Changing outcomes of coronary revascularization in British Columbia, 1995–2001

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OBJECTIVES: To examine outcomes following all first coronary revascularization procedures, isolated coronary artery bypass graft surgery (CABG) and percutaneous coronary intervention (PCI) on British Columbia (BC) resident adults from 1995 to 2001.

METHODS: CABG and PCI data were obtained from the BC Cardiac Registry, and mortality data were obtained from the BC Vital Statistics Agency. Analysis was performed by annual cohorts, and the rates reported are unadjusted.

RESULTS: An increasing percentage of revascularization procedures was performed with PCI (62% in 1995 to 73% in 2001; $P < 0.001$) due to the increased use of PCI procedures. Except in emergent cases, 30-day mortality improved after PCI (1.8% to 1.1%; $P = 0.02$) and CABG (1.8% to 1.2%; $P = 0.01$). Emergent cases accounted for 9.0% of PCIs and 2.7% of CABGs, the percentage treated by CABG decreasing from 14.5% in 1995 to 7.5% by 2001 ($P < 0.001$). Mortality rates among emergent cases was higher at 30 days, with no trend in PCI mortality (12%) but a substantial reduction in 30-day mortality after CABG (28% to 10%; $P = 0.003$). One-year survival free from repeat revascularization following PCI increased from 73% in 1995 to 83% in 2001 ($P < 0.001$) and from 94% to 95% ($P < 0.005$) following CABG.

CONCLUSIONS: Improvements in procedure-related mortality observed in trials have extended to clinical practice. With respect to emergent cases, an increasing proportion were treated by PCI with no change in PCI mortality but associated with a drop in surgical mortality. There has been a consistent and substantial drop in the need for repeat procedures within one year for patients selected for PCI.

Key Words: Angiography; Angioplasty; Epidemiology; Surgery

Coronary revascularization has an important role in the management of obstructive atheromatous coronary artery disease. Coronary artery bypass graft surgery (CABG) was the first procedure to become well established, and early operative mortality has recently been shown to be below 5% in an unselected series (1–7). The resulting long-term symptomatic relief is excellent. Mortality benefits have been well documented and appear to be chiefly related to the insertion of an arterial conduit, usually the left internal mammary artery to the left anterior descending artery, which has better long-term patency than saphenous vein grafts and has become standard (8,9). With more recent changes in surgical techniques, total arterial

L'évolution des issues de la revascularisation coronaire en Colombie-Britannique entre 1995 et 2001

OBJECTIFS : Examiner les issues après toutes les premières interventions de revascularisation coronaire, de pontage aortocoronarien isolé (PACI) et d'intervention coronaire percutanée (ICP) sur des citoyens adultes de la Colombie-Britannique (C.-B.) entre 1995 et 2001.

MÉTHODOLOGIE : Les données relatives aux PACI et aux ICP ont été tirées du registre des maladies cardiaques de la C.-B., et les données relatives à la mortalité proviennent du bureau de l'état civil de la C.-B. L'analyse a été effectuée par cohortes annuelles, et les taux déclarés ne sont pas corrigés.

RÉSULTATS : Un pourcentage croissant d'interventions de revascularisation a été effectué par ICP (62 % en 1995 à 73 % en 2001; $p < 0,001$) en raison de l'utilisation croissante d'ICP. Sauf dans les cas émergents, la mortalité au bout de 30 jours diminuait après les ICP (1,8 % à 1,1 %; $p = 0,02$) et les PACI (1,8 % à 1,2 %; $p = 0,01$). Les cas émergents représentaient 9,0 % des ICP et 2,7 % des PACI, le pourcentage de patients traités par PACI fléchissant de 14,5 % en 1995 à 7,5 % en 2001 ($p < 0,001$). Les taux de mortalité dans les cas émergents étaient plus élevés au bout de 30 jours, et on ne remarquait aucune tendance de mortalité après les ICP (12 %), mais une diminution substantielle de la mortalité au bout de 30 jours après un PACI (28 % à 10 %; $p = 0,003$). La survie au bout d'un an sans reprise de la revascularisation après les ICP est passée de 73 % en 1995 à 83 % en 2001 ($p < 0,001$), et de 94 % à 95 % ($p < 0,005$) après un PACI.

CONCLUSIONS : Les diminutions de la mortalité reliée à des interventions observées dans le cadre d'essais s'étendent à la pratique clinique. Pour ce qui est des cas émergents, une proportion croissante a été traitée par ICP sans modifier la mortalité causée par l'ICP, mais s'associe à une chute de la mortalité chirurgicale. On remarque une chute constante et substantielle du besoin de reprendre les interventions au cours de l'année suivante chez les patients ayant subi une ICP.

revascularization may lead to even more durable results (10); the benefits and risks of minimally invasive and off-pump surgery are also being debated (11).

Percutaneous coronary intervention (PCI) is a more recent but also well-established method of revascularization. Substantial technical and pharmacological improvements have been made over the past decade that have led to increased indications and, thus, an increased number of procedures (3–7,12). Symptom relief is good, but data concerning a mortality benefit are lacking. The major limitation of PCI has been the need for repeat procedures, either with PCI or CABG, often due to restenosis.

