Direct costs of coronary artery bypass grafting in patients aged 65 years or more and those under age 65

Evidence

Études

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? See related article page 823

Abstract

Background: Over the past 20 years, there have been marked increases in rates of coronary artery bypass grafting (CABG) among older people in Canada. The objectives of this study were to accurately estimate the direct medical costs of CABG in older patients (age 65 years or more) and to compare CABG costs for this age group with those for patients less than 65 years of age.

Methods: Direct medical costs were estimated from a sample of 205 older and 202 younger patients with triple-vessel or left main coronary artery disease who underwent isolated CABG at The Toronto Hospital, a tertiary care university-affiliated hospital, between Apr. 1, 1991, and Mar. 31, 1992. Costs are expressed in 1992 Canadian dollars from a third-party payer perspective.

Results: The mean costs of CABG in older and younger patients respectively were $16 500 and $15 600 for elective, uncomplicated cases, $23 200 and $19 200 for nonelective, uncomplicated cases, $29 200 and $20 300 for elective, complicated cases, and $33 600 and $23 700 for nonelective, complicated cases. Age remained a significant determinant of costs after adjustment for severity of heart disease and for comorbidity. Between 59% and 91% of the cost difference between older and younger patients was accounted for by higher intensive care unit and ward costs.

Interpretation: CABG was more costly in older people, especially in complicated cases, even after an attempt to adjust for severity of disease and comorbidity. Future studies should attempt to identify modifiable factors that contribute to longer intensive care and ward stays for older patients.

Résumé

Contexte : Les taux de pontages aortocoronariens (PAC) ont augmenté considérablement depuis 20 ans chez les personnes âgées au Canada. Cette étude visait à estimer avec précision les coûts médicaux directs du PAC chez les patients âgés (65 ans ou plus) et à en comparer les coûts chez les patients de ce groupe d'âge à ceux des PAC pratiqués sur les patients de moins de 65 ans.

Méthodes : On a estimé les coûts médicaux directs à partir d'un échantillon de 205 patients âgés et de 202 patients plus jeunes atteints à trois vaisseaux ou à l'artère coronaire principale gauche et qui ont subi un PAC isolé au Toronto Hospital, hôpital de soins tertiaires affilié à une université, entre le 1er avril 1991 et le 31 mars 1992. Les coûts sont calculés en dollars canadiens de 1992, du point de vue d'un tiers payeur.

Résultats : Les coûts moyens du PAC chez les patients âgés et plus jeunes respectivement se sont établis à 16 500 $ et 15 600 $ dans le cas des interventions électives sans complication, 23 200 $ et 19 200 $ dans celui des interventions non électives sans complication, 29 200 $ et 20 300 $ dans celui des interventions électives avec complication, et 33 600 $ et 23 700 $ dans celui des interventions non électives avec complications. L'âge est demeuré un important fac-

teur déterminant des coûts après rajustement en fonction de la gravité de la cardiopathie et de la présence de comorbidités. Dans une proportion variant de 59 % à 91 %, la différence du coût chez les patients âgés et les patients plus jeunes était attribuable aux coûts plus élevés à l'unité des soins intensifs et en salle de traitement.

Interprétation : Le PAC a coûté plus cher chez les sujets plus âgés, particulièrement dans les cas où il y eu des complications, même après qu'on a essayé d'en rajuster le coût en fonction de la gravité du problème et de la présence de comorbidités. D'autres études devraient essayer de cerner des facteurs modifiables qui contribuent à allonger le séjour des patients plus âgés aux soins intensifs et en salle de traitement.

