Clinical Investigations

Assessing the Appropriateness of Coronary Revascularization: The University of Maryland Revascularization Appropriateness Score (RAS) and Its Comparison to RAND Expert Panel Ratings and American College of Cardiology/American Heart Association Guidelines with Regard to Assigned Appropriateness Rating and Ability to Predict Outcome

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Summary

Background: Significant regional variation in procedural frequencies has led to the development of the RAND and American College of Cardiology/American Heart Association (ACC/AHA) guidelines; however, they may be difficult to apply in clinical practice. The University of Maryland Revascularization Appropriateness Score (RAS) was created to address the need for a simplified point scoring system.

Hypothesis: The study was undertaken to compare revascularization appropriateness ratings yielded by the RAND Expert Panel Ratings, ACC/AHA guidelines, and the University of Maryland RAS.

Methods: We applied these three revascularization appropriateness scoring systems to 153 catheterization laboratory patients with a variety of cardiac diagnoses and treatments. For each patient, appropriateness scores assigned by each of the three systems were compared with each other and with the actual treatment delivered. Concordance of care with appropriateness score was then correlated with outcome.

Results: There were significant differences among all three scoring systems in their ratings and in the concordance of treatment with appropriateness rating. When treatment provided was concordant with RAND rating, there was a lower

occurrence of subsequent coronary artery bypass grafting (CABG), the composite end point of either CABG or percutaneous transluminal coronary angioplasty (PTCA), and the composite end point of death, myocardial infarction (MI), or revascularization. When treatment was concordant with the ACC/AHA guidelines, there was lower occurrence of all-cause mortality, PTCA, the composite end point of either CABG or PTCA, and the composite end point of death, MI, or revascularization. When treatment provided was concordant with the RAS, there was lower occurrence of cardiac death, all-cause death, CABG, the composite end point of either CABG or PTCA, and the composite end point of death, MI, or revascularization.

Conclusions: The RAS is a simple scoring system to assess revascularization appropriateness. When the RAND, ACC/AHA, and RAS systems are compared in a catheterization laboratory population, they rate the same patient differently and vary in their correlation of appropriateness rating with outcome.

Key words: revascularization appropriateness, guidelines, coronary artery disease

Introduction

More than 850,000 percutaneous and surgical coronary revascularization procedures are performed annually in the United States at a cost of approximately \$30 billion. Despite assertions that most coronary revascularization is appropriate, significant regional variation in the frequency of use of coronary revascularization procedures continues to exist.¹ Whether this reflects an overuse of inappropriate procedures, underuse of appropriate procedures, or regional variation in disease remains in question.² In countries where financial resources for cardiac care have been restricted, studies have shown an ensuing reduction in both appropriate and inappropriate care.³ In a comparison of treatment in Canada and the United States, Canadian patients underwent significantly less angiography

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and revascularization but had markedly worse functional status and more cardiac symptoms during the first year post myocardial infarction (MI).⁴

Guidelines for many areas of cardiac care presently exist or are in development.⁵⁻¹⁷ Although their intent is to guide a physician in the appropriate management of a patient to achieve higher quality care, they are being prospectively and retrospectively applied as utilization management tools and as definitions of the medicolegal standard of care.¹⁸ Many criticisms of the guidelines movement exist, including (1) the difficulty applying complex guidelines to actual clinical decision making, (2) conflicting recommendations among different guidelines, and (3) lack of studies correlating adherence to guidelines with improved outcome.

Two established guidelines exist for evaluating the appropriateness of coronary revascularization with percutaneous transluminal coronary angioplasty (PTCA) and coronary artery bypass graft surgery (CABG). They are the Rand Expert Panel Ratings of Appropriateness and Necessity for PTCA and CABG, and the American College of Cardiology/American Heart Association (ACC/AHA) guidelines for PTCA and CABG.⁶⁻⁹

Both the RAND and ACC/AHA revascularization appropriateness guidelines may be difficult to apply in clinical practice. The RAND ratings are expressed as a series of tables containing thousands of situation-specific ratings. The ACC/AHA guidelines are descriptive, making assignment of definitive appropriateness challenging.

