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Clinical Decision Making

Staging of Multivessel Percutaneous Coronary Interventions: an Expert Consensus Statement from the Society for Cardiac Angiography and Interventions

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Percutaneous coronary interventions (PCIs) to treat multivessel coronary artery disease (MVCAD) may involve single-vessel or multivessel interventions, performed in one or more stages. This consensus statement reviews factors that may influence choice of strategy and includes six recommendations to guide decisions regarding staging of PCI [1]. Every patient who undergoes PCI should receive optimal therapy for coronary disease, ideally before starting the procedure [2]. Multivessel PCI at the time of diagnostic catheterization should be considered only if informed consent included the risks and benefits of multivessel PCI and the risks and benefits of alternative treatments [3]. When considering multivessel PCI, the interventionist should develop a strategy regarding which stenoses to treat or evaluate, and their order, method, and timing. This strategy should maximize patient benefits, minimize patient risk, and consider the factors described in this article [4]. For planned multivessel PCI, additional vessel(s) should be treated only if the first vessel is treated successfully and if anticipated contrast and radiation doses and patient and operator conditions are favorable [5]. After the first stage of the planned multistage PCI, the need for subsequent PCI should be reviewed before it is performed [6]. Third party payers and quality auditors should recognize that multistage PCI for MVCAD is neither an indication of poor quality nor an attempt to increase reimbursement when performed according to recommendations in this article.

Key words: stenting; percutaneous coronary intervention; staging

INTRODUCTION

Percutaneous coronary interventions (PCIs) to treat multivessel coronary artery disease (MVCAD) may involve single-vessel or multivessel interventions, performed in one or more stages. The choice of strategy may influence safety, efficacy, convenience for the patient, cost, and reimbursement. In some cases, careful consideration will lead to a single-vessel PCI with other lesions managed medically; in other cases, such consideration leads to multivessel PCI in the same procedure or in multiple stages. Although guidelines and appropriate use criteria (AUC) provide guidance regarding PCI for multivessel disease, none of these documents offer comprehensive recommendations for one-stage versus multistage approaches [1–3]. The purpose of this article is to offer guidance regarding the selection of optimal PCI strategies in patients with multivessel disease.

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Incidence of Multivessel PCI

MVCAD was present in 40–50% of patients undergoing PCI in the 1980s, and this percentage has remained stable since then [4,5]. PCI was performed on more than one artery in 15–20% of PCI patients in the 1980s, and this percentage has also remained stable [5].

Incidence of Multisession PCI

The prevalence of staged procedures to treat MVCAD is not precisely known. Curtis et al. analyzed 315,241 PCI procedures in Medicare patients, noting that 14.6% were readmitted within 30 days. Of these, 26% (4% of the total PCI cohort) had a revascularization procedure, and 84% had a primary diagnosis of chronic ischemic heart disease (3% of the total PCI cohort). Thus by extrapolation, about 3% of PCI patients were probably readmitted for planned additional revascularization (i.e., staged PCI) either after an initial ST elevation myocardial infarction (STEMI) or after a PCI for other indications [6].

Among patients with MVCAD who presented with STEMI in the New York State PCI registry, 87% underwent PCI of the culprit vessel only and 13% underwent multivessel intervention at the time of the primary PCI. Of patients who underwent culprit vessel PCI only, 23% returned for elective staged PCI to treat residual coronary disease [7]. Similar findings were reported from the Global Registry of Acute Coronary Events registry, with 18% of patients returning for elective staged procedures [8].

An American College of Cardiology survey of 441 cardiologists in 2010 found that the most common reasons for staging multivessel PCI were poor renal function, contrast dose, lesion complexity, and the presence of acute coronary syndrome [9]. The least frequent reason was administrative, including penalties for readmission and insurance status.

Staged Procedures in Other Specialties

Precedents of staging of interventional procedures can be found in other fields of medicine but there seems to be no evidence that one-stage procedures are more or less dangerous than multistage procedures [10–14].

IDENTIFICATION OF MULTIVESSEL CORONARY DISEASE

Definitions of Significant Coronary Disease in Non-left Main Coronary Arteries

Staging PCI over multiple sessions is only an issue when multiple arteries have significant lesions. Most of the previous guidelines have defined "significant" as a particular degree of angiographic stenosis. The 2002 guidelines for the management of chronic stable angina [3] define 70% stenosis as significant. The 2004 coronary artery bypass graft surgery (CABG) guidelines [15] use 50%, and the 2005 PCI guidelines [16] state only that a lesion $<50\%$ is not significant. The European Society of Cardiology 2005 stable angina guidelines [17] do not provide a specific definition [16], whereas the European Society of Cardiology PCI guidelines define 50–70% stenosis as "borderline" significant [18]. More recent guidelines define significant coronary disease as lesions $>70\%$ by angiography, or lesions that are hemodynamically significant by stress testing, fractional flow reserve (FFR), or intravascular ultrasound [19,20].

Many of the studies on which current guidelines are based are listed in Table I. About half use 50% as a threshold for lesion significance and the other half use 70%. Many large trials fail to report the percent stenosis that defined the significance of a lesion in their final publications.

Methods of Determining Significance of Coronary Disease

Angiographic percent stenosis is a notoriously poor measure of a lesion's functional significance. Interobserver variability in the interpretation of coronary angiograms further limits its utility as a gold standard [37,38]. Because PCI of nonsignificant lesions does not decrease major adverse events or improve symptoms [39,40] functional tests should be used to decide whether PCI is warranted for angiographically stable, intermediate severity (50–70%) lesions. Although most 50% stenoses by angiography are not functionally significant, several factors (eccentricity, length, or presence of serial lesions) can render a 50% stenosis hemodynamically significant [41–44].

Physiologic significance of a lesion can be demonstrated either noninvasively by stress testing or invasively. Many patients with stable coronary disease undergoing angiography will have functional testing results available. Stress imaging may underestimate the extent of significant coronary artery disease [42,45,46]. When precatheterization stress testing is not available or is thought to underestimate the severity of coronary disease, physiologic testing with FFR may be helpful. An FFR of <0.75 correlates well with ischemia on stress testing [40,42,47–50]. For patients with an FFR between 0.75 and 0.80, angina at follow-up was less prevalent in those who underwent PCI compared with those treated conservatively [50]. An FFR of >0.75 or >0.80 correlates with excellent long-term outcomes if PCI is deferred [40,43,51–53]. FFR has also been shown to predict physiologic significance of left main coronary lesions, although the data are not as robust [54–56].

TABLE I. Definitions of Significant Coronary Artery Disease in Various Studies and Guidelines

Publication/study	Lead author	Date	Angiographic definition of significant coronary disease
Guidelines			
2002 stable angina [3]	Gibbons	2002	≥70%
2005 PCI	Smith	2005	Not defined (but insignificant disease is defined as "less than 50%")
2005 European PCI [17]	Silber	2005	Not defined
2006 European stable angina [18]	Fox	2005	"Borderline"=50–70%
PCI Studies			
ACME [21]	Parisi	1992	≥70%
Rita-2 [22]	RITA-2 investigators	1997	≥50% in two views, or 70% in one view
VA Coop study [23]	Folland	1997	≥70%
AVERT [24]	Pitt	1999	≥50%
COURAGE [25]	Boden	2008	≥70%
PCI versus CABG			
Duke [26]	Whalen	1982	≥75%
EAST [27]	King	1994	≥50%
CABRI [28]	CABRI investigators	1995	50%
ERACI [29]	Rodriguez	1996	≥70%
French monocentric study [30]	Carrie	1997	≥70%
BARI [31]	BARI investigators	2000	≥50%
ERACI II [32]	Rodriguez	2001	≥70% is severe and 50% is significant
MASS II [33]	Hueb	2004	≥70%
Duke database [34]	Smith	2006	≥75%
Intermountain heart registry [35]	Bair	2007	≥60%
New England cardiovascular study group [36]	Dacey	2007	≥70%

The value of intravascular ultrasound (IVUS) for determining the physiologic significance of intermediate coronary lesions is less well established. A threshold of 3–4 mm^2 minimal cross-sectional area has been proposed [57–60]. Cross-sectional areas of <3 [57] and <4 mm^2 [58] correlate well with an FFR of <0.75. A cross-sectional area of <4 mm^2 correlated well with ischemia on myocardial perfusion imaging [59], and a cross-sectional area of >4 mm^2 predicted a benign course if PCI was deferred [60]. Compared with FFR-guided PCI, IVUS-guided PCI of intermediate coronary lesions resulted in significantly higher revascularization rates (33.7 vs. 91.5%) without differences in 1-year clinical outcomes [61].

STRATEGIES FOR MULTIVESSEL PCI

Complete Versus Incomplete Revascularization

Definition of complete revascularization. There is no universally accepted definition for complete revascularization (CR). Ong et al characterized CR as anatomic/unconditional (all stenotic vessels are revascularized), anatomic/conditional (all stenotic vessels greater than a certain diameter are revascularized), functional (all stenotic vessels supplying viable myocardium are revascularized), and numerical (for CABG, the number of graft anastomoses equals the number of major diseased vessels) [62].

