The improving outcomes of coronary artery bypass graft surgery in Ontario, 1981 to 1995

Evidence

Études

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See related article page 237

Abstract

Background: There is continuing uncertainty over the relative contribution of outcomes monitoring to changes in surgical outcomes over time. The authors studied temporal trends in the clinical characteristics and short-term outcomes of patients who underwent coronary artery bypass grafting (CABG) in Ontario before and after the implementation, in 1993, of a province-wide program to provide feedback on cardiac surgery outcomes.

Methods: The authors analysed data from hospital discharge abstracts on the clinical characteristics and in-hospital death rates of all 67 784 patients who underwent isolated CABG in Ontario between Apr. 1, 1981, and Mar. 31, 1996.

Results: Death rates were relatively stable during the first half of the 1980s, then declined gradually in the second half of the decade; this decline continued into the first half of the 1990s. In the 1990s patients were older than those in the 1980s, and a higher proportion had coexisting diseases. Between 1986/87 and 1995/96 the unadjusted death rate decreased by 52% (5.0% v. 2.4%) ($p < 0.001$). The annual relative rate of decline was approximately 6% (95% confidence interval 5% to 7%) in the period before the outcomes feedback program was implemented and about 9% (95% confidence interval 7% to 11%) in the period after implementation.

Interpretation: Rates of death after CABG have been declining steadily in Ontario since the mid-1980s. Outcomes-based quality improvement interventions may facilitate, but are not a prerequisite for, improvements in the quality of surgical care.

Résumé

Contexte : L'incertitude règne toujours au sujet de la contribution relative du suivi des résultats à l'évolution chronologique des résultats chirurgicaux. Les auteurs ont étudié les tendances chronologiques des caractéristiques cliniques et des résultats à court terme chez les patients qui ont subi un pontage aortocoronarien (PAC) en Ontario avant et après la mise en œuvre, en 1993, d'un programme provincial de rétroaction sur les résultats des interventions en chirurgie cardiaque.

Méthodes : Les auteurs ont analysé des données tirées des résumés de libération d'hôpitaux portant sur les caractéristiques cliniques et les taux de mortalité à l'hôpital des 67 784 patients qui ont subi des PAC isolés en Ontario entre le 1er avril 1981 et le 31 mars 1996.

Résultats : Les taux de mortalité ont été relativement stables au cours de la première moitié des années 80 et ont ensuite diminué graduellement au cours de la deuxième moitié de la décennie. Cette baisse s'est poursuivie au cours de la première moitié des années 90. Au cours des années 90, les patients étaient plus âgés que dans les années 80 et un pourcentage plus élevé présentaient une comorbidité. Entre 1986/1987 et 1995/1996, le taux de mortalité non corrigé a diminué de 52 % (5,0 % c. 2,4 %) ($p < 0,001$). La diminution annuelle relative a atteint environ 6 % (intervalle de confiance à 95 % de 5 % à 7 %) au cours de la période qui a précédé la mise en œuvre du programme de rétroaction sur les résultats et environ 9 % (intervalle de confiance à 95 % de 7 % à 11 %) au cours de celle qui l'a suivie.

Interprétation : Les taux de mortalité après un PAC diminuent régulièrement en Ontario depuis le milieu des années 80. Des interventions d'amélioration de la qualité fondées sur les résultats peuvent aider à améliorer la qualité des soins chirurgicaux mais ne constituent pas une condition préalable indispensable.

Since its introduction by Favaloro, in 1969,[1] coronary artery bypass grafting (CABG) has become the most studied procedure in the history of surgery.[2] With increasing numbers of high-risk surgical candidates and a moderately high death rate, it is important to determine whether and how the risks of CABG can be reduced. Several strategies for improving the outcomes of CABG have been advocated in the 1990s, including the public dissemination of CABG outcomes data in New York State and Pennsylvania[3,4] and a continuous quality improvement program in northern New England, based on outcomes feedback and rotating site visits to observe and compare the methods of surgical care.[5] The developers of these programs have all observed temporal improvements in surgical outcomes that they have attributed to quality improvement activities stimulated in part by outcomes feedback. These conclusions were recently challenged by the finding of declining rates of death after CABG in Massachusetts during the early 1990s in the absence of any outcomes monitoring.[6] However, the possibility of a "spillover" effect from the programs conducted in neighbouring states has not been excluded.[7]