To address the need for a simpler appropriateness scoring system, we developed the University of Maryland Revascularization Appropriateness Score (RAS).^{19,20} The RAS system is a simplified point system which consists of two parts: an appropriateness of intervention score and a type of intervention score.

No studies have been published comparing revascularization appropriateness ratings yielded by the guideline systems for a variety of clinical indications. An objective of this study was to introduce the RAS and to compare the ratings of revascularization appropriateness by RAND, ACC/AHA, and RAS by applying all three guidelines to the same clinical population of cardiac catheterization laboratory patients who were non-randomly selected to include a variety of diagnoses and who were receiving a variety of treatments.

An ongoing criticism of revascularization appropriateness guidelines has been the paucity of studies validating their ability to predict outcome. Only one study to date has addressed this issue. In all, 671 patients who met explicit clinical criteria for necessity of CABG or PTCA using the RAND expert panel ratings were studied. Those receiving a revascularization procedure deemed necessary (concordant therapy) had a lower mortality and less chest pain at 2 years post procedure than those in whom revascularization was deemed necessary but who were treated with medical therapy (discordant therapy).²¹ We therefore investigated clinical outcome in this selected population of catheterization laboratory patients to determine whether treatment that was concordant with the ratings of RAND, ACC/AHA, and RAS correlated with improved out-

come and further to identify which clinical outcomes were best predicted by each system.

Methods

RAND Expert Panel Ratings of Appropriateness and Necessity for PTCA and CABG

The RAND Expert Panel Ratings of Appropriateness and Necessity for PTCA and CABG^{6,7} were developed from an extensive literature review, creation of a list of potential indications for a procedure, and expert panel consensus to determine appropriateness. Procedures are categorized as *appropriate* and *crucial* if benefits exceed risks, the benefit is not small, and it would be improper care not to provide the service; *appropriate* if the benefits exceed risks; *inappropriate* if risks exceed benefit; *uncertain* if the benefits and risks are roughly balanced; and *uncertain with disagreement* if disagreement is present about risks versus benefits.

ACC/AHA Guidelines for PTCA and CABG

The ACC/AHA guidelines for PTCA and CABG^{8,9} were developed by committees with emphasis placed on results of clinical studies. They were simultaneously published in the *Journal of the American College of Cardiology* and *Circulation* and therefore are widely available to practicing cardiologists. The appropriateness of PTCA and CABG is related to clinical presentation, extent of disease, and myocardium at risk. A procedure is considered Class I if it is considered justified; Class II if there is divergence of opinion; and Class III if the procedure is not considered indicated.

Development of the University of Maryland Revascularization Appropriateness Score (RAS)

The University of Maryland RAS was developed to provide a simplified appropriateness scoring system that could be applied prospectively and retrospectively to patients. Key elements relevant to the decision to proceed to coronary revascularization were selected based upon an extensive literature review and empirically assigned a weighted score.

The RAS consists of two parts, the appropriateness of intervention score and the type of intervention score (Table I). The appropriateness of intervention score contains five categories of patient information: clinical presentation, extent of coronary disease, left ventricular function, exercise test results, and comorbidity. Points are assigned to each category and are added to yield a total point score. The modular design allows a score to be calculated for all patients, even if one module might be missing information.

Clinical presentation: Patients were assigned points for presenting symptoms, either angina or acute MI. Since revascularization can provide symptomatic relief of chronic stable angina, more points were assigned as the level of symptoms increased (no angina = 0 points, Canadian Cardiovascular Society Class I-II = 1 point, CCS III-IV = 2 points.²² If symp-