CABG studies tend to define CR as a graft to each major coronary artery with >50% stenosis. PCI studies have defined CR to include arteries with diameter greater than 1.5 [63], 2.0 [64], 2.25 [65], or 2.75 mm [66] with >50 or >70% stenoses. The Writing Group suggests the following definition of CR relevant to PCI: "revascularization of all significant arteries (as assessed by the angiographer) that threaten viable myocardium with stenoses either >70% diameter narrowing by angiography or of hemodynamic significance by stress testing or invasive assessment." Artery size is not included in this definition, as there is no consensus on the size of an artery considered "significant," and artery caliber is difficult to assess due to the diffuse nature of atherosclerosis.

Outcomes after CR (vs. incomplete revascularization). CR is relevant to the extent that CR improves clinical outcomes. However, the clinical benefits of CR using angiographic criteria are uncertain, with some [65,67–70] but not all [71–73] studies reporting superior outcomes with CR. CR does reduce the incidence of subsequent CABG [66,74] or subsequent PCI [64] (Table II). CR using FFR testing to identify significant stenoses improved outcomes compared with CR based only on angiographic analysis [41]. If an incomplete PCI revascularization strategy is used, stress testing may identify a high-risk subset of patients for whom additional revascularization procedures reduce subsequent ischemic events [86,87].

TABLE II. Impact of Completeness of Revascularization by PCI on Subsequent Outcomes

Lead author	Date	*n*	Revascularization technique	Presentation	CR (%)	Follow-up time (years)	Complete versus incomplete revascularization
Bell [75]	1990	867	Balloon angioplasty	Stable angina	41	2.2	Similar incidence of death. Angina and CABG more frequent with IR
Bourassa [72]	1998	757	Balloon angioplasty	Stable angina and ACS	17	9	Similar incidence of death and MI. CABG more frequent with IR
Bourassa [76]	1999	896	Balloon angioplasty	Stable angina and ACS	65	5	Similar incidence of death and MI
Mariani [73]	2001	208	Balloon angioplasty and bare metal stents	Stable angina and ACS	24	1	Similar incidence of death, MI, and repeat revascularization
Kloeter [77]	2001	250	Balloon angioplasty and bare metal stents	Stable CAD	40	2.5	Similar incidence of cardiac events. Revascularization less frequent with IR
Van den Brand [66]	2002	576	Bare metal stents	Stable angina and ACS	70	1	Similar incidence of death or MI. CABG more frequent with IR
Brener [78]	2002	290	Bare metal stents	NSTE ACS	23	0.5	Similar incidence of death or MI
Nikolsky [79]	2004	352	Balloon angioplasty and bare metal stents	Stable angina and ACS	26.7	3.1	Higher incidence of death with IR
Palmer [80]	2004	151	Bare metal stents	NSTE ACS	47		Similar incidence of death or MI. Angina more frequent with IR
Ijsselmuiden [64]	2004	219	Bare metal stents	Stable angina and ACS	51 (randomized trial)	4.6	Similar incidence of death, MI, CABG
Hannan [67]	2006	21,945	Bare metal stents	Stable CAD patients	31.1	3	Higher mortality with IR
Kong [69]	2006	1,982	Bare metal stents	Acute MI	32	In-hospital	Higher in-hospital mortality with IR
Kalarus [70]	2007	798	Bare metal and drug-eluting stents	Acute MI	24.2	1	Death and MACE more frequent with IR
Srinivas [71]	2007	1,781	Bare metal and drug-eluting stents	Both stable angina and ACS	17.7	1	Similar incidence of death and repeat revascularization
Shishehbor [68]	2007	1,240	Bare metal stents	NSTE ACS	39	2.3	Similar incidence of death and MI
Tamburino [65]	2008	508	Drug-eluting stents	Stable angina and ACS	41.7	2.25	Death, myocardial infarction, and target vessel revascularization more frequent with IR
Varani [81]	2008	399	Bare metal and drug-eluting stents	STEMI	46	30 days	Higher mortality with IR
Qarawani [82]	2008	120	Balloon angioplasty and bare metal stents	STEMI	79	1	Similar mortality. Reinfarction more frequent with IR
Hannan [83]	2009	11,294	Drug-eluting stents	Stable CAD patients	31	1.5	Higher mortality with IR
Yang [84]	2010	324	Bare metal and drug-eluting stents	ACS	31	1.5	Similar incidence of death, myocardial infarction, and repeat revascularization
Politi [85]	2010	214	Bare metal and drug-eluting stents	STEMI	66	2.5	More frequent MACE with IR

CR, complete revascularization; IR, incomplete revascularization; CABG, coronary artery bypass graft surgery, HR, hazard ratio; CI, confidence intervals; ACS, acute coronary syndrome; MI, myocardial infarction; NSTE, non-ST elevation; MACE, major adverse cardiac events.

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One-Stage Versus Multistage PCI for MVCAD

Multivessel PCI can be performed in one or multiple stages. The second stage of a multistage PCI may be planned or unanticipated. This article focuses only on multivessel PCI that is planned to occur during a single stage or multiple stages.

One-stage multivessel PCI is reasonable when the following conditions have been met: (a) multiple vessels have hemodynamically significant lesions (either angiographically severe or, if intermediate, proven by stress testing or invasive testing to be significant), (b) indications for PCI are present (e.g., to relieve symptoms in stable angina or to prevent death or recurrent ischemic events for acute coronary syndrome patients), (c) adequate informed consent was obtained and consideration of alternatives has occurred, (d) the first stage of PCI is uncomplicated and without excessive radiation or contrast doses, (e) the patient and the operator are willing to proceed with multivessel PCI, and (f) the impact of resulting delays for other patients and operators has been considered.

Strategies of one-stage versus multistage PCI are difficult to compare by retrospective analysis of large databases. Databases do not easily distinguish a planned staged PCI from an unplanned multisession PCI, where the second session is due to acute closure, early restenosis, or an additional significant stenosis detected by further invasive testing at the time of the initial procedure. Also, databases cannot identify a planned multistage PCI for which the second session is aborted due to complications from the first stage, complete relief of symptoms, or patient preference.

Multivessel PCI in the same session as diagnostic catheterization. PCI is frequently undertaken at the time of diagnostic catheterization, termed "ad hoc" PCI. This is the most convenient for patients, and compared with a staged strategy, it is much preferred by patients. However, when ad hoc PCI is multivessel, there are special risks to consider [88,89]. First, contrast and radiation used during the diagnostic catheterization may limit the additional doses that can be used during PCI. Second, the complexity of decision making increases with the number of lesions and vessels considered for PCI. Ad hoc multivessel PCI thus requires complex decision making that may not be optimal in the ad hoc scenario. Third, the informed consent before diagnostic catheterization may be inadequate for multivessel PCI. Patients scheduled for "cath possible PCI" should be informed about the risks of average single-vessel PCI, but it is unlikely that in-depth discussions of the pros, cons, and risks of multivessel PCI and the alternatives of medical therapy and bypass surgery have occurred. Fourth, logistical concerns may pose a special problem. If the patient is scheduled for a diagnostic catheterization time slot, the laboratory must be able to adjust to the addition of a multivessel PCI without undo delay to other patients, physicians, and catheterization laboratory staff. Finally, multivessel PCI done ad hoc does not allow input from cardiac surgeons, other specialists, or family members that might contribute to optimal decision making by the patient and interventionist. Recent guidelines have strongly encouraged a "heart team" approach for patients with unprotected left main or complex MVCAD [17,20]. The "heart team" approach includes giving the patient, interventionist, and cardiac surgeon an opportunity to talk about various revascularization strategies. This cannot occur when PCI is performed ad hoc at the time of diagnostic catheterization.

Necessity of the second stage of a multistage PCI. When PCI of the primary stenosis is completed, the interventionist must consider whether to proceed to a second stenosis. Even if a second stenosis is proven to be hemodynamically significant by FFR testing, the clinical need for additional vessel PCI may remain questionable and a rational strategy may be to defer the second PCI. This allows additional time to reassess the patient's symptoms and their improvement after the first PCI, as well as to provide a trial of medical therapy or additional testing to confirm the need for the second procedure. A second informed consent process is necessary before proceeding with the second stage.

Unfavorable risk-to-benefit ratio for the second stage of a multistage PCI. Occasionally, the risk-to-benefit ratio for PCI is favorable for one lesion but unfavorable for additional lesions. For example, a patient with a 95% type A proximal right coronary lesion and a 70% type C distal circumflex calcified bifurcation lesion may gain complete relief of symptoms with right coronary artery PCI. The safest approach may be the single-vessel PCI, with a second stage only if needed for refractory angina.

