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Cost-Effectiveness of Coronary Artery Bypass Surgery in Octogenarians

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Objective

The objective of this retrospective cohort study was to determine whether coronary artery bypass graft (CABG) surgery is effective and cost-effective relative to medical management of coronary artery disease (CAD) in the elderly.

Summary Background Data

The aging of the U.S population and the improvements in surgical techniques have resulted in increasing numbers of elderly patients who undergo this surgery. The three randomized, controlled trials (RCTs) that established the efficacy of CABG surgery completed patient enrollment from 19 to 24 years ago excluded patients older than 65 years. Although information regarding outcomes of CABG in this population is mainly available in case series, a major lacuna exists with respect to information on quality of life and cost effectiveness of surgery as compared with medical management.

Methods

The authors retrospectively formed surgical and medically managed cohorts of octogenarians with significant multivessel CAD. More than 600 medical records of patients older than 80 years who underwent angiography at our institution were reviewed to identify 48 patients who were considered reasonable surgical candidates but had not undergone surgery. This cohort was compared with 176 patients who underwent surgery.

Results

The cost per quality-adjusted life year saved was $10,424. At 3 years, survival in the surgical group was 80% as compared with 64% in the entire medical cohort and 50% in a smaller subset of the medical cohort. Quality of life in patients who underwent surgery was measurably better than that of the medical cohort with utility index scores, as measured by the EuroQoL, (a seven-item quality of life questionnaire) of 0.84, 0.61, and 0.74, respectively.

Conclusions

Performing CABG surgery in octogenarians is highly cost-effective. The quality of life of the elderly who elect to undergo CABG surgery is greater than that of their cohorts and equal to that of an average 55-year-old person in the general population.

Secondary to rapidly escalating health-care costs, the outcomes of highly invasive procedures in the elderly are subject to challenge. This study focuses on the survival, quality of life (QoL), and economic outcomes of coronary artery bypass graft (CABG) surgery in octogenarians.

The aging of the U.S. population and the improvements in surgical techniques have resulted in increasing numbers of elderly patients who undergo this surgery.[1] The three randomized, controlled trials (RCTs) that established the efficacy of CABG surgery completed patient enrollment from 19 to 24 years ago, enrolled few women, and excluded patients older than the age of 65.[3–5] In the years since these trials were reported, CABG surgical technique and medical management of patients have improved. Today, it is ethically and clinically infeasible to undertake a new random-

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ized, controlled trial of CABG *versus* medical management targeted to the elderly. Although a number of case series measuring various outcomes of CABG surgery in the elderly have been published,[6–8] there has been no study systematically comparing effectiveness and cost-effectiveness of CABG *versus* medical management in this population.

Therefore, we carried out a retrospective, relative effectiveness and cost-effectiveness analysis of CABG surgery *versus* medical management in 224 patients 80 years and older, who were treated at the Columbia Presbyterian Medical Center (CPMC) between 1992 and 1996. We attempted to match patients who underwent surgery and who were managed medically on the basis of coronary artery pathology and left ventricular function. Through review of medical records, we have tried to minimize the adverse selection bias in the medically managed group within the practical limits imposed by a retrospective study design. The cost-effectiveness estimates presented here will be refined in future publications of the results of our current prospective study comparing the costs and outcomes of CABG surgery and medical management in three academic medical centers.

OBJECTIVES

The primary objective of this retrospective cohort study was to determine whether CABG surgery is effective and cost-effective relative to medical management of coronary artery disease (CAD) in the elderly. The secondary objectives were to examine the longevity and QoL of octogenarians who have significant CAD.