toms were due to unstable angina, 2 points were assigned, however the "high risk" patient with overt electrocardiogram (ECG) changes with chest pain received 3 points. Post-MI angina was assigned 3 points reflecting the need to consider revascularization to prevent recurrent ischemic events.^{23,24} If the patient's symptoms were unresponsive to maximal medical therapy, 1 additional point was assigned, however -1 point was assigned if the addition of medication controlled symptoms. Maximal medical therapy for stable angina was defined as the patient receiving (or had documented intolerance to) any two of the following: beta blocker, calcium-channel blocker, or nitrate preparation. Maximal medical therapy for unstable or postinfarction angina was defined as aspirin or intravenous heparin, and intravenous nitroglycerin or any two of the following: beta blocker, calcium-channel blocker, or nitrate preparation. For patients presenting with acute MI within 6 h, 2 points were assigned, reflecting the benefit to early revascularization.²⁵ When acute MI had been present for 6-12 h, 1 point was assigned if the patient was pain free and 2 points if the patient was still having chest pain, given that reperfusion during this period is associated with a sustained but less dramatic reduction in mortality.²⁶ Non-Q-wave MI was assigned 2 points, reflecting the typically incomplete nature of the event.^{27,28} Any patient with acute MI who was deemed not a candidate for thrombolytic therapy was assigned 2 additional points to support the need for salvage revascularization.^{29,30}

Extent of coronary artery disease: Points were assigned for extent of coronary disease, but only if those vessels were approachable for revascularization by either PTCA or CABG. Using the fundamental principle that the greater the zone at risk, the more compelling the need to revascularize,^{31,32} left main disease was assigned 5 points, triple-vessel disease 3 points, double-vessel disease 2 points, and single-vessel disease 1 point. An additional point was awarded for proximal left anterior descending artery (LAD) involvement to reflect the increased myocardium at jeopardy.^{33,34} Significant left main disease was considered a 50% diameter stenosis. Triple-vessel disease was defined as one major artery with $\geq 70\%$ stenosis (or $\geq 60\%$ stenosis if longer than 10 mm) in one of the three major arteries or a large (≥ 2.5 mm) side branch and $\geq 50\%$ stenosis in the remaining two major arteries or large branch. Double-vessel disease was defined similarly, except that a $\geq 50\%$ stenosis was required in one of the two remaining arteries or large branch. Single-vessel disease was defined as one major artery with $\geq 70\%$ stenosis (or $\geq 60\%$ stenosis if longer than 10 mm) in one of the three major arteries or a large side branch. For arteries which had been revascularized by previous bypass surgery, any lesion in the corresponding graft was used for determination of single-, double-, or triple-vessel disease, unless the graft was chronically occluded and not amenable to any form of revascularization.

Left ventricular function: Since patients with left ventricular dysfunction are more likely to benefit from revascularization,³⁴⁻³⁷ if the ejection fraction was $\leq 40\%$ 1 point was assigned. Those in cardiogenic shock were assigned 2 points, reflecting the profound benefit if revascularization can be accomplished.^{38,39}

Exercise test results: Since a strongly positive exercise test has been associated with a poor prognosis,⁴⁰ 2 points were assigned to support revascularization. A negative exercise test was assigned -1 point to detract from the appropriateness of revascularization. Although a mildly positive exercise treadmill test (ETT) was assigned 0 points, if any positivity of exercise testing occurs post MI, 2 additional points were assigned. This reflects the high occurrence of adverse events in this population.⁴¹

Comorbidity: Points were assigned for concomitant medical conditions which would make both angioplasty or surgery less appropriate. The following are considered comorbid illnesses: serum creatinine >3.0 mg/dl and the patient not already receiving dialysis, severe obstructive lung disease with a forced expiratory volume over the first s of expiration (FEV_1) ≤ 1.0 liter, severe acute life-threatening condition such as sepsis, and terminal illness with a prognosis of less than 6 months, such as metastatic cancer or end-stage acquired immune deficiency syndrome. If one of these conditions was present then -1 point was assigned. If two or more such conditions were present, -2 comorbidity points were assigned. In addition, if the patient had documented ventricular tachycardia or ventricular fibrillation, which was clinically felt due to ischemia but not associated with the first 48 h of an acute MI, then 2 comorbidity points were assigned.

RAS Appropriateness of Intervention Score Total

If the total point score was ≥ 4 , revascularization was considered necessary; if 3, revascularization was considered appropriate; if ≤ 2 , revascularization was considered inappropriate.

RAS Type of Intervention Score

If the RAS total point score yielded a rating of necessary or appropriate for coronary revascularization, then the type of intervention score was calculated. Since the clinical decision to consider PTCA or CABG often depends on lesion-specific and vessel-specific anatomic considerations, revascularization history, and comorbidity, this score assigns points in five categories: extent of coronary disease, individual lesion morphology, individual vessel approachability, history of prior revascularization, and operative risk. In each of these categories, negative points favor PTCA and positive points favor CABG.

