

# Isolated LAD Revascularization in the Modern Era: Demographics and Preliminary Outcomes<sup>1</sup>

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**ABSTRACT.** Revascularization of the left anterior descending coronary artery is an important, evolving and controversial topic. There are differences in patient selection, hospital stay and readmission, and hospital cost.

We reviewed our institutional experience in 190 consecutive patients who underwent isolated initial left anterior descending revascularization via angioplasty, angioplasty plus stenting, conventional coronary artery bypass grafting and minimally invasive direct coronary artery bypass. We sought to determine if there were differences in patient demographics, clinical outcomes, and resource utilization. We sought to evaluate what were the principal determinants of any measured differences in outcome.

Inpatient and outpatient chart review, evaluation of hospital cost via micro cost method, and multivariate analysis were employed. Results with  $p \leq 0.05$  were considered significant by conventional statistical analysis.

Mortality was equal in all subgroups. Patients who underwent percutaneous revascularization had a shorter initial length of hospital stay and initial hospital cost. This was particularly true among those who received stents. Patients who received surgical therapy were less likely to require repeat hospital admission for both cardiac and noncardiac indications. During follow up, the initial resource savings attributable to percutaneous interventions dissipated. Multivariate analysis indicated that measured differences were likely attributable to differences in patient baseline demographics rather than the choice of revascularization procedure.

Though there are differences in resources, as measured by hospital days or hospital costs between patients undergoing LAD revascularization via different techniques, the differences are principally due to differences in the types of patients selected for these techniques rather than the revascularization procedure.

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## INTRODUCTION

The optimal revascularization technique for clinically important coronary artery disease is controversial. A variety of clinical studies have evaluated the relative effectiveness of coronary angioplasty, coronary atherectomy, and standard coronary artery bypass grafting (Versaci and others 1997; King III and others 1997; Tu and others 1997; Gersh 1997; Mariani and others 1997; Frierson and others 1992; Hueb 1995; Cameron and others 1994). While traditionally the most weight is given to randomized prospective studies, their clinical usefulness is often limited because of marked changes in clinical practice that can occur with time, making the results of the studies out of date by the time the results are known and disseminated. Retrospective analyses of clinical databases have proven particularly useful in this field, and may help with clinical decision making both at individual institutions and more generally. The clinical care of patients is decided by the responsible physicians in accord with their best judgment and analyzed subsequently. While such studies have their own limi-

tations, their timeliness may be more directly relevant to contemporary clinical practice. There have been several studies evaluating optimum revascularization strategies in multivessel disease, as well as some for single-vessel coronary artery disease (Versaci and others 1997; Gersh 1997; Mariani and others 1997; Frierson and others 1992; Hueb 1995; Cameron and others 1994; Goy and others 1994). Of patients with single-vessel disease, it is generally believed that isolated left anterior descending coronary disease carries the worst prognosis. Revascularization techniques have undergone major changes in the last several years with the development and use of intracoronary stents and minimally invasive direct coronary artery bypass surgery (MIDCAB) (Versaci and others 1997; Mariani and others 1997; Carrozza and Baim 1997; Bauters and others 1997; Moussa and others 1997). The purpose of this study was to analyze our single institutional experience with patients who have undergone isolated LAD coronary revascularization. We focused on this group of patients because of their clinical importance, the true uncertainty as to optimal revascularization strategies, and the fact that focusing on this particular group of patients may provide a degree of clinical homogeneity that might better help elucidate the role of revascularization strategy, rather than incompletely accounted for differences in patient populations.