Table 1. CHARACTERISTICS OF SURGICALLY AND MEDICALLY MANAGED COHORTS

	CABG (n = 176)	Medical RX (n = 48)	p value
Sex (male)	101 (57%)	29 (57%)	NS*
Age (range)	80–90	80–89	
(mean)	82.2 ± 2.0	82.6 ± 2.4	NS*
Vessels occluded			
2 vessels > 70%	52 (30%)	22 (46%)	0.06*
3 vessels > 70%	117 (66%)	20 (42%)	NS*
left main > 50%	3 (2%)	4 (8%)	NS*
left main > 70%	4 (2%)	2 (4%)	NS*
LVEF %	44.3% ± 16.2	42.1% ± 21.4	NS†
Hx HTN	121 (69%)	18 (38%)	0.04*
Hx Diabetes	26 (15%)	12 (25%)	NS*

* p value calculated by chi-square.
† p value calculated by Student's t test.
CABG = Coronary artery bypass surgery.

Table 2. CHARACTERISTICS OF SURGICAL COHORT AND MEDICALLY MANAGED COHORT REFUSING SURGERY

	CABG (n = 176)	Medical Rx (n = 12)
Sex (male)	101 (57%)	9 (75%)
Age (range)	80–90	80–88
(mean)	82.2 ± 2.0	83.4 ± 2.9
Vessels occluded		
2 vessels > 70%	52 (30%)	5 (42%)
3 vessels > 70%	117 (66%)	5 (42%)
left main > 50%	3 (2%)	1 (8%)
left main > 70%	4 (2%)	1 (8%)
LVEF %	44.3% ± 16.2	41.9 ± 19.5
Hx HTN	121 (69%)	4 (33%)
Hx Diabetes	26 (15%)	3 (25%)

CABG = coronary artery bypass surgery.

METHODS

Patient Population

We retrospectively formed surgical (isolated CABG) and nonsurgical cohorts of octogenarians treated for CAD at CPMC between 1992 and 1996. The surgical cohort was identified by the hospital database maintained for the New York State Cardiac Surgery Reporting Systems. Our surgical cohort was composed of 176 patients, 80 years and older, who underwent isolated CABG surgery during this period. A two-step process was used to create a comparable cohort of patients who were managed medically (n = 48). Candidates for the medically managed cohort were ascertained through a query of the database maintained in the Interventional Cardiology Center at CPMC from 1993 to 1996.

The medical records of more than 600 patients were then reviewed by nurses and physicians to exclude patients from the cohort if: 1) their pathology was not primarily CAD, 2) they were found to have single-vessel or diffuse, nonsignificant multivessel disease, 3) they were treated by percutaneous transluminal angioplasty, 4) they had severe comorbidities that would preclude CABG surgery, and 5) cardiac surgical consults found them not to be suitable surgical candidates. Patients were included if they had multivessel coronary disease defined as ≥70% occlusion of at least two major arteries or ≥50% occlusion of the left main coronary artery. Characteristics of both cohots are noted in Tables 1 and 2.

Health Outcomes

We ascertained survival in both cohorts either by a returned response to our mailing or by direct phone calls by the investigators. Deaths were confirmed either by letters returned with a notation of the patient's demise, direct

Table 3. EUROQOL QUESTIONNAIRE

Mobility
I have no problems in walking about
I have some problems in walking about
I am confined to bed
Self-Care
I have no problems with self-care
I have some problems washing or dressing myself
I am unable to wash or dress myself
Usual Activities (*e.g. work, study, housework, family or leisure activities*)
I have no problems with performing my usual activities
I have some problems with performing my usual activities
I am unable to perform my usual activities
Pain/Discomfort
I have no pain or discomfort
I have moderate pain or discomfort
I have extreme pain or discomfort
Anxiety/Depression
I am not anxious or depressed
I am moderately anxious or depressed
I am extremely anxious or depressed
Compared with my general level of health over the past 12 months, my health state today is:
Better
Much the same
Worse

phone contact with a family member, documentation of death in the hospital information system for subsequent hospitalizations, communication with the patient's cardiologist, or through a search of the Social Security Death Index.