Extent of coronary artery disease: It has become accepted practice to favor CABG as the number of diseased vessels increases. This score counted only those vessels that could be revascularized with either PTCA or CABG. For single-vessel disease, -2 points were assigned (favoring PTCA). Double-vessel disease was neutral. For triple-vessel disease 2 points were assigned; and for left main 3 points. The presence of proximal LAD involvement added 1 additional point.

Lesion morphology: Using the modified ACC/AHA Task Force classification,⁴² each vessel was characterized as Type A, B(B₁ or B₂), or C. For each vessel counted in the extent of CAD, the presence of a type A lesion favored PTCA with -1

point assigned for each vessel. Each type C lesion added 1 point favoring CABG.

Revascularization completeness: To reflect approachability by PTCA or CABG for each vessel that had significant disease, if only PTCA could be performed -1 point was assigned. If only CABG could be performed, then 1 point was assigned.

Prior revascularization: Since it is desirable to avoid repeat CABG if possible, -1 point was assigned for a history of prior CABG. The likelihood of restenosis after PTCA increases with the number of episodes of prior restenosis.^{43,44} For patients who had undergone prior PTCA and had restenosis, 1 point was assigned for two episodes of restenosis. Two points were assigned for three or more episodes of restenosis. In addition, since restenosis within 3 months increases the chance of subsequent restenosis, an additional point was added for this.⁴⁵

Operative risk: For the type of intervention score, operative risk was based upon the modified Parsonnet Score that was used in the RAND Expert Panel Ratings.⁴⁶ In the modified Parsonnet score, points are additively assigned for a variety of medical conditions. If they total ≤ 8 (corresponding to RAND low risk), 0 points were assigned in the type of intervention comorbidity category. If Parsonnet points total 9-18 (RAND moderate-high risk), -1 point was assigned. If Parsonnet points total ≥ 19 (RAND very high risk), -2 points were assigned. In addition to points based on the modified Parsonnet score, operative risk points were assigned to acknowledge the surgical risk associated with severely impaired ventricular function. If the left ventricular ejection fraction was $< 20\%$, -2 points were assigned. If the ejection fraction was $< 30\%$ and severe mitral regurgitation was present, -3 points were assigned.

RAS Type of Intervention Score Total

If the total was ≤ -2 , PTCA was the favored intervention; if ≥ 2 , CABG was the favored intervention. Otherwise the score was indeterminate and either procedure was considered appropriate.

Study population: The study population consisted of 153 patients referred to the University of Maryland Cardiac Catheterization Laboratory and the Baltimore Veterans Administration Medical Center Cardiac Catheterization Laboratory between March 1993 and October 1994. Patients were selected for inclusion in a nonrandom fashion to provide a broad variety of cardiac diagnoses and treatments for the purpose of comparing and evaluating the three scoring systems. Patient variables were recorded as outlined in Table II. All coronary angiograms were reviewed by the same interventional cardiologist (AAZ) who measured lesion severity using calipers, and determined morphology and approachability of all identified lesions. Following catheterization, all patient management decisions were made by the patient's attending physician without knowledge of the revascularization appropriateness rating.

Database for automated assignment of coronary Revascularization Appropriateness Score: A relational database was developed which allowed input of all clinical and angiograph-

ic data, treatment information, and clinical outcomes during follow-up. Using 4th Dimension (ACI US, Inc., Cupertino, Calif.) running on a Macintosh operating system (Apple Computer, Cupertino, Calif.), scripts were developed which automatically determined revascularization appropriateness score using the RAND Expert Panel Ratings, the ACC/AHA guidelines for PTCA and CABG, and the University of Maryland RAS.⁴⁷

Part I: Comparison of Revascularization Appropriateness Scores assigned by RAND expert panel ratings, ACC/AHA guidelines for PTCA and CABG, and the University of Maryland Revascularization Appropriateness Score: For each patient, the appropriateness scores for both PTCA and CABG assigned by each of the three guideline systems were compared using the automated relational database. Two scoring systems were considered in disagreement if they yielded frankly discordant recommendations, for example, if one system ranked PTCA as inappropriate for a patient, while the second system rated PTCA as either appropriate or necessary).