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## METHODS

All patients undergoing single-vessel left anterior descending coronary revascularization by angioplasty between 1 January 1995 and 31 December 1996 were included in our analysis. The time window for MIDCAB and CABG was extended to 31 March 1997 so as to facilitate patient accrual. The choice of revascularization technique was determined by the patient after discussion with their cardiologist and surgeon. Patient and procedure demographic data were recorded prospectively in a proprietary database (Summit Medical System) on all patients. The presence and severity of coronary stenosis was determined by a visual estimation of percent diameter, as is our typical clinical practice. Complications were recorded contemporaneously in the medical record as well as determined via retrospective chart review. The occurrence of hospital readmission and/or repeat revascularization procedure was determined via review of our institutional medical records as well as via contact with the patient's primary physician and/or cardiologist. The indication for repeat admission was determined primarily by the attending physician during the readmissions, and subsequently reviewed by one of the investigators. In cases of disagreement, the medical record was reviewed by other physicians for a consensus decision.

To focus the study on a homogenous group of patients, where the choice of surgical versus angioplasty procedure is commonly a real one, patients who underwent revascularization within the first 24 hours of an acute myocardial infarction were excluded. These patients typically underwent direct angioplasty or rescue angioplasty, and it is very rare in our institution and other institutions for these patients to have emergency surgery. Because we wish to assess the implications of a choice of revascularization strategy, and not just the isolated procedure, only patients presenting for initial revascularization of the LAD during the study period were included; patients who presented during our study interval with LAD restenosis were excluded.

Cost analysis was determined using micro-cost accounting. The micro-cost data system allows accurate costing of personnel, supplies, or time, and equipment on a per procedure, per physician basis.

Statistical analysis was performed utilizing statistical analysis for the Social Sciences (SAS). A student's *t*-test for continuous variables, correlational matrix for univariate analysis, and multiple linear regression analysis were used. Statistical significance was conventionally defined as  $p < 0.05$ . Corrections were made for multiple comparisons. (McNeil and others 1996) Power analysis was run for an effect size ( $f^2$ ) equaling 0.15, which has been identified by Cohen as a medium effect size for alpha equal to 0.05 and a population size ( $N$ ) of 193 (McNeil and others 1996; Cohen 1977). Power analysis was run for the most conservative regression model, which had seven linearly independent vectors. For a medium effect ( $f^2 = 0.15$ ) (Cohen 1977) we will be able to detect that effect 98 times out of 100. However, for a small effect, we would only be able to detect that effect 27 times out of 100 when  $N$  was 193 and alpha was 0.05.

Also, the Bonferroni correction was used to control for Type I error build-up due to multiple tests of significance. The Bonferroni correction would indicate that a  $p$ -value less than or equal to 0.008 would be needed to produce significance at the 0.05 level.

## RESULTS

### Demographics

Follow up data was available on 100% of patients. There were no deaths. Baseline demographics are described in Table 1. Patients undergoing conventional coronary artery bypass grafting were slightly older than those undergoing MIDCAB or PTCA. Those greater than 75 years of age comprised 17%, 28%, and 24% of PTCA, CABG, and MIDCAB respectively. The patients were predominantly male, particularly those undergoing surgical procedures. As might be expected in a population consisting of patients with single-vessel coronary artery disease, clinical congestive heart failure was relatively uncommon, comprising less than 10% of the patients. One-fifth of the total patient population had diabetes mellitus.

### Clinical Results

Clinical results including mortality, need for target vessel (that is, repeat LAD) revascularization (TVR), need for hospital readmission, and length of hospital stays are presented in Table 2. Readmissions were far more common in patients undergoing angioplasty than undergoing either of the surgical procedures. This was true even when the analysis was restricted to those readmissions for predominantly cardiac problems. The initial length of stay was much lower for angioplasty than for surgical revascularization, though the likelihood of a patient being readmitted for cardiac reasons was increased. There were three noncardiac readmissions out of a total of 17 MIDCAB patients. The small sample size precludes a definitive interpretation of this number. Including the index hospitalization as well as any follow up hospitalizations, patients undergoing angioplasty spent an average of 7.13 days in the hospital, those undergoing CABG 10.44 days, and those undergoing MIDCAB 8.88 days. Some of this time is attributable to the presenting medical condition (for example, acute myocardial infarction) and not solely the revascularization procedure. In sum, the initial benefit that percutaneous procedures, and to some extent MIDCAB, possess for a shortened hospital stay is dissipated with time. The need for repeat hospital admissions dramatically reduces the disparity in hospital stays between the various revascularization strategies.