Quality of life was assessed in both cohorts by the EuroQol Questionnaire.[9] This seven-item instrument examines five QoL dimensions and perception of general and present health states. Dimensions assessed by the EuroQol include: mobility, self-care, usual activity, pain, and anxiety/depression (Table 3). We did not include the seventh item of the questionnaire that assesses patients' overall impression of their present health on an analog scale because of difficulty in administering this question in our telephone interviews. We elected to use this standardized instrument because it is effective, simple to administer, not overly burdensome to patients, and allows for the estimation of a single index or utility score that may be used in clinical and economic evaluations.

Patients in the surgical cohort were mailed a copy of the questionnaire along with a postage-paid envelope. They were asked to complete the questionnaire and return it by mail. We followed up by phone if no questionnaire was returned to us within 4 weeks. Responses to the EuroQol questionnaire in the medically managed cohort were obtained by telephone only.

Costs

Problematic methodologic issues are inherent to the measurement of costs, particularly in a retrospective study. In lieu of information regarding actual resource-base costing, which can be difficult and extremely time-consuming, health services researchers have relied on the ratio-of-costs-to-charges (RCCs) methodology as a way of ameliorating potential difficulties in the estimation of actual costs. Essentially, the application of RCCs converts charges to costs. The resultant calculation most closely approximates actual costs.

Because the total cost equals the sum of the quantity of specific services rendered, multiplied by the unit cost or RCC of each service, we calculated the total average direct costs associated with either CABG surgery or medical management by applying proxies of resource costs or RCCs to actual resource utilization. The index in-hospital stay for patients who underwent surgery included the first day of admission for the surgery through discharge, and for patients who were managed medically, the in-hospital costs included all charges associated with their stay, which included their cardiac catheterization. Costs of the index or initial hospitalization for CABG surgery or cardiac catheterization and subsequent hospitalizations were calculated by applying RCCs for a particular year to the charges obtained from the hospital billing information system. Six major resource categories were considered: in-patient room charge or emergency room use, operating or catheterization suite use, diagnostics (*i.e.*, radiology services, radioisotopes, electrocardiograms, etc.), therapeutics (*i.e.*, drugs, blood, etc.), other (*i.e.*, cardiac rehabilitation, respiratory therapy), and professional payments (Table 4).

Costs and frequency of subsequent hospitalizations for both groups were queried from the hospital billing information system according to diagnostic-related groups related to cardiac illness. Hospitalizations for chest and cardiac procedures were searched for by diagnostic-related groups 75 to 78, 106 to 112, 538, 543 to 549, and 808 to 809, conduction disturbance and syncope by diagnostic-related

Table 4. SUMMARY OF HOSPITAL AND PROFESSIONAL SERVICES

Resource Category	Sub-categories
Inpatient	Emergency room, regular floor days, special care days (ICU, CUU, step-down)
Operating room & Catheterization laboratory	
Diagnostics & laboratory	CT Scan, echo, EEG, ECG, radioisotopes, radiology diagnostics, ultrasound, pathology, other lab clinical
Therapeutics	Drugs, blood products, medical supplies
Other	Cardiac rehabilitation, PT, OT, respiratory therapy, renal dialysis
Professional payments	Cardiology (*catheterization*), cardiothoracic surgery, anesthesiology

groups 115 to 118, 138 to 139, and circulatory, angina, congestive heart failure, myocardial infarction, and cardiac arrest-related illnesses were searched by diagnostic-related groups 120 to 127, 132 to 133, 129, and 140 to 145.

The accounting for costs associated with subsequent hospitalizations at CPMC where approximately 40% of patients are referred solely for their CABG surgery and then return to the referring hospitals for subsequent care, may be seen as a major limitation of this study. To minimize the impact of this limitation on the cost-effective analysis, patients and costs associated with their care were included in the cost analysis based on the admitting cardiologist's referral pattern. That is, we established that 11 cardiologists or referring physicians routinely hospitalized patients under their care at CPMC for all of their acute care needs. Therefore, we applied the costs of 72 patients managed surgically and 36 patients managed medically who were under the identified physicians' care.