During the past 20 years the volume of coronary artery bypass grafting (CABG) procedures has grown markedly in Canada, with large increases in CABG rates among older people accounting for most of the overall increase.[1–9] Similar trends have been described in the United States and the United Kingdom.[10–17]

In Ontario, between 1981 and 1989, CABG rates increased more than 2.5-fold among those 65 years of age or older, and more than 4-fold among those aged 75 years or more.[2] Patients aged 65 or older accounted for 17% of the procedures done in Ontario in 1981 and 37% of those done in 1989.[2] In Alberta, between 1984 and 1989, the largest increases in CABG rates were observed among those aged 70 years or more.[3] In the United States, between 1987 and 1990, CABG rates increased by 18% among those aged 65 years or older and by 67% among those aged 80 years or more.[10,11]

The increasing volume of CABG procedures in older people has prompted some authors to question whether this utilization represents an efficient use of resources.[5,18] A key component of a comprehensive economic analysis of CABG in older people is the cost of the procedure. Although there are numerous publications estimating the cost of CABG,[11,19–32] in most cases patient charges were used as a proxy for costs, and those that used actual costs were not designed to address specifically the relative costs in older and younger patients. The objectives of this study were to accurately estimate the true direct medical costs of CABG in older patients and to compare CABG costs in older and younger patients to establish whether there are systematic cost differences between these groups.

Methods

Patient selection

We derived cost estimates from a selected sample of patients at The Toronto Hospital, a tertiary care university-affiliated hospital. We limited our sample to patients with triple-vessel or left main coronary artery disease with no previous history of CABG who underwent isolated CABG (i.e., no concomitant valvular surgery) at the hospital between Apr. 1, 1991, and Mar. 31, 1992. We focused on triple-vessel and left main coronary artery disease because they are recognized indications for CABG.[33,34] For the purpose of this study all patients aged 65 or more were considered older, and all patients under 65 were considered younger. A total of 879 patients (365 older and 514 younger) with a mean age of 62.3 years met the inclusion criteria. Of the older patients, 47% were aged 65–69, 37% were aged 70–74, and 16% were aged 75 or more.

Costs were calculated for 4 subgroups of patients: 1) elective, uncomplicated cases (44.9% of the older patients and 55.4% of the younger patients), 2) elective, complicated cases (6.6% and 3.7% respectively), 3) nonelective, uncomplicated cases (40.3% and 36.5% respectively) and 4) nonelective, complicated cases (8.2% and 4.3% respectively). Nonelective CABG was defined as CABG performed during the same hospital stay for an event related to coronary artery disease (e.g., myocardial infarction or unstable angina). A complication was defined as any one of the following: death, myocardial infarction, stroke, infection or the need to reopen the chest cavity after the initial CABG procedure.

A total of 54 (14.8%) of the older patients and 41 (8.0%) of the younger patients had at least 1 complication. We reviewed all complicated cases. The uncomplicated cases were initially stratified by timing of surgery (elective v. nonelective) and left ventricular function (ejection fraction 40% or greater v. less than 40%). Cases were further stratified by sex and age subgroup (younger than 55, 55–59, 60–64, 65–69, 70–74 and 75 or older). The sampling goal for uncomplicated cases was to identify approximately 15 patients in each stratum. For all strata with 15 or fewer patients, we reviewed all cases, and for all strata with more than 15 patients, we selected a random sample of cases for review. The costing sample included 62 patients under 55 years, 68 patients aged 55–59, 72 patients aged 60–64, 86 patients aged 65–69, 71 patients aged 70–74 and 48 patients aged 75 or more.

Costing methods

All costs are presented in 1992 Canadian dollars. We used a third-party payer (Ontario Ministry of Health) perspective for estimating costs. Indirect costs and nonmedical direct costs were not considered.[35] Direct medical costs included costs for use of inpatient wards, operating rooms, intensive care, drugs,

laboratory and radiologic procedures, and professional services. For patients who had nonelective surgery the cost of CABG was calculated as the cost of the entire hospital stay during which the surgery was performed, including the cost for the portion of the hospital stay that preceded the surgical procedure.

We derived hospital costs by separately estimating the quantities of resources consumed by each patient and the cost per unit of each resource. To estimate unit costs at The Toronto Hospital, we used a costing model designed for the hospital in 1987 based on the Canadian Management Information Systems guidelines for allocating costs within hospital departments[36] (more details about the costing model are available from the first author on request). The costing model is based on a simultaneous, fully allocated costing approach.[35] Overhead costs associated with equipment and building depreciation were allocated among the hospital cost centres. The hospital was divided into cost centres providing services directly to patients (e.g., nursing units, intensive care units (ICUs), operating rooms, diagnostic and therapeutic services, pharmacy, social work and physiotherapy) and cost centres providing support services to other departments (e.g., finance, general administration, engineering, housekeeping, laundry, food services and health records). Costs associated with cost centres providing support services were allocated among themselves and then to cost centres providing patient services by means of simultaneous linear equations.[35] We then used these fully allocated costs to calculate the cost per hospital stay for each patient on the basis of resource use (e.g., the number of days spent on various nursing units or intensive care units, the number of hours in the operating room, and the weighted time units for laboratory services, radiology services, physiotherapy services, occupational therapy services and social work services).