Of the 155 patients who underwent percutaneous revascularization, 134 did not receive a stent, and 21 received one or more intracoronary stents. Data comparing baseline demographics are listed in Table 1. Data describing need for repeat admissions, repeat cardiac admission, and target vessel revascularizations is presented in Table 2. Stent patients were generally older and more likely to be female than patients who did not receive a stent. Patients who receive a stent were roughly half as likely to require (clinically driven) target vessel revascularization (9.5% vs. 21.6%).

TABLE 1

*Patient demographics.*

	PTCA w/Stent	PTCA w/o Stent	PTCA Total	CABG	Mid-CAB
# of Patients	21	134	155	18	17
Median Age	73	59	62	68	61
# > = 65 yrs	20	48	68	10	6
% > = 65 yrs	95.24%	35.82%	43.87%	55.56%	35.29%
# > = 75 yrs	5	21	26	5	4
% > = 75 yrs	23.81%	15.67%	16.77%	27.78%	23.53%
# male	10	82	92	12	15
% male	47.62%	61.19%	59.35%	66.67%	88.24%
Comorbidities					
# with diabetes	4	29	33	3	2
% with diabetes	19.05%	21.64%	21.29%	16.67%	11.75%
# with hypertension	11	60	71	8	4
% with hypertension	52.38%	44.78%	45.81%	44.44%	23.53%
# with clinical CHF	2	10	12	2	1
% with clinical CHF	9.52%	7.46%	7.74%	11.11%	5.88%
# with any/all of the above	12	79	91	11	5
% with any/all of the above	57.14%	58.96%	58.71%	61.11%	29.41%

Patients who received a stent likely differed in clinically important ways from those who did not, often in a manner not adequately captured in our database. At the point in time when this data was collected, patients who are a part of this study (a subset of all patients receiving angioplasty and/or stenting) were more likely to receive a stent for "bail-out" or threatened vessel closure. In the short time since this study was undertaken our laboratory, as well as others, are more likely to put stents in patients after balloon angioplasty, even when acute occlusion is not imminent. Our most recent review indicates more than 80% of all interventional patients in our catheterization laboratory receive stents.

### Hospital Cost Analysis

Hospital cost data is presented in Table 3. Initial hospital costs were lower for patients undergoing percutaneous revascularization than those undergoing surgical revascularization. The initial cost for patients receiving a stent was higher than those undergoing percutaneous revascularization without a stent. MIDCAB was initially less costly than conventional CABG. The initial advantage of lower cost in the percutaneous group is diminished with time due to hospital readmissions. In this particular study, cost analysis correlated with length of stay (LOS) analysis; increased LOS was associated with increased cost (Marrin and others 1997).

### Multiple Regression and Subgroup Analysis

The above data demonstrate that there exists sub-

stantial differences in length of stay and hospital costs for patients undergoing PTCA versus patients undergoing CABG or MIDCAB. To determine if these differences were due to differences in patient selection or the choice of procedure, multiple regression analyses were performed. This demonstrated that for both total LOS or total cost as the dependent variable (outcome) the choice of procedure did not account for a significant amount of variance if comorbidities are controlled for ( $p = 0.44$  for LOS,  $p = 0.15$  for cost). This is true for the measured comorbidities taken in aggregate or individually, though there was a nonsignificant trend for congestive heart failure to correlate with the outcome of LOS. Importantly, the occurrence of multiple comorbidities correlates with increased total LOS and total cost, and multiple comorbidities were more prevalent in surgical than angioplasty patients.

At least two studies (Chaitman and others 1997; King 1997) have evaluated the particular adverse outcome of revascularization of multivessel CAD in diabetics. We analyzed this important subgroup in our study. If baseline demographics and comorbidities were held constant, there was no difference in total LOS or total costs between percutaneous and either of the surgical procedures in diabetics.