GUIDELINES AND AUC

Guidelines Related to Multivessel PCI

The performance of multivessel PCI has been addressed in numerous guideline documents [1,3,16,19,20,90,91]. Although there are several class I, class IIa, and class IIb recommendations related to multivessel PCI, the majority of these recommendations do not specifically address one-stage versus multistage PCI. The 2004 STEMI guidelines provide a class III recommendation that PCI should not be performed in a noninfarct artery at the time of primary PCI in patients without hemodynamic compromise [92]. The 2009 focused PCI update supports the use

TABLE III. Appropriateness Criteria Relevant to Staged Multivessel PCI

Indication #7	After STEMI PCI, "Revascularization of a noninfarct-related artery during index hospitalization" is "inappropriate".
Indication #8	After STEMI/NSTEMI culprit PCI, "symptoms of recurrent myocardial ischemia and/or high-risk findings on noninvasive stress testing performed after index hospitalization, revascularization of one or more additional coronary arteries" is "appropriate". [8]
Indication #10	In patients with UA/NSTEMI and high-risk features for short-term risk of death or nonfatal MI, "revascularization of multiple coronary arteries when the culprit cannot be clearly determined" is "appropriate" [9]
Indication #11	In patients with STEMI or NSTEMI and cardiogenic shock, "revascularization of one or more coronary arteries" is "appropriate".
Indication #19	PCI for "one or two vessel coronary artery disease with borderline stenosis 50–60%, no noninvasive testing performed, and no further invasive evaluation performed (i.e., FFR, IVUS)" is "inappropriate"
Indication #20	PCI for "one or two vessel coronary artery disease with borderline stenosis 50–60%, no noninvasive testing performed or equivocal test results present, and FFR <0.75 and /or IVUS with significant reduction in cross-sectional surface area" is "appropriate" for class III/IV angina and "uncertain" for class I/II angina.
Indication #21	PCI for "one or two vessel coronary artery disease with borderline stenosis 50–60%, no noninvasive testing performed or equivocal test results present, and FFR or IVUS findings do not meet criteria for significant stenosis" is "inappropriate".

of FFR measurements (class IIa, level of evidence A) and intravascular ultrasound imaging in the context of multivessel disease to determine the need for PCI in vessels with angiographically intermediate lesions [19].

AUC and Multivessel PCI

The AUC for coronary revascularization complements practice guidelines and addresses many clinical situations encountered in daily practice for which there are insufficient data to support guideline development (Table III) [2]. However, most of the AUC evaluate only the appropriateness of revascularization without the mention of single-stage versus multistage strategies. As in the 2009 focused PCI update, the AUC identify nonculprit vessel PCI in the context of STEMI as inappropriate in the absence of ongoing symptoms or clinical instability. They also encourage the use of testing, such as FFR, to decide if additional vessel PCI is appropriate in stable patients.

SPECIFIC PATIENT SUBSETS

ST Elevation Myocardial Infarction

PCI of nonculprit lesions at the time of STEMI PCI in the absence of ongoing pain or clinical instability is currently a class III indication in the guidelines for acute myocardial infarction [92]. This is due to the concern that noninfarct vessel PCI at the time of PCI for STEMI may increase the risk of adverse events [93,94], although other studies suggest it may be safe [95–97]. In the American College of Cardiology (ACC) survey, only 2% of cardiologists advocated noninfarct-related PCI of severely stenosed vessels at the time of the initial PCI [9].

Occasionally, multiple arteries may occlude nearly simultaneously, so that patients present with multiple infarct-related arteries [98,99]. In this case, one-session multivessel PCI for STEMI is appropriate.

PCI of significant nonculprit lesions at a later session during initial hospitalization for acute MI has been deemed appropriate only if there are symptoms of ischemia or high-risk findings on stress testing [2]. These lesions may be identified at the time of STEMI PCI by FFR testing, as FFR at time of STEMI PCI correlates quite well with FFR obtained later when the patient is stable [100]. In the ACC survey, 80% of cardiologists advocated scheduling non-infarct-related artery (IRA) PCI at a separate session (most commonly during a separate hospitalization within a month of the index admission), and 14% suggested non-IRA PCI should only be done if indicated by symptoms or ischemia [9].

Cardiogenic Shock

Among patients with cardiogenic shock, one-stage multivessel PCI was associated with worse outcomes compared with single-vessel culprit PCI [101] and was associated with more complications than culprit stenosis PCI followed by delayed nonculprit stenosis PCI [106,107]. Culprit stenosis PCI with subsequent PCI of additional important stenoses during the same hospitalization has been recommended as the best strategy in patients with cardiogenic shock [102]. For patients who remain in shock after PCI of the culprit stenosis and have other stenoses limiting flow at rest to large myocardial regions, immediate (same session) multivessel PCI has been advocated [103].

Acute Coronary Syndromes (Unstable Angina/ Non-STEMI)

In patients with acute coronary syndromes, ad hoc PCI of the culprit vessel is often performed at the time of diagnostic catheterization. Occasionally, multiple unstable lesions will be identified [104], and multivessel one-stage PCI may be necessary for these patients. However,

ad hoc PCI patients may enter the interventional phase of treatment with a considerable contrast agent load and radiation dose. When renal function is abnormal or the diagnostic procedure unusually prolonged, deferring PCI of nonculprit lesions to a later session may be preferable to avoid contrast nephropathy or radiation burns.

The ACC survey found that for unstable angina/non-STEMI (NSTEMI), 42% of cardiologists advocated one-stage PCI, 37% advocated staged PCI (most commonly with the second stage occurring within a month), and 14% suggested a second stage of PCI be scheduled only for recurrent angina or ischemia [9].

Stable Ischemic Heart Disease

PCI does not decrease the risk of mortality or future ischemic events for most patients with stable coronary disease. Multivessel PCI should be directed only at lesions that are hemodynamically significant. One-stage multivessel PCI is often tolerated well by stable patients, but may be performed over multiple sessions due to the technical considerations mentioned below. The strategy of staging multivessel PCI appears to be safe [79].

The ACC survey found that 21% of cardiologists advocated one-stage PCI for stable patients, 50% advocated PCI of a nonculprit vessel at a later session, and 17% suggested it to be done only if indicated for ischemia or symptoms [9].

PROCEDURAL CONSIDERATIONS

Managing Radiographic Contrast

Several studies have associated total contrast load with the incidence of contrast-induced nephropathy (CIN) [105,106]. Contrast doses <100 cm^3 rarely cause CIN [107] in patients with normal or mildly impaired renal function, but the incidence of CIN increases by 14% for each 50 cm^3 increase in contrast volume [108], and contrast doses over 260 cm^3 particularly predispose patients to CIN [109].

When considering multivessel PCI, the interventionist should know the patient's glomerular filtration rate, assess the risk of CIN [110], provide adequate hydration before contrast administration, and carefully monitor contrast dose during the procedure. If PCI is performed ad hoc after cardiac catheterization, the interventionist may wish to avoid ventriculography, aortography, or peripheral angiography. Multivessel PCI requires higher contrast doses than single-vessel PCI and may increase the risk of CIN. This risk may be mitigated by staging multivessel PCI, particularly when contrast volumes are high or the patient is at increased risk for CIN. The second stage should be scheduled only after the CIN from the first stage has been excluded or resolved.

Managing Radiation Doses

Radiation dose management requires an informed patient before the procedure, a knowledgeable operator during the procedure, and appropriate protocols in place for patient follow-up if required. Interventionists should strive to minimize radiation doses during PCI [111–114] as outlined in Table IV. A radiation safety program that uses a qualified physicist, dosimetry monitoring, shielding, and training is essential [113].

Since 2006, all new imaging equipment has included time monitoring displays for total air kerma at the interventional reference point ($K_{a,r}$) in Gray (Gy). This measurement provides an assessment of radiation doses, known as $K_{a,r}$. No observable effects are present with $K_{a,r} < 2$ Gy. Radiation skin burns are more common above 5 Gy, and significant tissue injury is possible with >15 Gy, particularly in patients who have received previous radiation, radiation from an X-ray source close to the skin entry site, or radiation from a nonmoving X-ray source [115]. In clinical practice, higher dose is tolerated before the occurrence of skin burn by radiation because of the multiple angles of imaging that reduce the radiation dose at any one skin site to subclinical levels. If $K_{a,r} > 10$ Gy is delivered during a procedure, a qualified physicist should calculate the actual peak skin dose and assess potential tissue injury (Table IV). Appropriate steps for patient follow-up based on radiation dose should be followed [113].

When high radiation doses have been used during PCI of the first vessel of multivessel PCI, staging may be necessary to limit the radiation dose from that session. PCI of additional vessels should be delayed for 1–6 months, as recommended by a qualified physicist.

Challenging Access

Multistage PCI puts the patient at increased risk of vascular complications as compared to one-stage PCI. Operators must weigh this disadvantage of multistage PCI against possible benefits. In cases where vascular access is difficult, one-stage PCI may be relatively more attractive, and the risk/benefit ratio may shift in the direction of one-stage PCI. Compared with radial access, this is a larger issue with femoral access, which has a vascular complication rate of 2–4% and is currently used in $>90\%$ of PCIs in the United States [116–119].