Total resource use for each patient was based on a detailed retrospective chart review, a review of the hospital computer database for laboratory and radiologic investigations, and a review of physiotherapy, social work and occupational therapy records of weighted time units devoted to patients undergoing CABG. To establish drug and pharmacy costs for the 4 surgical subgroups considered in our analysis, we performed chart audits of drug use for 10 patients in each surgical subgroup. Pharmacy labour, management and support costs were added to drug costs to estimate an overall cost per patient-day for drugs and pharmacy services in each of the surgical subgroups.

We estimated costs for physician services from charges for services, including surgical procedures, intensive care, consultations, follow-up visits and interpretation of test results. Physician costing included charges for cardiovascular surgeons, surgical assistants, anesthetists, cardiologists, radiologists and all other physicians who provided care to patients undergoing CABG. Charges for physician services were derived from the Ontario Provincial Schedule of Benefits for Medical Services.[37]

Analysis

We calculated and compared costs using the SAS System (version 6.08 for Windows; SAS Institute Inc., Cary, NC) and S-PLUS software (version 3.3; StatSci [a division of MathSoft Inc.], Seattle). Mean hospital costs were determined for the 4 surgical subgroups of older and younger patients in the costing sample, and a detailed breakdown of costs was calculated for each subgroup. We also calculated the mean costs for the 6 age subgroups from the costing sample.

Since the costing sample oversampled complicated cases as well as other strata of interest, we carried out a direct adjustment to estimate the average cost for the total patient population from which the costing sample was drawn.[38] This was achieved by estimating the average cost for each stratum separately and then weighting the estimates to reflect the relative frequency of such patients in the total patient population. We obtained confidence intervals (CIs) for these costs by "bootstrapping" the above procedure 2000 times for each cost estimate.[39] The 50th and 1950th values were taken as the lower and upper limits respectively of the CI.

Finally, we used multiple linear regression analysis to estimate the effect of age on CABG costs after adjusting for other covariates. Two extensions of standard regression techniques were applied in the adjusted analysis. First, we used a weighted regression to give correct variable estimates while accounting for the oversampling of certain subgroups. Second, we used the with-replacement bootstrap (using 2000 repetitions) to estimate the standard errors and CIs of the regression coefficients under the sampling scheme described above.[40] We obtained p values for regression variables by referring a variable divided by its estimated standard error to a t-distribution. The regression model included the following covariates: sex, timing of surgery (elective or nonelective), left ventricular function, New York Heart Association functional class,[41] angina severity, left main coronary artery stenosis greater than 50%, or history of preoperative myocardial infarction, diabetes mellitus, hypertension, peripheral vascular disease, chronic obstructive lung disease, renal failure, congestive heart failure, stroke or transient ischemic attack.

Results

The characteristics of the total patient population meeting the inclusion criteria and of the costing sample are shown in Table 1. Because of the oversampling of various patient subgroups in our costing sample, some of the characteristics of the costing sample differed from those of the total population. In the costing sample the older patients differed from the younger patients in the following ways: a greater proportion of women (26% v. 14%), a greater proportion with left main coronary artery stenosis (26% v. 15%), a greater proportion with comorbidity (82% v. 63%) and a greater proportion with a postoperative complication (26% v. 20%).

The length of hospital stay was longer for older patients in all surgical subgroups, but especially in complicated cases. The mean values for length of stay for older and younger patients respectively were 11.1 and 10.1 days

for elective, uncomplicated cases, 18.0 and 12.9 days for elective, complicated cases, 20.6 and 16.1 days for nonelective, uncomplicated cases, and 31.5 and 17.4 days for nonelective, complicated cases.