In Ontario, the Institute for Clinical Evaluative Sciences has worked with the Cardiac Care Network of Ontario to provide feedback on cardiac surgery outcomes to the clinicians at all hospitals performing cardiac surgery in the province, since 1993, as part of a quality assurance program. Using data from the surgical registry of the Cardiac Care Network of Ontario, the institute provides annual surgical "report cards" to the chiefs of cardiology and cardiac surgery at each institution on their case-mix and risk-adjusted surgical outcomes (e.g., in-hospital mortality, use of intensive care unit and postoperative length of stay).[8,9] The surgical registry contains prospectively gathered clinical data for all patients waiting for cardiac surgery in the province. The data are collected by dedicated cardiac care coordinators at each surgical centre in Ontario.

The first report, on the 1991 data, was released to the participating hospitals in August 1993, with annual updates thereafter. Because of continuing uncertainty over the relative contribution of outcomes monitoring to changes in surgical outcomes over time, we conducted a study of 15 years of CABG outcomes in Ontario between 1981/82 and 1995/96, comparing trends in surgical outcomes before and after the outcomes feedback program was implemented. We were particularly interested in temporal trends in the use of internal mammary artery (IMA) grafts since other studies have suggested that IMA graft use is increasing over time[10] and that it improves short- and long-term patient outcomes.[11–13]

Methods

Data sources

Data for all patients who underwent isolated CABG (without concomitant valve surgery) in Ontario between Apr. 1, 1981, and Mar. 31, 1996, were obtained from the Canadian Institute for Health Information database. This database contains information on all hospital discharges in Ontario. All data for our study were analysed on a fiscal year basis (Apr. 1 of one calender year to Mar. 31 of the subsequent year). For example, 1981 was defined as Apr. 1, 1981, to Mar. 31, 1982. The database contains demographic information as well as information on coexisting conditions, urgency of hospital admission and in-hospital death for all patients admitted to an acute care hospital in Ontario. It codes as many as 16 discharge diagnoses, based on the ninth revision of the International Classification of Diseases, Clinical Modification (ICD-9-CM) system,[14] and 10 procedures, according to the Canadian Classification of Procedures (CCP).[15] An auxiliary code associated with each diagnosis permits the distinction between conditions that were present at the time of admission and complications occurring after hospital admission. For the current study, diagnoses coded as complications were excluded.

All patients with a CCP procedure code of 48.1 (coronary artery bypass graft surgery) were selected for the study, except those who also had a procedure code of 47.x, which indicates an associated valve procedure. To examine trends in the type of procedure being done, we looked at whether vein grafts or IMA grafts were used. We determined the number of vein grafts at the time of surgery from CCP codes 48.11 to 48.15, and the number of IMA grafts from CCP codes 48.16 and 48.17. Patients who had previously undergone CABG surgery were included. However, we were unable to determine the exact frequency of reoperation because of changes in the unique patient identifier coding system in Ontario during the study period.

Data analysis

We first determined temporal trends in the frequency of patient demographic and comorbidity characteristics. Patients were classified in 3 age groups: less than 65 years, 65 to 74 years, and 75 years or more. We calculated age-

and sex-adjusted rates of CABG using the 1991 population in Ontario over the age of 20 years as the standard reference population.[16] We determined the frequency of patients with coexisting diseases using an adaptation of the Charlson index.[17] Specific conditions were included only if their prevalence was greater than 1% of all patients. This resulted in the inclusion of acute myocardial infarction, congestive heart failure, peripheral vascular disease, cerebral vascular disease, pulmonary disease and diabetes mellitus as comorbid conditions. Records were analysed according to whether patients were admitted on an elective basis or an urgent or emergent basis. Urgent admissions were defined by the hospitals as those in which the patient required immediate assessment but further delays would not be life-threatening; emergent admissions were those in which the patient had a life-threatening condition requiring immediate assessment and treatment.