Difficulties arose in the estimation of professional payments because physician billing is not processed through the hospital's billing department. We therefore estimated the average physician and professional payment for cardiac catheterization, anesthesia, and surgeon fees according to Medicare reimbursement schedules. We then applied these costs to each patient in the appropriate group. Payments for consultations and attending cardiologists were unavailable, and therefore, not included. Although the frequency of consultations might have varied somewhat between the groups, we speculate that the differential between them may be small. Likewise, we encountered difficulty in ascertaining costs for outpatient care and were not able to include them in our analyses.

The first cost-effectiveness ratio is a quality-adjusted analysis that compares the long-term survival and QoL of both cohorts to the costs obtained in the 36 patients who were managed medically and the 72 patients who were managed surgically. These costs included subsequent hospitalizations. The second cost-effectiveness ratio, also quality-adjusted, was calculated by including the costs of 72 patients who underwent surgery with costs for 10 of the 12 patients who were managed medically whose preference was not to proceed with surgery and for whom notation of surgical candidacy was documented and retrieved from the patient's medical records. In all cases, an annual 3% discounting of costs was assumed as well as an average of 10.9 years of life expectancy for individuals aged 80 to 85 in the United States general population.[10]

Statistical Analyses

Between-group comparisons were undertaken to determine differences in patient characteristics. Data were analyzed by means of standard contingency tables. Kaplan-Meier product-limit estimates were used for purposes of estimating the probability of long-term survival given incomplete observations. Log-rank tests were used as the test of significance between actuarial survival of cohorts.[11] All data were analyzed using SAS System software (SAS Institute, Cary, NC).

RESULTS

Patient Population

Patient characteristics and risk factors of the surgical and nonsurgical cohorts are indicated in Tables 1 and 2. Much effort was taken to ensure comparability of groups in terms of coronary anatomy and surgical candidacy. As stated previously, candidates for the medical cohort were selected through chart review. Great care was taken to exclude candidates who either had severe comorbidities that would preclude surgery or their coronary anatomy did not meet the prespecified criteria. Interestingly, there were no significant differences in age, sex, left ventricular ejection fraction percentage, or incidence of diabetes; however, the surgical group had a significantly higher reported incidence of hypertension ($p = 0.04$).

Health Outcomes

Survival

Patients in the surgical cohort, on average, were followed up for 38 months and patients in the medically managed cohort for 31 months. Three-year survival of the surgical cohort was 80% and for the medically managed cohort 64% (Fig. 1). The long-term probability of survival in the surgical cohort takes into account a 6.8% perioperative mortality rate. For the subgroup of patients managed medically with a documented refusal of CABG surgery, a 50% 10-month survival rate was noted (Fig. 2).

Quality of Life

Responses to the EuroQol questionnaire were known for 64% of the surgical cohort and 73% of the medical cohort. Patients were asked to choose one of three possible responses for each domain. By selecting choice number 1, patients believed that they had no problem or limitation in that particular area; choice number 2 indicated some difficulty; and choice number 3 suggested the greatest difficulty or limitation. Therefore, higher scores indicated poorer QoL.

In general, patients in the surgical cohort reported a better QoL across all five dimensions and perception of their general health in comparison with other people they knew (Table 5). In particular, differences in pain, self-care, and patients' assessment of their general health accounted for the greatest disparities between the groups. A utility or index score of 1.00 represents full health, whereas scores of less than 1.00 indicate relatively poorer states of health. Patients in the surgical cohort were found to have an average utility of 0.84, and patients in the medical cohort had an average score of 0.61 ($p = <0.001$). Patients in the sub-