Elderly patients are an important clinical subgroup that often presents a therapeutic challenge. Multiple regression analysis in the elderly ( $\geq 75$  or  $\geq 65$  years) demonstrated results that were analogous to the overall study results. If baseline demographics and

TABLE 2

*Clinical outcomes.*

	PTCA w/Stent	PTCA w/o Stent	PTCA Total	CABG	Mid-CAB
Initial LOS – Median	2	4	4	9	7
Initial LOS – Mean	4.95	4.67	4.71	10.06	7.71
# of Deaths	0	0	0	0	0
% of Patients readmitted	47.6%	40.2%	41.1%	11.1%	23.5%
Total # of Readmits for group	15	80	95	2	5
Total # of Cardiac readmits for group	5	62	67	0	2
% of Readmits for cardiac reasons	33.3%	77.5%	70.5%	0.0%	40.0%
# of Readmits for TVR	2	29	31	0	0
% of Patients readmitted for TVR	9.5%	21.6%	20.0%	0.0%	0.0%
Median LOS of Strategy – Total (incl. any/all readmit)	7	5	5	9.5	7
Mean LOS of Strategy – Total (incl. any/all readmit)	10.1	6.7	7.1	10.4	8.9
Median LOS of Strategy – Cardiac readmit (incl. all initial)	3	5	5	9	7
Mean LOS of Strategy – Cardiac readmit (incl. all initial)	6	6	6	10.1	8.1

comorbidities are accounted for, there is no significant difference in either total LOS or total cost between the revascularization techniques in the elderly.

## DISCUSSION

The optimal current revascularization technique for patients with isolated left anterior descending coronary stenosis is uncertain (Versaci and others 1997; King III and others 1997; Gersh 1997; Hueb and others 1995; RITA 1993; Hlatky 1996). The clinicians caring for the patients in our study presumably made the best decision they could given the available clinical information and prior institutional experience. Our institution is broadly representative of others in America. It is a university-affiliated, (Northeast Ohio Universities College of Medicine) not for profit community hospital. There are a total of 530 medical-surgical-obstetric beds, with no pediatrics or psychiatry. Our active cardiac catheterization laboratory (approximately 1000 interventional procedures annually) uses a broad spectrum of currently available interventional techniques, including balloon angioplasty, intracoronary stents, and directional and rotational atherectomy. No investigational devices were employed during the time period of this study. Our cardiac surgical program is active and employs

recent surgical advances, including mitral valve repair and MIDCAB. All of the cardiothoracic surgeons and interventional cardiologists were board eligible/board certified. Patients generally presented directly to our institution or were referred from outlying institutions for evaluation and treatment of their clinical cardiac condition, rather than being referred for a specific cardiac procedure. Thus, the results of our single institutional experience may be of direct relevance to many other similar programs. It would appear that in this important group of patients, with single-vessel coronary artery disease, coronary revascularization can be done with a very high degree of efficacy and safety. Initial lengths of hospital stay are generally short, and in our current healthcare environment may decrease further. In accord with prior studies in multi-vessel CAD, the initial lengths of stay and initial costs are generally less for catheter based interventions, though the number and costs of repeat revascularization tend to minimize this initial advantage.

Importantly, patients were not randomized to which therapy they received. This fact must be borne in mind in interpretation of all the data, but perhaps particularly in the subgroups of patients who underwent PTCA. The use of intracoronary stents is an area of rapid change and