A detailed breakdown of the mean costs for older and younger patients in the 4 surgical subgroups is given in Table 2. In keeping with the data on length of stay, the costs were higher for older patients for all surgical subgroups: for uncomplicated cases the mean costs were 6% and 21% higher for older patients for elective and nonelective cases respectively, and for complicated cases the mean costs were 44% and 42% higher respectively. The

Table 1: Characteristics of older (aged 65 years or more) and younger (aged less than 65) patients who underwent coronary artery bypass grafting (CABG) at The Toronto Hospital between April 1991 and March 1992, and of a subset of patients included in the costing sample

	Total population; group		Costing sample; group	
Characteristic	Younger *n = 514*	Older *n = 365*	Younger *n = 202*	Older *n = 205*
Mean age, yr	56.0	71.1	56.8	71.8
Male, % of patients	86.8	74.2	86.1	73.7
No comorbidity, % of patients	34.2	21.9	37.1	18.5
Comorbidity, % of patients				
Diabetes mellitus	25.3	28.8	24.8	33.2
Hypertension	49.8	57.3	45.5	58.5
Peripheral vascular disease	8.9	18.9	7.4	22.0
Chronic obstructive pulmonary disease	12.8	17.8	17.8	17.1
Stroke or transient ischemic attack	5.8	14.2	7.4	16.6
Severity of heart disease, % of patients				
NYHA* functional class 3 or 4	82.1	87.4	88.1	88.3
Ejection fraction < 40%	21.6	24.4	44.6	41.5
Left main coronary artery stenosis	18.1	25.8	14.9	26.3
Elective surgery, % of patients	59.1	51.5	49.0	50.7
Mean no. of grafts	3.8	3.7	3.8	3.7
Left internal mammary artery graft, % of patients	92.8	75.9	90.1	71.7
Surgical complication, % of patients	8.0	14.8	20.3	26.3

*NYHA = New York Heart Association.

Table 2: Mean cost* of CABG per patient for the 4 surgical subgroups

	Surgical subgroup; patient group; mean cost, $							
	Elective, uncomplicated		Nonelective, uncomplicated		Elective, complicated		Nonelective, complicated	
Resource	Younger *n = 80*	Older *n = 80*	Younger *n = 81*	Older *n = 71*	Younger *n = 19*	Older *n = 24*	Younger *n = 22*	Older *n = 30*
Operating room	4 320	4 230	4 370	4 320	4 580	4 770	4 710	4 680
Cardiovascular ICU	2 670	3 330	2 840	3 960	5 020	9 430	4 690	7 750
Cardiovascular ward	2 640	2 780	2 740	3 550	2 870	3 550	3 020	5 960
Other wards†	20	50	2 530	3 570	170	350	2 900	4 170
Laboratory	340	380	490	680	540	910	670	1 110
Radiology	100	110	160	200	140	290	160	350
Blood bank	450	400	440	670	1 080	1 410	1 020	1 040
Pharmacy	800	820	1 060	1 190	1 000	2 270	1 190	2 010
Respiratory therapy	180	220	180	230	350	630	270	500
Other professional‡	50	60	40	90	60	180	70	240
Physician charges	3 970	4 090	4 330	4 760	4 490	5 430	4 950	5 750
Total cost (and range)	15 550 (12 570–22 270)	16 460 (12 860–32 630)	19 170 (12 880–38 150)	23 220 (14 760–46 340)	20 290 (13 940–44 600)	29 230 (13 520–68 890)	23 660 (14 830–63 210)	33 560 (11 390–58 120)

Note: ICU = intensive care unit.
*All costs are in 1992 Canadian dollars rounded to the nearest $10. Owing to rounding, the total cost may not add up exactly to the column sums.
†Includes the coronary care unit, the medical ICU, the emergency department and inpatient wards other than the cardiovascular ward.
‡Includes social work, physiotherapy, occupational therapy and dietary counselling.

main cost contributors across all patient categories were the operating room (accounting for 14% to 28% of total costs), the cardiovascular ICU (accounting for 15% to 32%), the cardiovascular ward (accounting for 12% to 18%) and physician charges (accounting for 17% to 26%). Operating room costs were similar for older and younger patients, but the costs were higher for older patients in every other cost category.