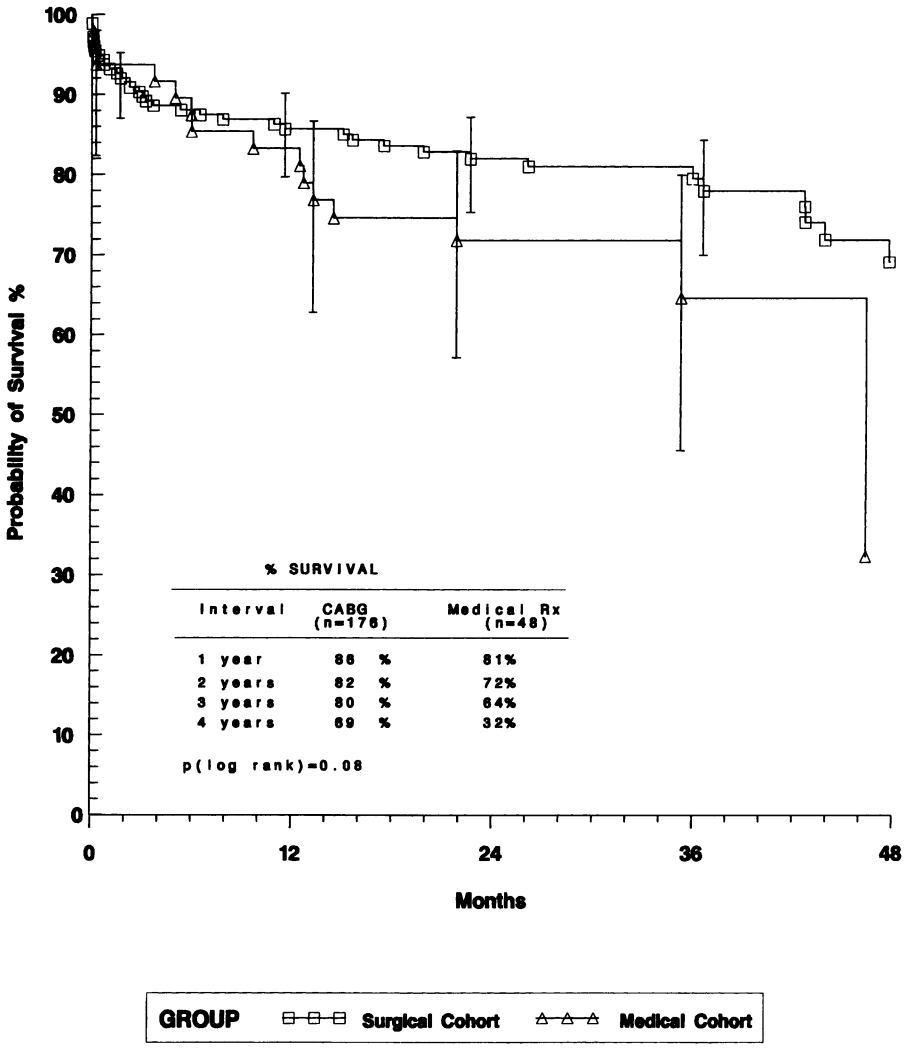

Figure 1. Actuarial survival of both cohorts. Average follow-up of patients who understand surgery and those treated medically was 38 months and 31 months, respectively.

group of the medical cohort who refused CABG surgery had a utility of 0.74.

Costs

On average, the cost of the index hospitalization for patients in the surgical, medically managed, and the sub-group of medically managed patients who refused CABG surgery were $41,348, $12,467, and $15,232 (U.S. dollars), respectively. The rate of subsequent hospitalizations over 3 years for cardiac related illnesses in the medically managed cohort was 2.2 per patient, whereas in the surgical cohort it was 1.6 per patient. On average, total long-term hospitalization costs, inclusive of the index and subsequent hospitalizations, are noted in Table 6. Costs relative to resource categories are depicted in Figure 3.

Cost-Effectiveness

Cost-effectiveness is expressed in terms of cost per quality-adjusted life years gained. The cost-effectiveness ratios derived in this study are according to standard accepted methodologies.[11]

$$\text{C/E Ratio} = \frac{\Delta \text{ Costs}}{(\text{QoL}) \times (\text{Lives Saved}) \times (\text{Years of Remaining Life}) \times (3\% \text{ Discounting or } 0.9151)}$$

The cost per quality-adjusted life years gained in comparing all patients managed surgically with all patients managed medically is $10,424. The cost per quality-adjusted life years gained in the group of patients treated surgically compared with the group of patients treated medically who refused CABG was $9,423.