Complications

When intervention on the first artery results in an important complication, it is often best to defer the second vessel to a different session. If PCI leads to

TABLE IV. Radiation Dose Management in PCI

Preprocedure
Radiation safety program for catheterization lab
Dosimeter use, shielding, training/education
Imaging equipment and operator knowledge
On screen dose assessment ($K_{a,r}$, P_{KA})
Dose saving: store fluoro, adjustable pulse and frame rate, and last image hold
Preprocedure dose planning
Assess patient and procedure including patient size and lesion(s) complexity
Informed patient with appropriate consent
Procedure
Limit fluoro: step on petal only when looking at screen
Limit cine: store fluoro when image quality not required
Limit magnification, frame rate, and steep angles
Use collimation and filters to fullest extent possible
Vary tube angle when possible to change skin area exposed
Position table and image receptor: X-ray tube too close to patient increases dose; high image receptor increases scatter
Keep patient and operator body parts out of field of view
Maximize shielding and distance from X-ray source for all personnel
Manage and monitor dose in real time from beginning of case
Post procedure
Document radiation dose in records (fluoroscopy time, $K_{a,r}$, P_{KA})
Patient and referring physician notification for high dose
$K_{a,r} > 5$ Gy, chart document; inform patient; arrange follow-up
$K_{a,r} > 10$ Gy, qualified physicist should calculate skin dose
PSD > 15 Gy, Joint Commission sentinel event
Adverse skin effects should be referred to appropriate consultant

$K_{a,r}$, total air kerma at reference point; P_{KA}, air kerma area product; PSD, peak skin dose.

myocardial damage or sustained ischemia in one territory, complications arising from PCI in a separate vascular territory have an increased chance of causing hemodynamic compromise or death. Appropriate termination of multivessel PCI when complications occur should be considered as the standard for all multivessel interventions. Complications that may justify early termination include significant side branch occlusion, transient or sustained no-reflow due to presumed distal embolization, sustained chest pain or ST elevation even in the absence of angiographic slow flow, access site complications such as hematoma expansion during the procedure, perforation of coronary artery, or any hemodynamic instability during the procedure.

LOGISTICAL ISSUES

Cath Lab Scheduling

One-stage PCI is more efficient for catheterization laboratory operations than staging PCI on different days. However, staging PCI may be necessary due to scheduling constraints for laboratories that follow strict block scheduling. In general, the Writing Group agrees that scheduling concerns should not dictate the choice of one-stage versus multistage PCI.

Patient Convenience

One-stage PCI is preferred by most patients over multistage PCI. The inconvenience of taking time away from normal responsibilities and the anxiety of awaiting the procedure are increased by staging PCI. However, convenience for the patient should not override concerns about patient safety and medical necessity.

Operator Factors

Although one-stage PCI procedures may be more convenient for the interventionist than staged PCIs, patient issues of safety, efficacy, and convenience should have priority over operator issues. One exception is operator fatigue. Interventionists should be aware of their ability to focus and perform, and should terminate procedures after the first stage of a planned multivessel procedure if their ability to complete the procedure is questionable.

Economic Ramifications of One-Stage Versus Multistage PCI

Medicare reimbursement to hospitals and physicians is greater for multistage PCI compared to one-stage PCI (Table V) [120]. However, following the ethical and legal principles outlined below, the Writing Group believes that the physician and hospital reimbursement should not be a factor in physicians' decisions regarding single-stage versus multistage PCI.

ETHICAL AND LEGAL 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 the patient's own care), and justice (considering how the patient's treatment will affect others in the healthcare system).

Beneficence

The interventionist is obligated to keep the patient's interests foremost. The revascularization strategy must be individualized for the patient and their clinical situation. When multivessel PCI is clearly indicated and can be performed quickly and with low risk, one-stage PCI is probably in the patient's best interest. When one-stage multivessel PCI may be unsafe due to contrast or radiation dosing, or the need for multiple vessel PCI is unclear, a staged strategy may be in the patient's best interest.

TABLE V. Payments to Physicians for Same-Sitting Multivessel PCI Versus Multisitting Multivessel PCI in 2011

	CPT codes	RVUs (2011 transitioned facility total RVUs)[a]	Total RVUs[b]	Physician medicare payment[c]	Ambulatory Payment Classification (APC) payment[b]	Diagnosis Related Group (DRG) payment
Scenario 1: multivessel PCI, one stage						
Diagnostic catheterization	93458	9.42	37.55	$1,276	$9,847	$15,573
+ Stent	92980	25.70				
+ Stent additional artery	92981	7.14				
Scenario 2: multi-vessel PCI, staged (separate sessions)						
Diagnostic catheterization	93458	9.42	56.11	$1,906	$12,674.49	$31,146
+ Stent	92980	25.70				
+ Staged separate stage stent	92980	25.70				
Scenario 3: PCI one vessel and pressure wire but no PCI of second vessel, one stage						
Diagnostic catheterization	93458	9.42	33.21	$1,128	$7,018.96	$15,573
+ Stent	92980	25.70				
+ Pressure wire	93571	2.80				

[a]Includes physician work relative value units (RVUs), practice expense RVUs, and malpractice insurance RVUs.
[b]When RVU values are added, they are discounted according to the multiple procedures rules.
[c]National average based on 2011 conversion factor $33.9764.
2011 National Physician Fee Schedule Relative Value File (RELEASED 12/21/2010).Addendum B.-OPPS Payment by HCPCS Code for CY 2011.

Autonomy

Patient autonomy is optimized by providing information to the patient, allowing time for the patient to consult with others, and taking the patient's wishes into consideration in medical decision making. These critical aspects should be part of obtaining informed consent. Preserving patient autonomy may be challenging when patients request a convenient strategy (e.g., one-stage PCI) over an inconvenient strategy (e.g., multistage PCI) that would offer better efficacy or safety. In cases where respecting patient autonomy would lead to suboptimal care, the physician must resolve this conflict.

Informed Consent Regarding Risk

When patients are scheduled to undergo diagnostic catheterization with possible PCI "to follow," the physician has a responsibility to obtain fully informed consent. The presence of MVCAD increases the risk of PCI-related death by 50–137% and increases the risk of complications by 32–86% [120] as compared to patients undergoing single-vessel PCI. Informed consent must be provided not only for the most typical scenario (single-vessel PCI) but also for the higher risk scenarios (multivessel PCI), if they are to be undertaken ad hoc at the time of catheterization [88]. It would be unethical to perform high-risk multivessel PCI on a patient after informed consent was given only for a much lower risk procedure.

Informed Consent Regarding Alternative Treatments

The presence of multivessel disease raises questions of appropriateness of PCI versus bypass surgery and the preference of patients for each. For the patient to be able to make a deliberate informed decision, termination of the procedure after diagnostic catheterization may be appropriate [88,89].

Justice

Distributive justice requires consideration of how the patient's treatment affects the interests of others. One-stage multivessel PCI, particularly if it proves to be longer or more complicated than initially expected, may delay subsequent procedures and cause inconvenience for other patients, other physicians, and technical staff. In some cases (e.g., when an ambulance with a STEMI patient is minutes away), the requirements for the care of other patients may dictate a strategy of staged PCI for the patient on the catheterization laboratory table.

Legal Aspects

The importance of determining and documenting the necessity for coronary intervention has assumed legal importance as several health systems and individual cardiologists have been prosecuted by the Department of Health and Human Services Office of the Inspector General and the Federal Bureau of Investigation for performing allegedly unnecessary coronary stenting procedures [121].

RECOMMENDATIONS

The Writing Group concurs with recommendations regarding the use of multivessel PCI as outlined in guideline documents and the AUC. In addition, the Writing Group makes the following recommendations:

1. Medical therapy: every patient who undergoes PCI should receive optimal therapy for coronary disease, ideally before starting the procedure (20). For patients with residual significant lesions and angina after the first stage of planned multistage PCI, therapy should include a trial of antianginal agents to control symptoms. "Optimal therapy" was not defined by the Writing Group.
2. Informed consent: multivessel PCI at the time of diagnostic catheterization should be considered only if informed consent included the risks and benefits of multivessel PCI and the risks and benefits of alternative treatments.
3. PCI strategy: when considering multivessel PCI, the interventionist should develop a strategy regarding which stenoses to treat or evaluate, and their order, method, and timing. This strategy should maximize patient benefits, minimize patient risk, and consider the factors described in this article.
4. Flexibility of PCI strategy: the PCI treatment strategy should be flexible. For planned multivessel PCI, additional vessel(s) should be treated only if the first vessel is treated successfully and if anticipated contrast and radiation doses and patient and operator conditions are favorable. Otherwise, deferral of PCI of the additional vessel(s) is reasonable. For patients with STEMI or cardiogenic shock for whom single-vessel culprit lesion PCI fails to relieve ongoing ischemia, conversion to a multivessel PCI strategy may be appropriate.
5. Reassessment between stages of multistage PCI: after the first stage of planned multistage PCI, the need for subsequent PCI should be reviewed before it is performed.
6. Regulatory and reimbursement status: third party payers and quality auditors should recognize that multistage PCI for MVCAD is neither an indication of poor quality nor an attempt to increase reimbursement when performed according to recommendations in this article. Although the revascularization strategy should be justifiable, the judgment of the operator in selecting the best strategy for the patient must be protected.