We then conducted a 15-year longitudinal analysis of in-hospital death rates during the study period. We calculated unadjusted and adjusted death rates, adjusting for changes in age, sex, urgency of hospital admission and individual comorbid diseases, as defined in the adaptation of the Charlson index.[17] To determine the relative change in CABG surgery outcomes over time within specific patient subgroups, we subdivided the data into 3 fiscal year periods: 1981 to 1986, 1987 to 1992, and 1993 to 1995. The mid-1990s represent the period during which clinicians were receiving ongoing outcomes feedback. We calculated the relative change in in-hospital death rates in these 3 periods, comparing the early to mid-1980s with the late 1980s and early 1990s, and the late 1980s and early 1990s with the mid-1990s.

Continuous variables were compared by means of unpaired *t*-tests, and categorical variables were compared with the use of χ^2 statistics.[16] To determine whether there were significant temporal changes in the prevalence of various patient characteristics (e.g., demographic features, coexisting conditions and type of graft) over the study period, we constructed linear regression models in which the year was the independent variable and the individual characteristic was the dependent variable. Logistic regression models were also developed to determine the independent predictors of in-hospital mortality and adjusted death rates using the whole data set. We evaluated the predictive power of these models by calculating the area under the receiver operating characteristic curve.[18] We conducted all statistical analyses using SAS software (version 6.11, SAS Institute, Inc., Cary, NC).

Results

Patient characteristics

Overall, 67 784 patients underwent isolated CABG surgery in Ontario between 1981 and 1995. The age- and sex-adjusted rate of surgery increased by 53%, from 50.3 per 100 000 adults in fiscal year 1981 to 77.1 per 100 000 adults in fiscal year 1995 (Table 1). This increase was associated with a steady rise in the mean age of patients undergoing the procedure, from 55.5 years in 1981 to 62.3 years in 1995 ($p < 0.001$). Although the procedure was performed only rarely in patients aged 75 years or more in 1981 (0.9% of all patients), by 1995, 8.9% of patients were

Table 1: Demographic characteristics of patients who underwent isolated coronary artery bypass graft (CABG) surgery in Ontario between Apr. 1, 1981, and Mar. 31, 1996

Fiscal year*	No. of patients	CABG rate per 100 000†	Mean age (and standard deviation), yr	% aged 65–74 yr (and % female)	% aged ≥ 75 yr (and % female)	% with urgent or emergent admission
1981	2 971	50.3	55.5 (8.9)	13.9 (27.5)	0.9 (42.9)	24.7
1982	3 366	55.9	55.9 (8.9)	15.4 (28.8)	0.9 (31.0)	26.6
1983	3 639	59.4	56.9 (9.1)	18.8 (26.6)	1.5 (29.1)	30.8
1984	3 503	56.1	57.8 (9.0)	21.0 (28.3)	2.0 (32.9)	29.0
1985	3 710	58.3	58.0 (9.2)	22.2 (27.5)	2.3 (31.4)	37.7
1986	3 844	59.3	59.0 (9.4)	27.0 (25.1)	3.1 (30.0)	31.2
1987	4 074	61.4	59.2 (9.4)	28.0 (25.7)	3.3 (36.8)	30.0
1988	4 123	57.9	59.4 (9.2)	28.6 (24.7)	3.1 (26.2)	32.7
1989	4 635	63.2	59.9 (9.4)	31.0 (27.4)	3.9 (29.7)	32.8
1990	4 945	66.0	60.6 (9.4)	33.5 (26.1)	4.4 (27.9)	33.6
1991	5 181	67.8	61.1 (9.5)	34.6 (27.1)	5.5 (30.3)	35.7
1992	5 533	70.7	61.1 (9.5)	34.7 (26.7)	5.9 (34.3)	38.0
1993	5 724	71.5	61.6 (9.7)	35.4 (26.1)	7.3 (29.8)	32.7
1994	6 166	75.7	62.2 (9.6)	37.3 (26.6)	7.9 (30.5)	38.6
1995	6 370	77.1	62.3 (9.8)	37.0 (27.8)	8.9 (32.6)	40.1
Overall	67 784	65.1	59.8 (9.6)	29.6 (26.7)	4.6 (31.2)	33.7

*Fiscal years ran from Apr. 1 of the calendar year given to Mar. 31 of the next calendar year. For example, Apr. 1, 1981, to Mar. 31, 1982, was defined as fiscal year 1981.
†Adjusted for age and sex using the 1991 population in Ontario over age 20 years as the standard population.

in this age group. The proportion of women undergoing surgery stayed relatively constant over time (Table 1). The proportion of patients undergoing the procedure during an urgent or emergent hospital admission also increased, from 24.7% in 1981 to 40.1% in 1995 ($p < 0.001$).