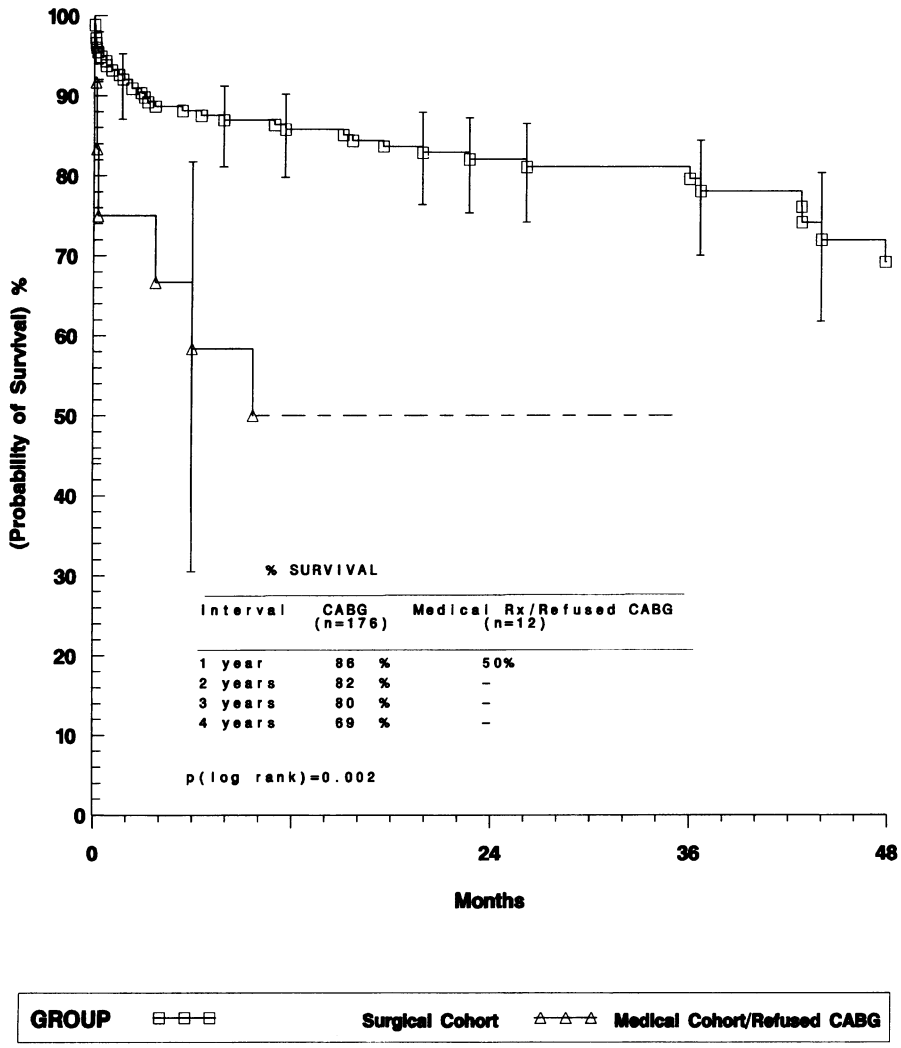

Figure 2. Actuarial survival of the entire surgical cohort compared with a subset of 12 patients from the medical cohort for whom surgery was offered but refused. Two of the 12 patients died before hospital discharge.