REFERENCES

1. King SB, Smith SC, Hirshfeld JW, Jacobs AK, Morrison DA, Williams DO. 2007 focused update of the ACC/AHA/SCAI 2005 guideline update for percutaneous coronary intervention: A report of the American College of Cardiology/American Heart Association Task Force on Practice guidelines. J Am Coll Cardiol 2008;51:172–209.
2. Patel MR, Dehmer GJ, Hirshfeld JW, Smith PK, Spertus JA. ACCF/SCAI/STS/AATS/AHA/ASNC 2009 appropriateness criteria for coronary revascularization. J Am Coll Cardiol 2009;53:530–553.
3. Gibbons RJ, Abrams J, Chatterjee K, Daley J, Deedwania PC, Douglas JS, Ferguson TB Jr, Fihn SD, Fraker TD Jr, Gardin JM, O'Rourke RA, Pasternak RC, Williams SV, Gibbons RJ, Alpert JS, Antman EM, Hiratzka LF, Fuster V, Faxon DP, Gregoratos G, Jacobs AK, Smith SC Jr. ACC/AHA 2002 guideline update for the management of patients with chronic stable angina: A report of the American College of Cardiology/American Heart Association Task Force on practice guidelines (committee on the management of patients with chronic stable angina). J Am Coll Cardiol 2003;41:159–168.
4. Kesani M, Aronow WS, Weiss MB. Prevalence of multivessel coronary artery disease in patients with diabetes mellitus plus hypothyroidism, in patients with diabetes mellitus without hypothyroidism, and in patients with no diabetes mellitus or hypothyroidism. J Gerontol A Biol Sci Med Sci 2003;58:M857–M858.
5. Hilliard AA, From AM, Lennon RJ, Singh M, Lerman A, Gersh BJ, Holmes DR, Rihal CS, Prasas A. Percutaneous revascularization for stable coronary artery disease. JACC Cardiovasc Interv 2010;3:172–179.
6. Curtis JP, Schreiner G, Wang Y, Chen J, Spertus JA, Rumsfeld JS, Brindis RG, Krumholz HM. All-cause readmission and repeat revascularization after percutaneous coronary intervention in a cohort of Medicare patients. J Am Coll Cardiol 2009;54:903–907.
7. Hannan EL, Samadashvili Z, Walford G, Holmes DR Jr, Jacobs AK, Stamato NJ, Venditti FJ, Sharma S, King SB 3rd., Culprit vessel percutaneous coronary intervention versus multivessel and staged percutaneous coronary intervention for ST-segment elevation myocardial infarction patients with multivessel disease. JACC Cardiovasc Interv 2010;3:22–31.
8. Barringhaus KG, Park KL, McManus DD, Steg PG, Montalescot G, Van de Werf F, López-Sendón J, FitzGerald G, Gore JM. Outcomes from patients with multi-vessel disease following primary PCI: Staged PCI imparts very low mortality. Cathet Cardiovasc Intervent 2011;77:617–622.
9. Dangas GD, George JC, Weintraub W, Popma JJ. Timing of staged percutaneous interventnion in multivessel coronary artery disease. JACC Cardiovasc Interv 2010;3:1096–1099.
10. Salvati EA, Hughes P, Lachiewicz P. Bilateral total hip-replacement arthroplasty in one stage. J Bone Joint Surg Am 1978;60:640–644.
11. Bhan S, Pankaj A, Malhotra R. One- or two-stage bilateral total hip arthroplasty: A prospective, randomised, controlled study in an Asian population. J Bone Joint Surg Br 2006;88:298–303.
12. Soudry M, Binazzi R, Insall JN, Nordstrom TJ, Pellicci PM, Goulet JA. Successive bilateral total knee replacement. J Bone Joint Surg Am 1985;67:573–576.
13. Hazelrigg SR, Boley TM, Magee MJ, Lawyer CH, Henkle JQ. Comparison of staged thoracoscopy and median sternotomy for lung volume reduction. Ann Thorac Surg 1998;66:1134–1139.
14. Barrett J, Baron JA, Losina E, Wright J, Mahomed NN, Katz JN. Bilateral total knee replacement: Staging and pulmonary embolism. J Bone Joint Surg Am 2006;88:2146–2151.
15. Eagle K, Guyton R, Davidoff R, Edwards F, Ewy G, Gardner T, Hart J, Herrmann H, Hillis L, Hutter A, Lytle B, Marlow R, Nugent W, Orszulak T, Antman E, Smith S, Alpert J, Anderson J, Faxon D, Fuster V, Gibbons R, Gregoratos G, Halperin J, Hiratzka L, Hunt S, Jacobs A, Ornato J. ACC/AHA 2004 guideline update for coronary artery bypass graft surgery: Summary article. A report of the American College of

Cardiology/American Heart Association Task Force on Practice Guidelines (Committee to Update the 1999 Guidelines for Coronary Artery Bypass Graft Surgery). J Am Coll Cardiol 2004;44:e213–e310.

16. Smith S, Feldman T, Hirshfeld J, Jacobs A, Kern M, King S, Morrison D, O'Neill W, Schaff H, Whitlow P, Williams D, Antman E, Adams C, Anderson J, Faxon D, Fuster V, Halperin J, Hiratzka L, Hunt S, Nishimura R. ACC/AHA/SCAI 2005 guideline update for percutaneous coronary intervention: A report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (ACC/AHA/SCAI Writing Committee to Update the 2001 Guidelines for Percutaneous Coronary Intervention). J Am Coll Cardiol 2006;47:e1–e121.
17. Fox K, Garcia MA, Ardissino D, Buszman P, Camici PG, Crea F, Daly C, De Backer G, Hjemdahl P, Lopez-Sendon J, Marco J, Morais J, Pepper J, Sechtem U, Simoons M, Thygesen K, Priori SG, Blanc JJ, Budaj A, Camm J, Dean V, Deckers J, Dickstein K, Lekakis J, McGregor K, Metra M, Morais J, Osterspey A, Tamargo J, Zamorano JL. Guidelines on the management of stable angina pectoris: Executive summary: The task force on the management of stable angina pectoris of the European society of cardiology. Eur Heart J 2006;27:1341–1381.
18. Silber S, Albertsson P, Avilés FF, Camici PG, Colombo A, Hamm C, Jørgensen E, Marco J, Nordrehaug JE, Ruzyllo W, Urban P, Stone GW, Wijns W. Guidelines for percutaneous coronary interventions. The task force for percutaneous coronary interventions of the European Society of Cardiology. Eur Heart J 2005;26:804–847.
19. Kushner FG, Hand M, Smith SC Jr, King SB 3rd, Anderson JL, Antman EM, Bailey SR, Bates ER, Blankenship JC, Casey DE Jr, Green LA, Hochman JS, Jacobs AK, Krumholz HM, Morrison DA, Ornato JP, Pearle DL, Peterson ED, Sloan MA, Whitlow PL, Williams DO. 2009 focused updates: ACC/AHA guidelines for the management of patients with ST-elevation myocardial infarction (updating the 2004 guideline and 2007 focused update) and ACC/AHA/SCAI guidelines on percutaneous coronary intervention (updating the 2005 guideline and 2007 focused update): A report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines. J Am Coll Cardiol 2009;54:2205–2241.
20. 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: 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. J Am Coll Cardiol 2011;58. (in press)
21. Parisi AF, Folland ED, Hartigan P. A comparison of angioplasty with medical therapy in the treatment of single-vessel coronary artery disease. Veterans Affairs ACME Investigators. N Engl J Med 1992;326:10–16.
22. RITA-2 Trial Participants. Coronary angioplasty versus medical therapy for angina: The second randomised intervention treatment of angina (RITA-2) trial. Lancet 1997;350:461–468.
23. Folland ED, Hartigan PM, Parisi AF. Percutaneous transluminal coronary angioplasty versus medical therapy for stable angina pectoris: Outcomes for patients with double-vessel versus single-vessel coronary artery disease in a veterans affairs cooperative randomized trial. Veterans affairs ACME investigators. J Am Coll Cardiol 1997;29:1505–1511.
24. Pitt B, Waters D, Brown W, van Boven A, Schwartz L, Title L, Eisenberg D, Shurzinske L, McCormick L. Aggressive lipid-lowering therapy compared with angioplasty in stable coronary artery disease. Atorvastatin versus revascularization treatment investigators. N Engl J Med 1999;341:70–76.
25. Boden W, O'Rourke R, Teo K, Hartigan P, Maron D, Kostuk W, Knudtson M, Dada M, Casperson P, Harris C, Spertus J, Shaw L, Chaitman B, Mancini G, Berman D, Gau G, Weintraub W. The evolving pattern of symptomatic coronary artery disease in the United States and Canada: Baseline characteristics of the clinical outcomes utilizing revascularization and aggressive DruG evaluation (COURAGE) trial. Am J Cardiol 2007;99:208–212.
26. Whalen RE, Harrell FE Jr, Lee KL, Rosati RA. Survival of coronary artery disease patients with stable pain and normal left ventricular function treated medically or surgically at Duke University. Circulation 1982;65:49–52.
27. King S, Lembo N, Weintraub W, Kosinski A, Barnhart H, Kutner M, Alazraki N, Guyton R, Zhao X. A randomized trial comparing coronary angioplasty with coronary bypass surgery. Emory angioplasty versus surgery trial (EAST). N Engl J Med 1994;331:1044–1050.
28. CABRI Trial Participants. First-year results of CABRI (coronary angioplasty versus bypass revascularisation investigation). Lancet 1995;346:1179–1184.
29. Rodriguez A, Mele E, Peyregne E, Bullon F, Perez-Baliño N, Liprandi MI, Palacios IF. Three-year follow-up of the Argentine randomized trial of percutaneous transluminal coronary angioplasty versus coronary artery bypass surgery in multivessel disease (ERACI). J Am Coll Cardiol 1996;27:1178–1184.
30. Carrié D, Elbaz M, Puel J, Fourcade J, Karouny E, Fournial G, Galinier M. Five-year outcome after coronary angioplasty versus bypass surgery in multivessel coronary artery disease: Results from the French Monocentric Study. Circulation 1997;96:II1–II6.
31. The Bypass Angioplasty Revascularization Investigation (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.
32. Rodriguez A, Bernardi V, Navia J, Baldi J, Grinfield L, Martinez J, Vogel D, Grinfield R, Delacasa A, Garrido M, Oliveri R, Mele E, Palacios I, O'Neill W. 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.
33. Hueb W, Lopes NH, Gersh BJ, Gersh BJ, Soares P, Machado LAC, Jatne FB, Oliveira SA, Ramires JAF. Five-year follow-up of the medicine, angioplasty, or surgery study (MASS II): A randomized controlled clinical trial of 3 therapeutic strategies for multivessel coronary artery disease. Circulation 2007;115:1082–1089.
34. Smith PK, Califf RM, Tuttle RH, Shaw LK, Lee KL, Delong ER, Lilly RE, Sketch MH Jr, Peterson ED, Jones RH. Selection of surgical or percutaneous coronary intervention provides differential longevity benefit. Ann Thorac Surg 2006;82:1420–1428.
35. Bair TL, Muhlestein JB, May HT, Meredith KG, Horne BD, Pearson RR, Li Q, Jensen KR, Anderson JL, Lappe DL. Surgical revascularization is associated with improved long-term outcomes compared with percutaneous stenting in most subgroups of patients with multivessel coronary artery disease: Results from the Intermountain Heart Registry. Circulation 2007;116:I226–I231.