In 1981 only 3.6% of patients underwent CABG during an admission for acute myocardial infarction, compared with 13.1% in 1995 ($p < 0.001$) (Table 2). The prevalence of congestive heart failure, cerebral vascular disease, pulmonary disease and diabetes also increased over the study period ($p < 0.001$). The 178% increase in the prevalence of diabetes between 1981 and 1992 was striking (5.9% v. 16.4%).

Types of CABG graft

Fig. 1 shows the longitudinal trends in the proportion of patients who received vein grafts or IMA grafts over the study period. There was little use of IMA grafts until the mid-1980s, when the frequency of their use started to in-

Table 2: Coded coexisting conditions*

Fiscal year	Condition; % of patients					
	Acute myocardial infarction	Congestive heart failure	Peripheral vascular disease	Cerebral vascular disease	Pulmonary disease	Diabetes mellitus
1981	3.6	2.5	1.8	1.4	1.6	5.9
1982	4.2	2.6	1.8	1.9	2.1	6.4
1983	4.3	2.4	2.5	2.2	2.0	8.1
1984	4.2	2.2	2.8	2.0	2.5	8.9
1985	4.5	1.8	3.4	2.9	2.6	11.4
1986	6.1	2.1	3.2	2.2	2.9	12.0
1987	5.6	3.8	2.8	2.3	3.8	12.4
1988	5.3	2.3	2.2	2.3	2.6	10.8
1989	6.2	2.4	2.4	2.8	3.0	12.1
1990	7.6	2.6	2.6	3.0	3.7	13.6
1991	8.8	2.9	3.0	2.4	3.4	15.8
1992	10.8	3.2	3.4	3.6	5.8	16.4
1993	10.4	3.1	2.6	2.7	4.4	15.8
1994	12.8	3.8	3.0	2.9	5.3	15.5
1995	13.1	5.4	2.3	3.1	5.7	15.6
Overall	7.9	3.0	2.7	2.6	3.7	12.8

*There was a statistically significant increase in the prevalence of all coexisting conditions ($p < 0.001$ for the trend from 1981 to 1995) except peripheral vascular disease.

