, Reid KJ, Soto GE, Gansert S, Spertus JA. Converting the informed consent from a perfunctory process to an evidence-based foundation for patient decision making. Circ Cardiovasc Qual Outcomes 2008;1:21–22.
50. Peterson ED, Dai D, DeLong ER, Brennan JM, Singh M, Rao SV, Shaw RE, Roe MT, Ho KK, Klein LW, Krone RJ, Weintraub WS, Brindis RG, Rumsfeld JS, Spertus JA; NCDR Registry Participants. Contemporary mortality risk prediction for percutaneous coronary intervention: results from 588,398 procedures in the National Cardiovascular Data Registry. J Am Coll Cardiol 2010;55:1923–1932.
51. Nam CW, Mangiacapra F, Enties R, Chung IS, Sels JW, Tonino PAL, De Bruyne B, Pijls NHJ, Fearon WF. Functional SYNTAX score for risk assessment in multivessel coronary artery disease. J Am Coll Cardiol 2011;58:1211–1218.
52. Hochholzer W, Trenk D, Frundi D, Blanke P, Fischer B, Andris K, Bestehorn HP, Büttner HJ, Neumann FJ. Time dependence

of platelet inhibition after a 600-mg loading dose of clopidogrel in a large, unselected cohort of candidates for percutaneous coronary intervention. Circulation 2005;111:2560–2564.

53. Montalescot G, Wiviott SD, Braunwald E, Murphy SA, Gibson CM, McCabe CH, Antman EM. Prasugrel compared with clopidogrel in patients undergoing percutaneous coronary intervention for ST-elevation myocardial infarction (TRITON-TIMI 38): Double-blind, randomised controlled trial. 2009;373:723–731.
54. Klima T, Christ A, Marana I, Kalbermatter S, Uthoff H, Burri E, Hartwiger S, Schindler C, Breidthardt T, Marenzi G, Mueller C. Sodium chloride vs. sodium bicarbonate for the prevention of contrast medium-induced nephropathy: A randomized controlled trial. Eur Heart J 2012;33:2071–2079.
55. Adele C, Vaitkus PT, Wells SK, Zehnacker JB. Cost advantages of an ad hoc angioplasty strategy. J Am Coll Cardiol 1998;31: 321–325.