Between 59% and 91% of the cost difference between older and younger patients was accounted for by higher ICU and ward costs (Table 2). For uncomplicated cases cardiovascular ICU costs were 25% to 39% higher for older patients, and for complicated cases they were 65% to 88% higher. The mean cardiovascular ICU stay for older and younger patients respectively was 2.6 v. 2.0 days in uncomplicated cases and 6.0 v. 3.4 days in complicated cases. The costs for the cardiovascular ward were also higher for older patients, ranging from 5% to 30% higher in uncomplicated cases and 24% to 97% higher in complicated cases. The mean cardiovascular ward stay for older and younger patients respectively was 9.7 v. 8.4 days for uncomplicated cases and 15.2 v. 9.2 days for complicated cases. The costs for "other" wards (e.g., medical wards and medical intensive care units) were markedly higher in nonelective cases, reflecting the costs associated with ward stays preceding the surgery, and were higher for older patients. Physician fees were 3% to 10% higher for older patients than for younger patients in uncomplicated cases and 16% to 21% higher in complicated cases.

Table 3 shows the mean costs of CABG for patients in the 6 age subgroups. The results show a trend toward a progressive increase in the mean cost of CABG with increasing age in each of the surgical subgroups.

For the total patient population, from which the costing sample was drawn, the mean CABG cost was $20 910 for older patients and $17 130 for younger patients (difference $3780, 95% CI $2460 to $5130). The difference between older and younger patients after adjustment for all covariates was $2340 (95% CI $1230 to $3420). The adjusted analysis showed that age (older v. younger), timing of surgery (nonelective v. elective) and development of complications had the most significant effect on cost (Table 4).

The results for uncomplicated cases (elective and nonelective) yielded an unadjusted CABG cost of $19 040 for older patients and $16 700 for younger patients (difference $2340, 95% CI $1100 to $3660). The cost difference after adjustment for all covariates was $1450 (95% CI $500 to 2470). For complicated cases (elective and nonelective) the unadjusted CABG cost was $31 630 for older patients and $22 100 for younger patients (difference $9530, 95% CI $4770 to $14 130). No adjusted analysis was performed for complicated cases owing to insufficient sample size.

Table 4: Adjusted mean cost difference for variables entered into the multiple linear regression model*

Variable	Adjusted cost difference, $ (and 95% CI)	*p* value
Age (older v. younger)	2 340 (1 230 to 3 420)	< 0.01
Timing of surgery (nonelective v. elective)	3 740 (2 440 to 5 030)	< 0.01
Complications (yes v. no)	8 200 (5 840 to 10 840)	< 0.01
Sex (female v. male)	270 (–1 310 to 1 800)	0.74
Diabetes (yes v. no)	720 (–710 to 2 000)	0.29
Hypertension (yes v. no)	460 (–610 to 1 660)	0.44
Peripheral vascular disease (yes v. no)	1 190 (–960 to 3 590)	0.32
Chronic obstructive pulmonary disease (yes v. no)	20 (–1 440 to 1 380)	0.97
Renal failure (yes v. no)	3 280 (130 to 6 040)	0.04
Stroke or transient ischemic attack (yes v. no)	950 (–1 140 to 2 920)	0.35
NYHA class (3 or 4 v. 1 or 2)	110 (–1 140 to 1 260)	0.86
Ejection fraction (< 40% v. ≥ 40%)	1 230 (–20 to 2 300)	0.05
Left main coronary artery stenosis (yes v. no)	310 (–1 140 to 1 740)	0.67
Angina severity (unstable v. stable)	–90 (–1 350 to 1 170)	0.88
Preoperative myocardial infarction (yes v. no)	1 750 (–320 to 3 650)	0.09

*The adjusted mean cost difference for each variable is calculated for the first level of the variable minus the second level (e.g., older – younger), adjusted for all other variables listed in the table. Costs are in 1992 Canadian dollars rounded to the nearest $10.