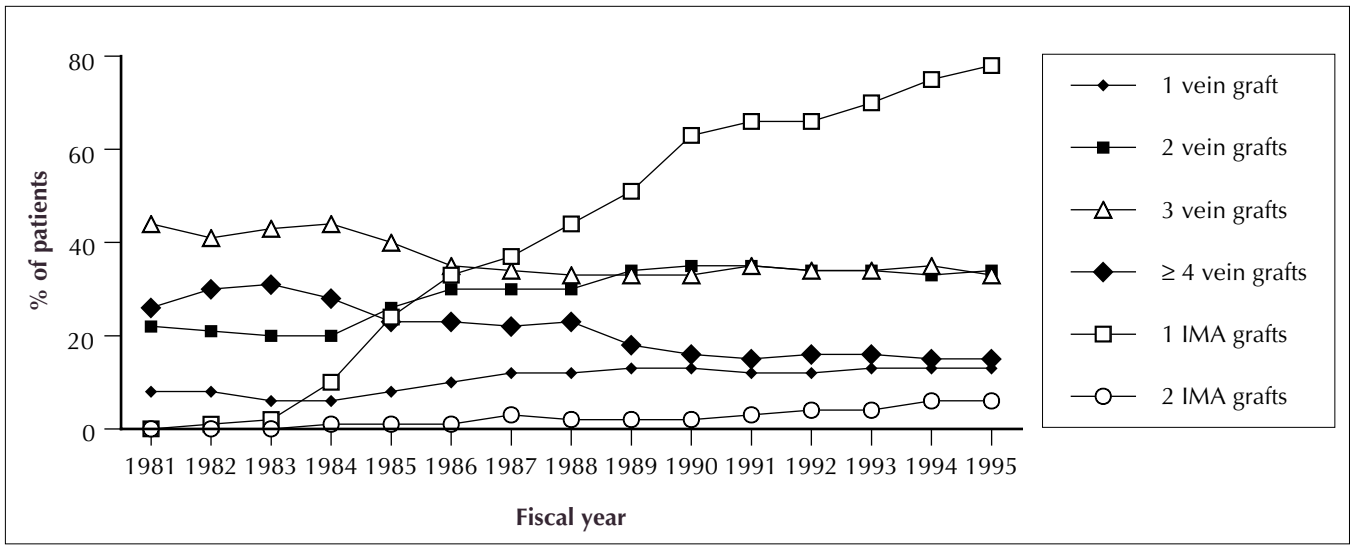

Fig. 1: Type and number of grafts in patients who underwent isolated coronary artery bypass graft surgery in Ontario between fiscal years 1981 and 1996 (each fiscal year ran from Apr. 1 of one calender year to Mar. 31 of the subsequent year; for example, fiscal year 1981 was defined as Apr. 1, 1981, to Mar. 31, 1982). IMA = internal mammary artery. Note that these groups are not mutually exclusive.

crease dramatically. By 1995, 84% of patients undergoing CABG received 1 or 2 IMA grafts. From 1981 to 1995 the number of patients who received 1 or 2 vein grafts increased significantly ($p < 0.001$), whereas the number of patients who received more than 2 vein grafts decreased ($p < 0.001$). This change reflects the substitution of IMA grafts for vein grafts, since the mean number of grafts per patient stayed relatively constant (data not shown).

Trends in death rates

The unadjusted and adjusted rates of in-hospital death decreased significantly over the study period (Fig. 2). The unadjusted death rate varied between 4% and 5% during the first half of the 1980s and then declined gradually in the latter half of the 1980s. Between fiscal year 1986 and fiscal year 1995 the unadjusted rate decreased from 5.0% to 2.4%, a decline of 52% ($p < 0.001$). The adjusted death rates declined by 65% over the same period, from 5.5% to 1.9% ($p < 0.001$). The area under the receiver operating characteristic curve of the statistical adjustment model was 0.72, which indicated that the model fit the data reasonably well.[8,18] The annual relative rate of decline was approximately 6% (95% confidence interval [CI] 5% to 7%) in the period before our outcomes feedback program was implemented and about 9% (95% CI 7% to 11%) in the period after implementation (Fig. 2).

The declines in the in-hospital death rates occurred in all patient subgroups (Table 3). There were particularly striking declines in the rates for patients undergoing surgery after acute myocardial infarction ($p < 0.001$). The overall death rate decreased by 30% between the early to mid-1980s (4.6%) and the late 1980s to early 1990s (3.2%), and by another 16% between the late 1980s to early 1990s and the mid-1990s (2.7%). From the late 1980s onward, patients who received at least 1 IMA graft had significantly lower death rates than those who received vein grafts ($p < 0.001$). In a regression model that included patient age, sex, urgency of hospital admission and coexisting diseases, the odds of dying after CABG was significantly lower for patients who received IMA grafts than for those who received vein grafts (adjusted odds ratio 0.51, 95% CI 0.46 to 0.55). The increase in the unadjusted death rate for patients who received vein grafts only during the 1990s was accounted for by patients who were at higher risk (e.g., elderly people and those undergoing emergency surgery) (data not shown).

Interpretation

In this study we evaluated temporal trends in the case-mix and short-term outcomes of patients who underwent CABG in Ontario between 1981 and 1995. There were many important findings. Patients who underwent the procedure in the 1990s were more likely to be older and to have associated conditions than those in the 1980s. The relative proportion of women undergoing surgery did not change markedly over the study period, a finding that contrasts with studies published in the 1990s suggesting that there are differences between the sexes in access to cardiovascular procedures.[19,20] Death rates were relatively stable during the first half of the 1980s, then declined gradually in the second half of the decade; this decline continued into the first half of the 1990s. Overall, there was a decline of 52% in the unadjusted death rates and a decline of 65% in the adjusted death rates between 1986 and 1995. These declining death rates were observed in all patient subgroups and were associated with increases in the rate of IMA grafting. Although our study did not permit us to determine all the reasons for the improved outcomes, our results show