36. Dacey LJ, Likosky DS, Ryan TJ Jr, Robb JF, Quinn RD, DeVries JT, Hearne MJ, Leavitt BJ, Dunton RF, Clough RA, Sisto D, Ross CS, Olmstead EM, O'Connor GT, Malenka DJ. Long-term survival after surgery versus percutaneous intervention in octogenarians with multivessel coronary disease. Ann Thorac Surg 2007;84:1904–1911.
37. Leape LL, Park RE, Bashore TM, Harrison JK, Davidson CJ, Brook RH. Effect of variability in the interpretation of coronary angiograms on the appropriateness of use of coronary revascularization procedures. Am Heart J 2000;139:106–113.
38. Fisher LD, Judkins MP, Lesperance J, Cameron A, Swaye P, Ryan T, Maynard C, Bourassa M, Kennedy JW, Gosselin A, Kemp H, Faxon D, Wexler L, Davis KB. Reproducibility of coronary arteriographic reading in the coronary artery surgery study (CASS). Cathet Cardiovasc Diagn 1982;8:565–575.
39. Lavi S, Rihal CS, Yang EH, Fassa AA, Elesber A, Lennon RJ, Mathew V, David HR Jr, Lerman A. The effect of drug eluting stents on cardiovascular events in patients with intermediate lesions and borderline fractional flow reserve. Catheter Cardiovasc Interv 2007;70:525–531.
40. Pijls NH, van Schaardenburgh P, Manoharan G, Boersma E, Bech J, van't Veer M, Bär F, Hoorntje J, Koolen J, Wijns W, de Bruyne B. Percutaneous coronary intervention of functionally nonsignificant stenosis: 5-Year follow-up of the DEFER Study. J Am Coll Cardiol 2007;49:2105–2111.
41. Pijls NHJ, Fearon WF, Tonino PAL, Siebert U, Ikeno F, Bornschein B, van't Veer M, Klauss V, Manoharan G, Engstrom T, Oldroyd KG, Ver Lee PN, MacCarthy PA, De Bruyne B. Fractional flow reserve versus angiography for guiding percutaneous coronary intervention in patients with multivessel cornary artery disease. J Am Coll Cardiol 2010:56:177–184.
42. Christou M, Siontis G, Katritsis D, Ioannidis J. Meta-analysis of fractional flow reserve versus quantitative coronary angiography and noninvasive imaging for evaluation of myocardial ischemia. Am J Cardiol 2007;99:450–456.
43. Costa MA, Sabate M, Staico R, Alfonso F, Seixas AC, Albertal M, Crossman A, Angiolillo DJ, Zenni M, Sousa JE, Macaya C, Bass TA. Anatomical and physiologic assessments in patients with small coronary artery disease: Final results of the physiologic and anatomical evaluation prior to and after stent implantation in small coronary vessels (PHANTOM) trial. Am Heart J 2007;153:296–297.
44. Tonino P, De Bruyne B, Pijls N, Siebert U, Ikeno F, van't Veer M, Klauss V, Manoharan G, Engstrøm 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.
45. Melikian N, De Bondt P, Tonino P, De Winter O, Wyffels E, Bartunek J, Heyndrickx GR, Fearon WF, Pijls NHJ, Wijns W, De Bruyne B. Fractional flow reserve and myocardial perfusion imaging in patients with angiographic multivessel coronary artery disease. JACC Cardiovasc Interv 2010;3:307–314.
46. Kobori Y, Tanaka N, Takazawa K, Yamashina A. Usefulness of fractional flow reserve in determining the indication of target lesion revascularization. Catheter Crdiovasc Intervent 2005;65:355–360.
47. Caymaz O, Fak AS, Tezcan H, Inanir SS, Toprak A, Tokay S, Turoglu T, Oktay A. Correlation of myocardial fractional flow reserve with thallium-201 SPECT imaging in intermediate-severity coronary artery lesions. J Invasive Cardiol 2000;12:345–350.
48. Yanagisawa H, Chikamori T, Tanaka N, Hatano T, Morishima T, Hida S, Iino H, Amaya K, Takazawa K, Yamashina A. Correlation between thallium-201 myocardial perfusion defects and the functional severity of coronary artery stenosis as assessed by pressure-derived myocardial fractional flow reserve. Circ J 2002;66:1105–1109.
49. Yanagisawa H, Chikamori T, Tanaka N, Usui Y, Takazawa K, Yamashina A. Application of pressure-derived myocardial fractional flow reserve in assessing the functional severity of coronary artery stenosis in patients with diabetes mellitus. Circ J 2004;68:993–998.
50. Courtis J, Rodés-Cabau J, Larose E, Déry JP, Nguyen CM, Proulx G, Gleeton O, Roy L, Barbeau G, Noël B, DeLarochellière R, Bertrand OF. Comparison of medical treatment and coronary revascularization in patients with moderate coronary lesions and borderline fractional flow reserve measurements. Cathet Cardiovasc Intervent 2008;71:541–548.
51. Bech GJ, De Bruyne B, Bonnier HJ, Bartunek J, Wijns W, Peels K, Heyndrickx GR, Koolen JJ, Pijls NH. Long-term follow-up after deferral of percutaneous transluminal coronary angioplasty of intermediate stenosis on the basis of coronary pressure measurement. J Am Coll Cardiol 1998;31:841–847.
52. Chamuleau S, Meuwissen M, Koch K, van Eck-Smit B, Tio R, Tijssen J, Piek J. Usefulness of fractional flow reserve for risk stratification of patients with multivessel coronary artery disease and an intermediate stenosis. Am J Cardiol 2002;89:377–380.
53. Verna E, Lattanzio M, Ghiringhelli S, Provasoli S, Caico SI. Performing versus deferring coronary angioplasty based on functional evaluation of vessel stenosis by pressure measurements: A clinical outcome study. J Cardiovasc Med (Hagerstown) 2006;7:169–175.
54. Jasti V, Ivan E, Yalamanchili V, Wongpraparut N, Leesar M. Correlations between fractional flow reserve and intravascular ultrasound in patients with an ambiguous left main coronary artery stenosis. Circulation 2004;110:2831–2836.
55. Legutko J, Dudek D, Rzeszutko L, Wizimirski M, Dubiel JS. Fractional flow reserve assessment to determine the indications for myocardial revascularisation in patients with borderline stenosis of the left main coronary artery. Kardiol Pol 2005;63:499–506.
56. Hamilos M, Muller O, Cuisset T, Ntalianis A, Chlouverakis G, Sarno G, Nelis O, Bartunek J, Vanderheyden M, Wyffels E, Barbato E, Heyndrickx G, Wijns W, De Bruyne B. Long-term clinical outcome after fractional flow reserve-guided treatment in patients with angiographically equivocal left main coronary artery stenosis. Circulation 2009;120:1505–1512.
57. Takagi A, Tsurumi Y, Ishii Y, Suzuki K, Kawana M, Kasanuki H. Clinical potential of intravascular ultrasound for physiological assessment of coronary stenosis: Relationship between quantitative ultrasound tomography and pressure-derived fractional flow reserve. Circulation 1999;100:250–255.
58. Briguori C, Anzuini A, Airoldi F, Gimelli G, Nishida T, Adamian M, Corvaja N, Di Mario C, Colombo A. Intravascular ultrasound criteria for the assessment of the functional significance of intermediate coronary artery stenoses and comparison with fractional flow reserve. Am J Cardiol 2001;87:136–141.
59. Nishioka T, Amanullah AM, Luo H, Berglund H, Kim CJ, Nagai T, Hakamata N, Katsushika S, Uehata A, Takase B, Isojima K, Berman DS, Siegel RJ. Clinical validation of intravascular ultrasound imaging for assessment of coronary stenosis severity: Comparison with stress myocardial perfusion imaging. J Am Coll Cardiol 1999;33:1870–1878.
60. Abizaid AS, Mintz GS, Mehran R, Abizaid A, Lansky AJ, Pichard AD, Satler LF, Wu H, Pappas C, Kent KM, Leon MB. Long-term follow-up after percutaneous transluminal coronary angioplasty was not performed based on intravascular ultrasound findings: Importance of lumen dimensions. Circulation 1999;100:256–261.