Part II: Comparison of Revascularization Appropriateness Scores and actual treatment received: For each patient, the

TABLE II Clinical data collected for determination of revascularization appropriateness

- Demographic, procedure, and treatment information (name, gender, age, address, phone, procedure, date of procedure, attending physician, date of admission, date of discharge)
- Angina history (characterization of angina - stable/unstable, Canadian Cardiovascular Class, presence of reversible ECG changes, history of antecedent MI, cardiac medications including those added after presentation, and persistence of symptoms on current medical regimen)
- Myocardial infarction history (interval between MI and catheterization, type of MI, presence of continued chest pain, treatment with thrombolytics)
- Comorbidity (hypertension, diabetes, renal insufficiency, dialysis, obesity, severe lung disease, severe peripheral vascular disease, prior cerebrovascular accident, aortic aneurysm, left ventricular aneurysm, history of ischemic VT/VF (not within 48 h of acute MI), intra-aortic balloon counterpulsation, comorbid illness)
- Prior revascularization status (acutely failed PTCA, prior PTCA and date, prior CABG and vessels grafted)
- Stress test results (protocol used, data, workload achieved, occurrence of chest pain, extent of ST depression, abnormal blood pressure response, high-grade ventricular arrhythmias, and nuclear perfusion results)
- Left ventricular function (ejection fraction, data, method of determination, history of congestive heart failure, presence of cardiogenic shock, ischemic pulmonary edema, severe mitral regurgitation)
- Coronary anatomy (percent diameter stenosis, ACC/AHA Task Force lesion morphology, lesion specific approachability by PTCA or CABG, coronary dominance)

Abbreviations: ECG = electrocardiogram. Other abbreviations as in Table I.

FIG. 1 Method used to determine concordance or discordance of care with appropriateness ratings yielded by RAND, ACC/AHA, or RAS systems.

revascularization appropriateness scores yielded by the three systems were related to the actual treatment received. Clinical treatment decisions for all patients were made by an attending cardiologist who was blinded to the assigned appropriateness ratings. The method used to determine treatment concordance with each appropriateness score is illustrated in Figure 1.

Part III: Clinical follow-up: Comparison of treatment concordance with outcome: All patients were followed after the initial catheterization to identify subsequent treatment and adverse outcomes. Telephone or written questionnaire follow-up was performed at 3 months, 6 months, and every 6 months

thereafter. Outcomes were recorded including death, MI, any revascularization with PTCA or CABG, congestive heart failure requiring admission, and recurrent or persistent angina.

Statistical analyses: The percent of patients with each adverse outcome after concordant versus discordant care was analyzed using Fisher's exact test.

Results

Study population: Clinical characteristics of the 153 patients are shown in Table III.

Part I: Comparison of Revascularization Appropriateness Scores assigned by RAND expert panel ratings, ACC/AHA guidelines for PTCA and CABG, and the University of Maryland Revascularization Appropriateness Score: The distribution of appropriateness ratings, irrespective of treatment received, is shown in Figure 2. For PTCA appropriateness,

TABLE III Clinical characteristics of study population (n = 153)

	n (%)
Mean age: 58.9 ± 11.6 years (range 28–87)	
Sex: 107 male, 46 female	
Diagnosis	
Unstable angina	46 (30.1)
Chronic stable angina	39 (25.5)
Acute MI	10 (6.5)
Post-MI	40 (26.1)
Asymptomatic (silent ischemia or preoperative evaluation)	16 (10.5)
Near sudden death	2 (1.3)
Extent of coronary disease	
Left main disease	9 (5.9)
Triple-vessel disease	17 (11.1)
Double-vessel disease with proximal LAD involvement	16 (10.5)
Double-vessel disease without proximal LAD involvement	43 (28.1)
Single-vessel disease with proximal LAD involvement	15 (9.8)
Single-vessel disease without proximal LAD involvement	39 (25.5)
No lesions ≥ 70%	14 (9.1)
Post-catheterization treatment	
PTCA	93 (60.8)
CABG	27 (17.6)
Medical therapy	33 (21.6)
Mean follow-up: 15 ± 7 months (range 10–28)	

Abbreviations as in Table I.