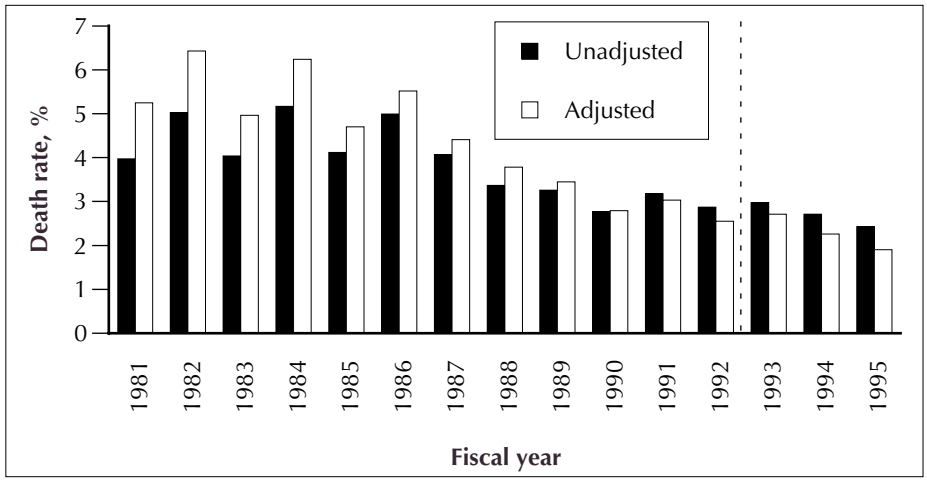

Fig. 2: Unadjusted and adjusted rates of in-hospital death. Adjusted rates are adjusted for changes in patient age, sex, urgency of hospital admission and coexisting diseases. Dotted line indicates the time of implementation of the outcomes feedback program.

that CABG outcomes in Ontario were improving long before clinicians were receiving outcomes feedback.

Why did death rates in Ontario decrease in the 1980s independently of any organized quality improvement strategy? We suggest that clinicians have always strived to optimize their patients' outcomes and that many quality-enhancing strategies have long been part of surgical practice. For example, there have been many technical advancements in cardiac surgery since the mid-1980s, including refined methods of cardioplegia, new techniques in cardiac anesthesia and increased use of IMA grafts,[10,21] all of which probably led to improved patient management and better surgical outcomes. These advances have gradually been adopted over time by cardiac surgical teams in Ontario as they have become aware of them through the medical literature, conferences and other forms of continuing medical education. Conferences on morbidity and mortality during which deaths associated with surgery are reviewed and possible errors in surgical practice identified are also a time-honoured tradition in many surgical programs. Increasing clinical experience at the individual surgeon level with new surgical techniques and with patients at high risk (e.g., elderly patients) has likely contributed to better surgical results over time as well. Other studies have shown a correlation between higher volumes of surgery performed and better surgical outcomes.[22,23]

Our use of administrative data did not permit us to examine all the technical factors that may have contributed to the improved CABG outcomes. Increasing rates of use of IMA grafts may be one contributor to our findings. The improved long-term graft patency results associated with IMA grafting were first reported in the mid-1980s.[11,12] We observed relatively stable death rates in the early 1980s, followed by declining death rates between 1986 and 1995, the same time as IMA graft use was increasing in Ontario. When included in a multivariate regression model, use of IMA grafts was strongly associated with improved short-term survival, although we cannot rule out confounding by other, unmeasured factors. Other investigators have also found that the use of IMA grafts was associated with improved short-term and long-term survival after CABG when other surgical risk factors were controlled for.[10–13]

The slightly higher annual rate of decline in death rates (approximately 9%) in the period after our outcomes feedback program was implemented (1993–1995) as compared to the rate (approximately 6%) in the period before implementation (1987–1992) is difficult to interpret because of confounding factors. Nevertheless, we believe that our efforts to provide feedback on risk-adjusted car-