61. Nam CW, Yoon HJ, Cho YK, Park HS, Kim H, Hur SH, Kim YN, Chung IS, Koo BK, Tahk SJ, Fearon WF, Kim KB. Outcomes of percutaneous coronary intervention in intermediate coronary artery disease: Fractional flow reserve-guided versus intravascular ultrasound-guided. JACC Cardiovasc Interv 2010;3:812–817.
62. Ong ATL, Serruys PW. Complete revascularization. Coronary artery bypass graft surgery versus percutaneous coronary intervention. Circulation 2006;114:249–255.
63. Serruys PW, Unger F, Souse JE, Jatene A, Bonnier HJ, Schonberger JP, Buller N, Bonser R, van den Brand MJ, van Herwerden LA, Morel MA, van Hout BA. Comparison of coronary artery bypass surgery and stenting for the treatment of multi-vessel disease. N Engl J Med 2001;344:1117–1124.
64. Ijsselmuiden AJJ, Ezechiels JP, Westendorp ICD, Tijssen JGP, Kiemeneij F, Slagboom T, van der Wieken R, Tangelder GJ, Serruys PW, Laaman GJ. Complete versus culprit vessel percutaneous coronary intervention in multivessel disease: A randomized comparison. Am Heart J 2004;148:467–474.
65. Tamburino C, Angiolillo DJ, Capranzano P, Dimopoulos K, La Manna A, Barbagallo R, Tagliareni F, Mangiafico S, Guzman LA, Galassi AR, Bass TA. Complete versus incomplete revascularization in patients with multivessel disease undergoing percutaneous coronary intervention with drug-eluting stents. Cathet Cardiovasc Intervent 2008;72:448–456.
66. Van den Brand MJBM, Rensing BJWM, Morel M-AM, Foley DP, de Valk V, Breeman A, Suryapranata H, Haalebos MMP, Wijns W, Wellens F, Balcon R, Magee P, Ribeiro E, Buffolo E, Unger F, Serruys PW. The effect of completeness of revascularization on event-free survival at one year in the ARTS trial. J Am Coll Cardiol 2002;39:559–564.
67. Hannan EL, Racz M, Holmes DR, King SB, Walford G, Ambrose JA, Sharma S, Katz S, Clark LT, Jones RH. Impact of completeness of percutaneous coronary intervention revascularization on long-term outcomes in the stent era. Circulation 2006;113:2406–2412.
68. Shishehbor MH, Lauer MS, Singh IM, Chew DP, Karha J, Brener SJ, Moliterno DJ, Ellis SG, Topol EJ, Bhatt DL. In unstable angina or non-ST-segment acute coronary syndrome, should patients with multivessel coronary artery disease undergo multivessel or culprit-only stenting? J Am Coll Cardiol 2007;49:849–854.
69. Kong JA, Chou ET, Minutello RM, Wong SC, Hong MK. Safety of single versus multi-vessel angioplasty for patients with acute myocardial infarction and multi-vessel coronary artery disease: Report from the New York state angioplasty registry. Coron Artery Dis 2006;17:71–75.
70. Kalarus Z, Lenarczyk R, Kowalczyk J, Kowalski O, Gasior M, Was T, Zebik T, Krupa H, Chodor P, Polonski L, Zembala M. Importance of complete revascularization in patients with acute myocardial infarction treated with percutaneous coronary intervention. Am Heart J 2007;153:304–312.
71. Srinivas VS, Selzer F, Wilensky RL, Holmes DR, Cohen HA, Monrad ES, Jacobs AK, Kelsey SF, Williams DO, Kip KE. Completeness of revascularization for multivessel coronary artery disease and its effect on one-year outcome: A report from the NHLBI dynamic registry. J Interv Cardiol 2007;20:373–380.
72. Bourassa MG, Yeh W, Holubkov R, Sopko G, Detre KM. Long-term outcome of patients with incomplete vs complete revascularization after multivessel PTCA. A report from the NHLBI PTCA registry. Eur Heart J 1998;19:103–111.
73. Mariani G, De Servi S, Dellavalle A, Repetto S, Chierchia S, D'Urbano M, Repetto A, Klersy C,ROSAI Study Group. Complete or incomplete percutaneous coronary revascularization in patients with unstable angina in stent era: Are early and one-year results different? Catheter Cardiovasc Interv 2001;54:448–453.
74. McLellan CS, Ghali WA, Labinaz M, Davis RB, Galbraith D, Southern DA, Shrive FM, Knudtson ML for the APPROACH Investigators. Association between completeness of percutaneous coronary revascularization and postprocedure outcomes. Am Heart J 2005;150:800–806.
75. Bell MR, Bailey KR, Reeder GS, Lapeyre AC 3rd, Holmes DR Jr. Percutaneous transluminal angioplasty in patients with multivessel coronary disease: How important is complete revascularization for cardiac event-free survival? J Am Coll Cardiol 1990;16:553–562.
76. Bourassa MG, Kip KE, Jacobs AK, Jones RH, Sopko G, Rosen AD, Sharaf BL, Schwartz L, Chaitman BR, Alderman EL, Holmes DR, Roubin GS, Detre KM, Frye RL. Is a strategy of intended incomplete percutaneous transluminal coronary angioplasty revascularization acceptable in nondiabetic patients who are candidates for coronary artery bypass graft surgery? The bypass angioplasty revascularization investigation (BARI). J Am Coll Cardiol 1999;33:1627–1636.
77. Kloeter UC, Jander NG, Buser PT, Osswald S, Mueller-Brand J, Pfisterer ME. Long-term outcome of angioplasty for multivessel coronary disease: Importance and price of complete revascularization. Int J Cardiol 2001;79:197–205.
78. Brener SJ, Murphy SA, Gibson CM, DiBattiste PM, Demopoulos LA, Cannon CP. Efficacy and safety of multivessel percutaneous revascularization and tirofiban therapy in patients with acute coronary syndromes. Am J Cardiol 2002;90:631–633.
79. Nikolsky E, Gruberg L, Patil CV, Roguin A, Kapeliovich M, Petcherski S, Boulos M, Grenadier E, Amikam S, Linn S, Markiewicz W, Beyar R. Percutaneous coronary interventions in diabetic patients: Is complete revascularization important? J Invasive Cardiol 2004;16:102–106.
80. 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.
81. Varani E, Balducelli M, Aquilina M, Vecchi G, Hussien MN, Frassineti V, Maresta A. Single or multivessel percutaneous coronary intervention in ST-elevation myocardial infarction patients. Cathet Cardiovasc Intervent 2008;72:927–933.
82. Qarawani D, Nahir M, Abboud M, Hazanov Y, Hasin Y. Culprit only versus complete coronary revascularization during primary PCI. Int J Cardiol 2008;123:288–292.
83. Hannan EL, Wu C, Walford G, Holmes DR, Jones RH, Sharma S, King SB 3rd., Incomplete revascularization in the era of drug-eluting stents: Impact on adverse outcomes. JACC Cardiovasc Interv 2009;2:17–25.
84. Yang HH, Chen Y, Gao CY. The influence of complete coronary revascularization on long-term outcomes in patients with multivessel coronary heart disease undergoing successful percutaneous coronary intervention. J Int Med Res 2010;38:1106–1112.
85. Politi L, Sgura F, Rossi R, Monopoli D, Guerri E, Leuzzi C, Bursi F, Sangiorgi GM, Modena MG. A randomised trial of target-vessel versus multi-vessel revascularisation in ST-elevation myocardial infarction: Major adverse cardiac events during long-term follow-up. Heart 2010;96:662–667.
86. Wenawesar P, Surmely J-F, Windecker S, Roffi M, Togni M, Billinger M, Cook S, Vogel R, Seiler C, Hess OM, Meier B. Prognostic value of early exercise testing after coronary stent implantation. Am J Cardiol 2008;101:807–811.