DISCUSSION

Older Americans represent the fastest growing segment of the U.S. population. Coronary artery bypass surgery performed in U.S. octogenarians has been rising by more than 15% each year since the mid-1980s.[8] In 1997, there were approximately 8.5 million Americans older than the age of 80, and it is estimated that by the year 2010, there will be approximately 12 million. Considering the trend in a demographic shift in the United States toward a graying population, and assuming that the rate of CABG surgery

Table 5. RESPONSES TO THE EUROQOL QUESTIONNAIRE

		Mobility (%)	Self-Care (%)	Activity (%)	Pain (%)	Depression (%)
Surgical Cohort	No problem (1)	52.7	89.9	67.8	70.5	72.7
	Some problem (2)	46.2	9	30	29.5	27.3
	Extreme problem (3)	1.1	1.1	2.2	–	–
Medical Cohort	No problem (1)	37.5	76	52	32	52
	Some problem (2)	62.5	12	48	60	48
	Extreme problem (3)	–	12	–	8	–

Percentage of patients responding to particular degrees of perceived problem across each of the domains.

Table 6. SUMMARY OF AVERAGE PER PATIENT COSTS FOR SURGICAL AND MEDICAL COHORTS

	Index Hospitalization	Subsequent Hospitalization	Total Average Long-Term Costs
CABG	$41,438	$3,984	$45,422
Med Rx	$12,467	$3,673	$16,140
MED Rx/Refused CABG	$15,232	$1,508	$17,042

Cost per QALY saved; CABG vs Med Rx = $10,424; CABG vs Med Rx/Refused CABG = $9,423.

performed in the elderly remains constant, more than 30,000 surgeries will be performed in this population by the year 2050. This represents a nearly fourfold increase from the 8000 performed in 1990, and a cost that will roughly exceed $1.2 billion.[1]

In light of these projections, we find the results of this study to be highly relevant in discussions of whether CABG surgery should be performed in the elderly. Based on the three major findings of this study, we conclude that CABG surgery should be offered to octogenarians with multivessel CAD who are considered reasonable surgical candidates. We have found isolated CABG surgery to be a highly effective form of treatment in octogenarians with a 3-year survival of 80% as compared with 64% in the medically managed cohort. Likewise, we have determined that the long-term QoL experienced by the patients treated surgically is far superior to that of the patients treated medically in our sample, with 3-year utility scores of 0.84 and 0.61, respectively. Quite strikingly, the utility score of 0.84, as assessed in the surgical group, is equal to that of an average 55-year old person in the general population.[10] And lastly, in addition to effectiveness in terms of survival and QoL, we have determined that performing CABG in the elderly is highly cost-effective, with a cost of $10,424 per quality-adjusted life year saved.

These findings are not only of importance to practicing physicians and surgeons, but also, have significant implications for global health policy. A rise in the number of CABG surgeries performed in this age group will undoubtedly impact greatly on health care spending and subsequently on the allocation of health care resources.

For equitable decisions to be made, policy makers, purchasers, and payers of health care have become increasingly reliant on measures of effectiveness that are comprehensive and precise in the estimation of cost-effectiveness of particular treatments. One such example of this is the Health Care Financing Administration's interest regarding the effectiveness of a new treatment for chronic end-stage emphysema. This concern has resulted in joint sponsorship between Health Care Financing Administration and the National Institutes of Health of a multicenter randomized, controlled trial examining health outcomes and costs of lung volume reduction surgery.

Data pertaining to the incidence of survival and morbidity in the elderly after CABG surgery are abundant.[1,6–8] Similarly, information on associated costs also is available;[1] however, a major lacuna exists with respect to information on the relationship of health-related QoL and in particular, cost per quality-adjusted life year saved as a result of performing CABG surgery in the elderly.

To address these concerns, we carried out this comparative study of the relative effectiveness and cost-effectiveness of CABG surgery and medical management within the constraints of a retrospective cohort design. We acknowledge that this is a suboptimal research design as compared with the gold standard of a prospective randomized, con-