Table 3: In-hospital death rates after CABG

	Period; death rate, %			
Patient characteristic	1981–1986 *n = 21 033*	1987–1992 *n = 28 491*	1993–1995 *n = 18 260*	Overall *n = 67 784*
Age, yr				
< 65	3.6	2.2*	1.6†	2.6
65–74	7.7	4.6*	3.5†	4.9
> 75	10.6	8.1	6.5	7.6
Sex				
Male	4.0	2.9*	2.4†	3.1
Female	7.2	4.6*	3.6	5.1
Type of admission				
Elective	3.6	2.4*	1.8†	2.6
Emergent or urgent	6.7	4.9*	4.2	5.2
Type of graft				
Vein only	4.6	4.6	5.5†	4.7
Internal mammary artery	4.3	2.3*	2.0	2.3
Coexisting condition				
Acute myocardial infarction	23.5	9.3*	6.4	10.7
Congestive heart failure	26.4	13.5*	10.1†	15.3
Peripheral vascular disease	8.4	7.7	5.4	7.3
Cerebral vascular disease	10.4	7.5	5.3	7.6
Pulmonary disease	6.2	3.3*	2.6	3.6
Diabetes mellitus	5.3	3.4*	2.7	3.5
All patients	4.6	3.2*	2.7†	3.5

*$p < 0.05$ for difference between 1981–1986 and 1987–1992.
†$p < 0.05$ for difference between 1987–1992 and 1993–1995.

diac surgery outcomes to all hospitals performing cardiac surgery in the province have been of value. Our analyses show that there are no high-outlier hospitals (i.e., with death rates significantly higher than the provincial average)[9] and that the outcomes of surgery are fairly comparable across the province. We have also provided benchmark data on intensive care unit use and postoperative length of stay that centres have used for evaluating the relative efficiency of their care. However, we believe that further improvements in surgical outcomes will still need to come primarily from advances in surgical and anesthetic techniques attained through basic research, clinical trials and, when clinical trials are not possible, observational studies. Organized quality improvement interventions may facilitate the transfer of these technical innovations into routine clinical care.[5]

As with any study using administrative data, our study had several limitations. First, the accuracy of the database records of type of graft (IMA or vein) has not been verified with other sources. However, the prevalence of IMA graft use in our study is similar to that reported by other investigators.[10] Second, we cannot rule out the possibility that part of the decrease in adjusted death rates over time was a reflection of better coding of surgical risk factors in administrative databases rather than true increases in the severity of patients' conditions. Jollis and colleagues[24] reported that coexisting diseases are often undercoded in administrative databases. However, this would not account for the striking decline of 55% in unadjusted death rates between 1986 and 1995. Third, we did not have data on other important clinical risk factors, such as left ventricular function and left main coronary artery disease, which also influence short-term outcomes after CABG. Our previous analysis of data from the registry of the Cardiac Care Network of Ontario showed that risk-adjusted rates of death after CABG decreased between 1991 and 1993, when these other factors were also included in a risk-adjustment model.[9]

In conclusion, our results show that rates of death following CABG in Ontario have been steadily declining over time and that CABG was considerably safer in the mid-1990s than it was in the early 1980s despite a higher proportion of patients at high risk. The gradual adoption of technical advances in cardiac surgery, better perioperative management and increasing surgical experience all likely contributed to the improvements in surgical outcomes. A population-based outcomes feedback program may also have played a role in the declining death rates observed during the mid-1990s. Outcomes-based feedback programs will continue to be important in efforts to improve the quality of health care. Advances in the technical aspects of surgical care in combination with quality improvement initiatives will likely lead to the best possible outcomes for patients undergoing CABG surgery.