FIG. 2 Distribution of revascularization appropriateness ratings when the 153 patient population was rated for percutaneous transluminal coronary angioplasty (PTCA) and coronary artery bypass grafting (CABG) by the RAND, ACC/AHA, and RAS systems. For RAND: A+C = appropriate and crucial, A = appropriate, U/Ud = undecided or undecided with disagreement, I = inappropriate. For ACC/AHA: I = Class I, II = Class II, III/Contraindicated = Class III or contraindicated. For RAS: N = necessary, A = appropriate, I = inappropriate.

TABLE IV Disagreement between scoring systems in appropriateness of revascularization for a given patient

Comparison of scoring systems	PTCA (%)	CABG (%)
RAND vs. ACC/AHA	20	30
RAND vs. RAS	7	18
ACC/AHA vs. RAS	39	36

Abbreviations as in Table I.

there were statistically significant differences among all three scoring systems in the percentage of patients ranked inappropriate (RAND vs. ACC/AHA $p < 0.0001$; RAND vs. RAS $p < 0.008$; and ACC/AHA vs. RAS $p < 0.02$). For CABG appropriateness, there were statistically significant differences in the percentage of patients ranked inappropriate between ACC/AHA vs. RAND ($p < 0.0001$) and RAND vs. ACC/AHA $p < 0.0001$. There was no significant difference between RAND and RAS in the percentage of patients rated inappropriate.

For a given patient, disagreement between the scoring systems in revascularization appropriateness is presented in Table IV.

Part II: Comparison of Revascularization Appropriateness Scores and actual treatment received: Concordance of treatment (PTCA, CABG, or medical therapy) with the rated appropriateness of that treatment is shown in Figure 3.

Part III: Clinical follow-up: Comparison of treatment concordance with outcome: Follow-up was obtained on 150 (98%) patients with a mean follow-up of 15 ± 7 months (range 10–28). There were 119 adverse events seen in 76 patients. For each of the three scoring systems, concordance of treatment with appropriateness rating was correlated with outcome (Table V). If treatment provided was concordant with RAND rating, there was a lower occurrence of CABG, the composite end point of either CABG or PTCA, and the composite end

FIG. 3 Percentage of patients whose treatment was concordant with revascularization appropriateness ratings for percutaneous transluminal coronary angioplasty (PTCA), coronary artery bypass grafting (CABG), and all patients (including those treated with medical therapy). ▨ = RAND, □ = ACC/AHA, ■ = RAS.

point of death, MI, or revascularization. If treatment provided was concordant with the ACC/AHA guidelines, there was lower occurrence of all-cause mortality, PTCA, the composite end point of either CABG or PTCA, and the composite end point of death, MI, or revascularization. If treatment provided was concordant with the University of Maryland RAS, there was lower occurrence of cardiac death, all-cause death, CABG, the composite end point of either CABG or PTCA, and the composite end point of death, MI, or revascularization.

Discussion

Assuring appropriateness of coronary revascularization is particularly important since coronary disease is common, revascularization procedures are frequent, and the costs of those

TABLE V Adverse outcomes during follow-up: Correlation of treatment concordance with outcome

Outcome	n	%	Percent of patients with adverse event after concordant vs. discordant treatment ($^a p < 0.05$)		
			RAND expert panel ratings	ACC/AHA guidelines	U. of Maryland RAS
Cardiac death	9	5.9	5 vs. 8	4 vs. 12	2 vs. 16 ^a
Noncardiac death	4	2.6	3 vs. 0	2 vs. 5	3 vs. 2
All causes death	13	8.5	10 vs. 13	7 vs. 20 ^a	7 vs. 20 ^a
Myocardial infarction	7	4.6	5 vs. 9	5 vs. 5	5 vs. 7
PTCA	11	7.2	6 vs. 13	4 vs. 18 ^a	7 vs. 9
CABG	18	11.8	8 vs. 70 ^a	10 vs. 18	7 vs. 25 ^a
Revascularization (PTCA or CABG)	27	17.6	13 vs. 43 ^a	14 vs. 30 ^a	12 vs. 32 ^a
Persistent or recurrent angina	58	38.0	37 vs. 52	35 vs. 50	35 vs. 53
CHF requiring hospital admission	12	7.8	7 vs. 13	7 vs. 10	6 vs. 17
Composite end point (death, MI, revascularization)	40	26.1	23 vs. 52 ^a	20 vs. 48 ^a	18 vs. 50 ^a