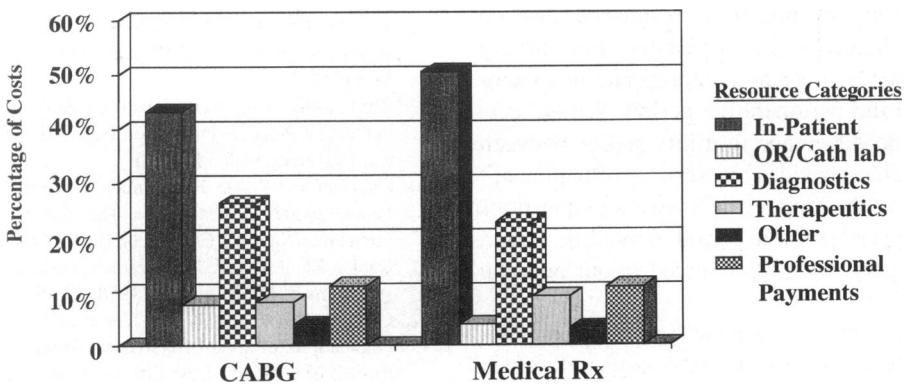

Figure 3. Percentage of total costs for index hospitalization for all patients by resource category.

trolled trial. The greatest limitation of any retrospective study comparing two therapies is the potential for bias of patient selection. We made a strong effort to review the medical records of the nonsurgical cohort to eliminate all patients for whom surgery would have been contraindicated. It is our opinion that the characteristics of all 48 patients in the medical cohort were similar and that physician preference may have been the primary reason for a lack of documentation of refusal for CABG surgery in 36 of the patients who were managed medically. Nevertheless, although great care was taken to exclude inappropriate patients from the nonsurgical group, the possibility that this group included sicker patients than those in the surgical group cannot be eliminated. The fact that CABG surgery proved to be cost-effective compared with the small subgroup in the nonsurgical cohort who were offered surgery but refused strengthens our overall conclusion that performing CABG surgery is cost effective in the elderly.

We emphasize that given the metric of cost effectiveness in cost per quality-adjusted year of life saved, there is an inherent bias against any treatment provided to elderly patients. For every life saved by a treatment of an 80-plus year old, the survivor gains on average 10.9 more years of life. Compare this with a life saved in a 20-year old patients who would be expected to live some 50 more years or longer. If the life-saving treatments in these two patients each cost $60,000, for the 80-year old patient it would cost $5,500 per year of life saved as compared with $1,200 per year of life saved for the 20 year old. In spite of this inherent age bias in cost-effectiveness analyses, CABG surgery fits comfortably under the generally accepted $50,000 per year of life saved benchmark. In our current prospective study of long-term outcomes of CABG surgery, we are repeating this analysis with a more systematic approach to evaluating patients managed medically for inclusion in the nonsurgical cohort.

Evidence that performing CABG surgery in octogenarians provides a better overall QoL than that of their medically managed cohorts is important information for patients, families, and providers. Anecdotally, some physician's have been somewhat skeptical of the added benefit to elderly patients' QoL, particularly in the immediate perioperative period. We recognize the potential bias toward favorable outcomes of surgery based upon these results because no information on QoL before and immediately after surgery was available. As such, it may be inappropriate to extrapolate these results to the perioperative period. We are certain, however, that the difference in utility scores between the cohorts, 3 years later, provides reassurance of the benefit of providing surgery in the long term. Answers to questions regarding QoL in the perioperative period, 6 months, 1 year, and 2 years after surgery, is being assessed in our ongoing study.

In sum, within the context of a growing elderly population, coupled with evolving global health care policies in which implicit or explicit rationing of costly treatments is a threatening possibility, we believed that it was important to assess the cost-effectiveness of CABG surgery in octogenarians. Considering the limitations of a retrospective comparison such as this, we are reasonably satisfied with the selection of patients in the medical cohort because a major effort was put forth in the identification of patients who were either offered surgery and refused or who otherwise would have been surgical candidates. We find that patients who underwent surgery live longer and enjoy a quality of life 3 years after surgery, which is measurably better than that of age-matched control subjects.[10] And finally, we find that CABG surgery is cost-effective in this population and compares favorably with a number of treatments considered to be cost-effective within a $50,000 per year of life saved benchmark.

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