Table 3: Mean cost* of CABG per patient for the 4 surgical subgroups and 6 age subgroups

Patient age, yr	Surgical subgroups; mean cost, $ (and no. of patients)			
	Elective, uncomplicated	Nonelective, uncomplicated	Elective, complicated	Nonelective, complicated
< 55	14 900 (22)	19 700 (26)	19 300 (7)	25 700 (7)
55–59	15 700 (27)	17 900 (25)	20 200 (7)	24 800 (9)
60–64	15 900 (31)	19 800 (30)	21 800 (5)	19 500 (6)
65–69	15 800 (36)	21 900 (27)	27 600 (13)	34 300 (10)
70–74	16 400 (25)	24 500 (27)	34 000 (7)	35 800 (12)
≥ 75	17 900 (19)	23 200 (17)	26 100 (4)	29 300 (8)

*All costs are in 1992 Canadian dollars rounded to the nearest $100.

Interpretation

We estimated the true costs of CABG, as opposed to hospital charges, which may bear little resemblance to actual economic costs.[19,20,42] The most significant finding was that CABG costs were higher for older patients for each of the 4 surgical subgroups that we assessed. Differences in cost between older and younger patients were modest in elective, uncomplicated cases, were greater in nonelective, uncomplicated cases, and were greatest in cases with complications. In a secondary analysis that excluded from the costing of complicated cases the data for patients who died postoperatively, the cost trends identified in the primary analysis did not change. Age remained an important predictor of costs in a regression analysis that adjusted for several important risk factors.[24,27,28,30,43–46] Therefore, our findings confirm earlier reports that suggested that CABG costs may be higher in older patients.[11,21,22,24–28]

Our cost estimates are comparable to other published estimates of true CABG costs. The 2 studies most comparable to ours showed mean aggregate CABG costs of $17 681 (in 1988 Canadian dollars) and $20 937 (in 1991 US dollars).[22,23] Operating room, ICU and ward costs accounted for 62% to 67% of the total cost of CABG in our study subgroups, as compared with 63% to 69% in other studies.[22,23] Physician charges accounted for 17% to 26% of the total cost of CABG in our study subgroups, as compared with 19% to 24% in other studies.[20–22]

A review of the breakdown of CABG costs shows that 59% to 91% of the cost difference between the older and younger patients in our subgroups was accounted for by higher ICU and ward costs. Why do older patients have longer hospital stays than younger patients? Several studies have documented that admission to hospital of older patients often results in a decline in functional status and mobility and, consequently, longer stays.[47–53] Mathew and colleagues[54] found that older patients who undergo CABG are more likely than younger patients to develop atrial fibrillation postoperatively, which is associated with longer ICU and ward stays. In our study population, as in many others, older patients had significantly more neurologic complications than younger patients.[55–60] This may contribute to longer stays. Arom and associates[61] noted that age was an important predictor of late extubation in patients undergoing CABG, with associated longer ICU stays. They also found that, based on clinical features, extubation could have been done earlier in many older patients. Therefore, some proportion of the longer hospital stay in this age group may be due to perceived care needs that go beyond objective medical considerations.

Our study has several limitations. First, since the cost estimates are based on a single institution, they may not be representative of other hospitals. However, the comparability of our cost estimates with those of previous true-costing studies suggests that our results are likely generalizable at least to university-affiliated hospitals. Second, our regression analysis, which attempted to adjust for several risk factors, was restricted by the modest sample size, the accuracy of chart-derived data describing the presence or absence of comorbid conditions, the lack of information describing the severity of such conditions and the assumptions of the model itself. Therefore, the actual values of the coefficients as indicators of costs should be interpreted with caution. However, our estimate of an age effect on cost was corroborated by propensity analysis (adjusted mean cost difference $2000, 95% CI $500 to $3900), a method that attempts to mitigate some of the methodologic uncertainties associated with adjustment by linear regression.[62] Third, our calculations of costs and resource use are based on data from 1991/92. Since then, the length of ICU and hospital stays has decreased and unit costs have increased. These changes would not likely influence our qualitative conclusions, but future studies will have to confirm these findings.

We conclude that CABG is more costly in older patients, especially in complicated cases, and that most of the cost difference is accounted for by longer ICU and ward stays. Future research should focus on strategies to reduce the incidence of complications in older patients undergoing CABG and on identifying modifiable factors that contribute to longer ICU and ward stays in this age group.

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