TABLE 3

*Resource utilization.*

	PTCA w/Stent	PTCA w/o Stent	PTCA Total	CABG	Mid-CAB
Initial Median Cost	\$8,335	\$10,139	\$9,768	\$20,954	\$14,779
Initial Mean Cost	\$11,175	\$10,493	\$10,586	\$21,309	\$16,342
Median Cost of Strategy – Cardiac readmit (incl. all initial)	\$9,473	\$11,747	\$11,542	\$20,954	\$14,450
Mean Cost of Strategy – Cardiac readmit (incl. all initial)	\$12,815	\$13,841	\$13,702	\$21,309	\$17,028
Median Cost of Strategy – Total (incl. any/all readmit)	\$11,428	\$11,873	\$11,851	\$20,954	\$15,764
Mean Cost of Strategy – Total (incl. any/all readmit)	\$17,561	\$14,557	\$14,964	\$21,704	\$18,027

growth. In our laboratory, as well as most other active laboratories throughout the country, the indications for the placement of intracoronary stents broaden continually and the fraction of patients receiving intracoronary stents continues to increase. Nevertheless, it appears that our data would indicate that patients who receive intracoronary stents are approximately half as likely to have clinically needed target vessel revascularization during the follow up period. As this field evolves, and as the price of stents decreases, it may be expected that the overall clinically favorable results seen with intracoronary stenting will be reflected in an overall shorter length of stay, and an overall lower cost. Future studies of this evolving field will be necessary to see if this hypothesis is true.

There are several limitations to our study design. Patients were not randomized to revascularization technique, rather it was determined by clinical judgment. However, this may enhance the overall generalizability of our findings. It has been shown, for example, that patients from the EAST registry (where revascularization strategy was determined by the clinicians and patients, rather than by randomization) fared better than those whose revascularization techniques were chosen by randomization. Even in a study such as this one where 13.3% of patients received intracoronary stents, data may not be translatable into today and tomorrow's clinical decision making. Nevertheless, the results are fairly current and there have been no dramatic changes in recent interventional practices. MIDCAB is a new and still evolving surgical procedure; there is almost surely a learning curve, both for the individual surgeon and the institution. Exactly where, if ever, that curve tends to plateau, is undefined and the results of our initial small group of patients may be less favorable than the future use of this technique. This study represents our institution's initial experience with MIDCAB. Our follow up

time is limited; this is necessitated by the desire to have data that is current. Nevertheless, the vast majority of angioplasty patients were studied for six months after the procedure, a time when most clinical restenosis and other reasons for readmissions and repeat revascularizations will be manifest. There were several admissions "early" after bypass surgery. Comparison with other studies would suggest that the need for repeat cardiac readmissions on patients undergoing surgical interventions will be quite low for several years, though it will undoubtedly increase with time due to the progressive nature of coronary atherosclerosis (Mariani and others 1997; RITA 1993; Cameron and others 1994). Further study of these and other patients, with particular emphasis on longer term follow up, will be necessary and informative.

Our study was limited to patients with isolated LAD revascularization, and excluded patients undergoing revascularization within the first 24 hours of acute MI (that is, direct or rescue angioplasty). As such, its generalization to patients with single-vessel disease in other territories, or those requiring multi-vessel revascularization is speculative. Perhaps clinicians could incorporate these current results of this study, with prior data, addressing angioplasty versus surgery for multi-vessel coronary artery disease to guide clinical decision making.

### SUMMARY AND IMPLICATIONS

Patients with isolated left anterior descending coronary artery disease undergoing nonemergent revascularization may be successfully treated currently with angioplasty (often with the concomitant use of intracoronary stent), conventional CABG, or the new and evolving technique of MIDCAB. A high degree of success will likely occur with any procedure, though the surgical procedures will typically result in a longer length of

initial hospital stay and initial costs. Patients undergoing catheter-based techniques will likely require repeat hospitalizations and revascularizations during follow up with additional costs. Total costs for the initial hospitalization and early follow up hospitalizations and procedures would be less for patients undergoing catheter-based techniques; however with time, initial differences in clinical outcomes and hospital costs are substantially decreased. It cannot be concluded that choice of *revascularization technique* accounts for a significant amount of unique variance in predicting total LOS or hospital costs, independent of patient characteristics. Rather, it appears that differences in the type of *patients* undergoing LAD revascularization is the predominant determinant of clinical outcome (total LOS or total cost).

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