Abbreviation: CHF congestive heart failure. Other abbreviations as in Table I.

procedures are high. A variety of factors have contributed to growth in the use of coronary revascularization procedures. They include advances in interventional catheter technology and aging of the population. However, fee-for-service driven practice, defensive medicolegal pressures, and desires to maintain volume-based credentials may also contribute. This unrestricted growth has led to revascularization rates that are two to three times higher than in other well-industrialized countries.

Revascularization appropriateness scoring systems may be used prospectively during physician decision-making or the preauthorization of care. They may also be used retrospectively to identify patterns of inappropriate care or problem indications. Ideally, they should reflect best practice by showing demonstrable improvement in clinically relevant outcomes when they are followed. For such systems to be effective, they must be able to communicate meaningfully with the decision-making physicians.⁴⁸

In this study, revascularization appropriateness ratings provided by the RAND, ACC/AHA, and RAS scoring systems were compared in patients referred to an academic medical center cardiac catheterization laboratory. On both population and individual patient bases, there were significant differences between all three systems in the appropriateness ratings for PTCA and CABG. This raises the question of which scoring system or guideline, if any, should be considered the "standard of reference." The need to correlate use of these appropriateness scoring systems with improved outcome has become paramount.

In this study, all treatment decisions were made by the attending physician without knowledge of the appropriateness rating. Significant discordance was seen between treatment received and the appropriateness ratings for those patients treated with PTCA and medical therapy. However, no patient received a CABG that was ranked inappropriate by any of the scoring systems. This is similar to the study of 1,338 New York State patients who underwent CABG in 1990, in which 2.4% were rated by RAND criteria as inappropriate.⁴⁹ In previous studies of CABG appropriateness, most surgery that was considered inappropriate was for single- and double-vessel disease which would now be easily approached with current catheter-based therapy.⁵⁰

Of the 93 patients in our study who underwent PTCA, 17% were rated as inappropriate by RAND. This rate is substantially higher than the 4% rate of inappropriate use of PTCA in 1,306 New York State patients in 1990.⁵¹ This may reflect that fact that our methodology employed review of all angiograms, rather than medical record abstraction, to determine coronary anatomy and lesion morphology. As a result, we found that 9% had no coronary stenosis $\geq 70\%$ compared with 0.4% in the New York State study.⁵¹

We have demonstrated that concordance of treatment with these revascularization appropriateness scores predicted improved outcome; however, the three scoring systems differed in the outcomes that they predicted. Although RAS yielded more necessary ratings than the other systems, it was the only system that predicted cardiac mortality with discordant care. All three systems predicted the composite end point of death,

MI, and coronary revascularization. While RAND and RAS predicted the need for CABG, the ACC/AHA guidelines predicted the need for subsequent PTCA.

Although data based on this population are useful to compare the scoring systems and validate the RAS, they do contain the bias of being nonrandom and reflecting patients referred to a tertiary hospital catheterization laboratory. Since many of the patients in this study were referred specifically for PTCA, the relatively high percentage of patients ranked inappropriate for CABG should be expected.

The 4th Dimension-based relational database which automatically determines revascularization appropriateness scores holds promise for the validation of future revascularization appropriateness scoring systems, the guidance of individual patient care, and the retrospective analysis of patterns of care. It will be a useful tool as these scoring systems are evaluated in larger populations.

Conclusion

To supplement the existing RAND and ACC/AHA systems for assessing revascularization appropriateness, we have developed a new and simpler revascularization score, the University of Maryland RAS. These three scoring systems rank the same patient differently. As well, the different systems vary in their correlation of appropriateness rating with outcome. There is now a need to evaluate guidelines and appropriateness scoring systems prospectively with regard to patient outcomes.

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