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References

1. Favaloro RG. Saphenous vein graft in the surgical treatment of coronary artery disease: operative technique. *J Thorac Cardiovasc Surg* 1969;58:178-85.
2. ACC/AHA Task Force Report. Guidelines and indications for coronary artery bypass graft surgery: a report of the American College of Cardiology/American Heart Association Task Force on assessment of diagnostic and therapeutic cardiovascular procedures (Subcommittee on Coronary Artery Bypass Graft Surgery). *J Am Coll Cardiol* 1991;17:543-89.
3. Hannan EL, Kilburn H Jr, Racz M, Shields E, Chassin MR. Improving the outcomes of coronary artery bypass surgery in New York State. *JAMA* 1994;271:761-6.
4. Pennsylvania Health Care Cost Containment Council. *A consumer guide to coronary artery bypass graft surgery: volume IV 1993*. Harrisburg (PA): The Council; 1995.
5. O'Connor GT, Plume SK, Olmstead EM, Morton JR, Maloney CT, Nugent WC, et al. A regional intervention to improve the hospital mortality associated with coronary artery bypass graft surgery. *JAMA* 1996;275:841-6.
6. Ghali WA, Ash AS, Hall RE, Moskowitz MA. Statewide quality improvement initiatives and mortality after cardiac surgery. *JAMA* 1997;277:379-82.
7. Jencks SF. Can large-scale interventions improve care? *JAMA* 1997;277:419-20.
8. Tu JV, Jaglal SB, Naylor CD, and the Steering Committee of the Provincial Adult Cardiac Care Network of Ontario. Multicenter validation of a risk index for mortality, intensive care unit stay, and overall hospital length of stay after cardiac surgery. *Circulation* 1995;91(3):677-84.
9. Tu JV, Naylor CD, and the Steering Committee of the Provincial Adult Cardiac Care Network of Ontario. Coronary artery bypass mortality rates in Ontario: a Canadian approach to quality assurance in cardiac surgery. *Circulation* 1996;94(10):2429-33.
10. Peterson ED, Jollis JG, Bebchuk JD, DeLong ER, Muhlbaier LH, Mark DB, et al. Changes in mortality after myocardial revascularization in the elderly: the national Medicare experience. *Ann Intern Med* 1994;121:919-27.
11. Loop FD, Lytle BW, Cosgrove DM, Stewart RW, Goormastic M, Williams GW, et al. Influence of the internal-mammary-artery graft on 10-year survival and other cardiac events. *N Engl J Med* 1986;314:1-6.
12. Grondin CM, Campeau L, Lespérance J, Enjalbert M, Bourassa MG. Comparison of late changes in internal mammary artery and saphenous vein grafts in two consecutive series of patients 10 years after operation. *Circulation* 1984;70(Suppl I):I208-12.
13. Edwards FH, Clark RE, Schwartz M. Impact of internal mammary artery conduits on operative mortality in coronary revascularization. *Ann Thorac Surg* 1994;57:27-32.
14. *International classification of diseases, 9th revision, clinical modification*. Ann Arbor (MI): Commission on Professional and Hospital Activities; 1992.
15. *Canadian classification of diagnostic, therapeutic, and surgical procedures*. Ottawa: Minister of Industry, Science and Technology; 1993.
16. Hennekens CH, Buring JE. *Epidemiology in medicine*. Boston: Little, Brown; 1987.
17. Deyo RA, Cherkin DC, Ciol MA. Adapting a clinical comorbidity index for use with ICD-9-CM administrative databases. *J Clin Epidemiol* 1992;45:613-9.
18. Hanley JA, McNeil BJ. The meaning and use of the area under a receiver operating characteristic (ROC) curve. *Radiology* 1982;143:29-36.
19. Ayanian JZ, Epstein AM. Differences in the use of procedures between women and men hospitalized for coronary heart disease. *N Engl J Med* 1991;325:221-5.
20. Jaglal SB, Goel V, Naylor CD. Sex differences in the use of invasive coronary procedures in Ontario, Canada. *Can J Cardiol* 1994;10:239-44.
21. Warm Heart Investigators. Randomised trial of normothermic versus hypothermic coronary bypass surgery. *Lancet* 1994;343:559-63.
22. Hannan EL, Siu AL, Kumar D, Kilburn H Jr, Chassin MR. The decline in coronary artery bypass graft surgery in New York State: the role of surgeon volume. *JAMA* 1995;273:203-13.
23. Grumbach K, Anderson GM, Luft HS, Roos LL, Brook R. Regionalization of cardiac surgery in the United States and Canada: geographic access, choice, and outcomes. *JAMA* 1995;274:1282-8.
24. Jollis JG, Ancukiewicz M, DeLong ER, Pryor DB, Muhlbaier LH, Mark DB. Discordance of databases designed for claims payment versus clinical information systems. Implications for outcomes research. *Ann Intern Med* 1993; 119:844-50.

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