87. Breisblatt WM, Barnes JV, Weiland F, Spaccavento LJ. Incomplete revascularization in multivessel percutaneous transluminal coronary angioplasty: The role for stress thallium-201 imaging. J Am Coll Cardiol 1988;11:1183–1190.
88. Nallamothu B, Krumholz HM. Putting ad hoc PCI on pause. JAMA 2010;304:2059–2060.
89. 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.
90. Fraker TD Jr, Fihn SD; Writing on Behalf of the 2002 Chronic Stable Angina Writing Committee. 2007 chronic angina focused update of the ACC/AHA 2002 guidelines for the management of patients with chronic stable angina: A report of the American college of cardiology/American heart association task force on practice guidelines Writing Group to develop the focused update of the 2002 guidelines for the management of patients with chronic stable angina. J Am Coll Cardiol 2007;50:2264–2274.
91. Anderson JL, Adams CD, Antman EM, Bridges CR, Califf RM, Casey DE Jr, Chavey WE II, Fesmire FM, Hochman JS, Levin TN, Lincoff AM, Peterson ED, Theroux P, Wenger NK, Wright RS. ACC/AHA 2007 guidelines for the management of patients with unstable angina/non-ST-elevation myocardial infarction: Executive summary: 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). Circulation 2007;116:803–877.
92. Antman EM, Anbe DT, Armstrong PW, Bates ER, Green LA, Hand M, Hochman JS, Krumholz HM, Kushner FG, Lamas GA, Mullany CJ, Ornato JP, Pearle DL, Sloan MA, Smith SC Jr. ACC/AHA guidelines for the management of patients with ST-elevation myocardial infarction: Executive summary: A report of the ACC/AHA Task Force on Practice Guidelines (Committee to Revise the 1999 Guidelines on the Management of Patients With Acute Myocardial Infarction). Circulation 2004;110:588–636.
93. Cavendar MA, Milford-Beland S, Roe MT, Peterson ED, Weintraub WS, Rao SV. Prevalence, predictors, and in-hospital outcomes of non-infarct artery intervention during primary percutaneous coronary intervention for ST-elevation myocardial infarction (from the National Cardiovascular Data Registry). Am J Cardiol 2009;104:507–513.
94. Corpus RA, House JA, Marso SP, Grantham JA, Huber KC, Laster SB, Johnson WL, Daniels WC, Barth CW, Giorgi LV, Rutherford BD, Di Mario C, Sansa M, Flavio A, Imad S, Manari A, Petronio A, Piccaluga E, De Servi S, Ramondo A, Colusso S, Formosa A, Cernigliaro C, Colombo A. Single vs multivessel treatment during primary angioplasty: Results of the multicentre randomized HEpacoat for cuLPrit or multivessel stenting for acute myocardial infarction (HELP AMI) study. Int J Cardiovasc Interv 2004;2–4:128–133.
95. Qarawani D, Nahir M, Abboud M, Hazanov Y, Hasin Y. Culprit only versus complete revascularization during primary PCI. Int J Cardiol 2008;123:288–292.
96. Khattab AA, Abdel-Wahab M, Rother C, Liska B, Toelg R, Kassner G, Geist V, Richardt G. Multi-vessel stenting during primary percutaneous coronary intervention for acute myocardial infarction. Clin Res Cardiol 2008;97:32–38.
97. Varani E, Balducelli M, Aquilina M, Vecchi G, Hussien MN, Frassineti V, Maresta A. Single or multivessel percutaneous coronary intervention in ST-elevation myocardial infarction patients. Cathet Cardiovaasc Intervent 2008;72:927–933.
98. Yoshitomi Y, Kuramochi M, Kojima S. Acute myocardial infarction with simultaneous occlusions of two major coronary arteries in a young man. Clin Cardiol 1998;21:140–142.
99. Shen AY-J, Mansukhani PW, Aharonian VJ, Jorgensen MB. Primary angioplasty for acute myocardial infarction resulting from the simultaneous occlusion of two major coronary arteries. Cathet Cardiovasc Diagn 1999;47:203–207.
100. Ntalianis A, Sels JW, Davidavicius G, Tanaka N, Muller O, Trana C, Barbato E, Hamilos M, Mangiacapra F, Heyndrickx GR, Wijns W, Pijls NH, De Bruyne B. Fractional flow reserve for the assessment of nonculprit coronary rrtery stenoses in patients With acute myocardial infarction. JACC Cardiovasc Interv 2010;3:1274–1281.
101. Webb JG, Lowe AM, Sanborn TA, White HD, Sleeper LA, Carere RG, Buller CE, Wong SC, Boland J, Dzavik V, Porway M, Pate G, Bergman G, Hochman JS; for the SHOCK Investigators. Percutaneous coronary intervention for cardiogenic shock in the SHOCK trial. J Am Coll Cardiol 2003;42:1380–1386.
102. Hochman JS. Cardiogenic shock complicating acute myocardial infarction: Expanding the paradigm. Circulation 2003;107:2998–3002.
103. Reynolds HR, Hochman JS. Cardiogenic shock: Current concepts and improving outcomes. Circulation 2008;117;686–697.
104. Rioufol G, Finet G, Ginon I, André-Fouët 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.
105. Dangas G, Iakovou I, Nikolsky E, Aymong ED, Mintz GS, Kipshidze NN, Lansky AJ, Moussa I, Stone GW, Moses JW, Leon MB, Mehran R. Contrast-induced nephropathy after percutaneous coronary interventions in relation to chronic kidney disease and hemodynamic variables. Am J Cardiol 2005;95:13–19.
106. Freeman RV, O'Donnell M, Share D, Meengs WL, Kline-Rogers E, Clark VL, DeFranco C, Eagle KA, McGinnity JG, Patel K, Maxwell-Eward A, Bondie D, Moscucci M. Nephropathy requiring dialysis after percutaneous coronary intervention and the critical role of an adjusted contrast dose. Am J Cardiol 2002;90:1068–1073.
107. McCullough PA, Wolyn R, Rocher LL, Levin RN, O'Neill WW. Acute renal failure after coronary intervention: Incidence, risk factors, and relationship to mortality. Am J Med 1997;103:368–375.
108. Brar SS, Shen AY-J, Jorgensen MB, Kotlewski A, Aharonian VJ, Desai N, Ree M, Shah AI, Burchette RJ. Sodium bicarbonate vs sodium chloride for the prevention of contrast medium-induced nephropathy in patients undergoing coronary angiography. JAMA 2008;300:1038–1046.
109. Bartholomew BA, Harjai KJ, Dukkipati S, Boura JA, Yerkey MW, Glazier S, Grines CL, O'Neill WW. Impact of nephropathy after percutaneous coronary intervention and a method for risk stratification. Am J Cardiol 2004;93:1515–1519.
110. Klein LW, Sheldon MW, Brinker J, et al. The use of radiographic contrast media during PCI: A focused review. Catheter Cardiovasc Interv 2009;74:728–746.
111. Hirshfeld JW Jr, Balter S, Brinker JA, Kern MJ, Klein LW, Lindsay BD, Tommaso CL, Tracy CM, Wagner LK, Creager MA, Elnicki M, Lorell BH, Rodgers GP, Weitz HH. ACCF/AHA/HRS/SCAI clinical competence statement on physician knowledge to optimize patient safety and image quality in fluoroscopically guided invasive cardiovascular procedures. A report of the American College of Cardiology Foundation/

American Heart Association/American College of Physicians Task Force on Clinical Competence and Training. J Am Coll Cardiol 2004;11:2259–2282.
112. Balter S, Hopewell JW, Miller DL, Wagner LK, Zelefsky MJ. Fluoroscopically guided interventional procedures: A review of radiation effects on patient's skin and hair. Radiology 2010;257:1527–1315.
113. Chambers CE, Fetterly KA, Holzer R, Pei-Jan PL, Blankenship JC, Balter S, Laskey WK. Radiation safety program for the cardiac catheterization laboratory. Cathet Cardiovasc Intervent 2011;77:546–556.
114. Stecker MS, Balter S, Towbin RB, Miller DL, Vano E, Bartal G, Angle F, Chao CP, Cohen AM, Dixon RG, Gross K, Hartnell GG, Scheuler B, Statler JD, de Baere T, Cardella JF. Guidelines for patient radiation management. J Vasc Interv Radiol 2009;20:S263–S273.
115. Einstein AJ, Moser KW, Thompson RC, Cerqueira MD, Henzlova MJ. Radiation dose to patients from cardiac diagnostic imaging procedures. Circulation 2007;116:1290–1305.
116. Brueck M, Bandorski D, Kramer W, Holtgen R, Tillmanns. A randomized comparison of transradial versus transfemoral approach for coronary angiography and angioplasty. JACC Cardiovasc Interv 2009;2:1047–1054.
117. Jolly SS, Amlani S, Hamon M, Yusuf S, Mehta SR. Radial versus femoral access for coronary angiography or intervention and the impact on major bleeding and ischemic events: A systematic review and meta-analysis of randomized trials. Am Heart J 2009;157:132–140.
118. Pristipino C, Trani C, Nazzaro MS, Berni A, Patti G, Patrizi R, Pironi B, Mazzarotto P, Gioffrè G, Biondi-Zoccai GG, Richichi G; PREVAIL (Prospective Registry of Vascular Access in Interventions in Lazio Region). Prospective registry of vascular access in interventions in lazio region study group. Major improvement of percutaneous cardiovascular procedure. Heart 2009;95;476–482.
119. Rao SV, Cohen MG, Kandzari DE, Bertrand OF, Gilchrist IC. The transradial approach to percutaneous coronary intervention. J Am Coll Cardiol 2010;55:2187–2195.
120. Singh M, Rihal CS, Lennon RJ, Garratt KN, Holmes DR. A critical appraisal of current models of risk stratification for percutaneous coronary interventions. Am Heart J 2005;149:753–760.
121. Brindis R, Goldberg SD, Turco MA, Dean LS. President's page: Quality and appropriateness of care: The response to allegations and actions needed by the cardiovascular professional. J Am Coll Cardiol 2011;57:111–113.