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TABLE 1
Unadjusted mortality rates after first coronary revascularization procedures on British Columbia residents, 1995–2001 (all cases)

Year	Number of cases		Mortality postprocedure, %			
			30-day		One-year	
	PCI	CABG	PCI	CABG	PCI	CABG
1995	2153	1337	2.83	2.47	4.60	5.01
1996	2313	1414	1.77	3.61	3.85	5.30
1997	2465	1463	2.39	2.12	4.34	3.76
1998	2811	1636	2.17	2.02	4.02	4.10
1999	2733	1545	2.01	1.75	4.61	3.17
2000	3051	1518	2.20	1.38	4.65	3.03
2001	3528	1330	1.87	1.43	4.17	3.46
Overall	19,054	10,243	2.15	2.10	4.32	3.95

CABG Coronary artery bypass graft surgery; PCI Percutaneous coronary intervention

Although improved outcomes after both PCI and CABG have been demonstrated in clinical trials, patients enrolled in randomized trials are highly selected, and outcomes from these studies cannot always be generalized to clinical practice (4). Furthermore, significant improvements in one modality may change application patterns, so the outcomes of each can only be interpreted well in the context of understanding the referral patterns of both modalities. The present study was undertaken to examine the number of PCIs and CABGs in British Columbia (BC) between 1995 and 2001, with particular attention to changing trends and the need for repeat revascularization procedures.

METHODS

Data sources

There are four institutions in BC that provide PCI and open-heart surgery, with the number of cardiac catheterization suites increasing from nine to 10 in 1999. Detailed data concerning open-heart surgery operations since 1991, as well as all PCI procedures since 1994, have been prospectively collected through the BC Cardiac Registry (BCCR). These include all procedures performed in BC, where the health care system is publicly funded. The information is collected at the time of the procedure and collated by a dedicated management team.

Population

The study population comprised all BC resident adults 20 years of age and older who underwent a first revascularization procedure between 1995 and 2001 in BC. Deaths were identified from the deaths registry of the BC Vital Statistics Agency through probabilistic record linkage.

Definitions

For the purpose of the present report, CABG included all BC patients who underwent isolated CABG, excluding those who underwent concomitant procedures such as valve replacement. The time to repeat revascularization refers to the period from the first repeat revascularization event (either PCI or CABG). Procedures were graded by the operator as emergent or non-emergent at the time of the procedure. Emergent procedures included cases of acute ST-elevation myocardial infarction

(STEMI) (including primary and rescue PCI), persistent chest pain with electrocardiographic changes despite medical therapy, shock and presumed ischemic cardiac arrest. Coronary artery territories were categorized into the left anterior descending, circumflex and right coronary artery territories, according to receiving revascularization to the major vessel or to one or more branches. The left main stem counted as two territories (left anterior descending and circumflex artery territories) and the ramus intermedius was considered a component of the circumflex distribution.

Statistical analysis

Patients were divided into yearly cohorts on the basis of the calendar year of the index procedure. The index procedure was defined as the first revascularization procedure, PCI or CABG, of a patient in the study population. To examine the temporal trends in patient demographics, emergency status of the procedure, revascularization mode (PCI versus CABG), and 30-day and one-year postprocedure mortalities, Mantel-Haenszel χ^2 statistics and Spearman's rank correlation analysis were used for binary and continuous variables, respectively. Reported mortality rates are unadjusted.

Time to first repeat revascularization or death (survival free from repeat revascularization) was estimated separately for PCI and CABG patients using the Kaplan-Meier method for each of the seven yearly cohorts. The rates of survival free from repeat revascularization for annual cohorts were compared using the log-rank test for differences and the log-rank trend test for temporal trends. All statistical analyses were performed using SAS software (SAS/STAT User's Guide, version 8, SAS Institute Inc, USA).

RESULTS

Characteristics of patients and procedures

The number of first revascularization procedures in BC residents is shown in Table 1. An increasing proportion of revascularization procedures was performed with PCI (from 61.7% to 72.6%; $P < 0.001$), mainly resulting from the increase in the number of PCI procedures being performed among all age groups and both sexes rather than from any decrease in the number of CABGs being performed. Male patients accounted for an average of 72.3% (95% CI 71.6% to 72.9%) of those undergoing PCI, but they accounted for a greater percentage of those undergoing CABG surgery, the proportion increasing from 77.1% to 80.8% over the seven-year study ($P = 0.008$). The mean age of CABG patients remained unchanged at 65.2 ± 9.7 years, while the mean age of PCI patients increased slightly from 62.1 years in 1995 to 63.3 years in 2001 ($P = 0.014$). Overall, 13.4% of all revascularization procedures were performed in patients younger than 50 years of age, and 78.2% of these procedures were PCI. Patients older than 80 years of age accounted for 3.8% of all index procedure cases, 75.8% of which were PCI. In the 51- to 80-year age range, PCI accounted for 62.4% of index procedures (Figure 1).

The percentage of patients receiving PCI to two or more artery territories increased from 13.9% to 25.2% ($P < 0.001$). There were no trends over time for the number of territories treated by CABG; overall, two territories were treated in 25.5% of cases and three were treated in 71.3%. The percentage of PCIs involving the use of one or more stents increased from 20% in 1995 to 95% in 2001 ($P < 0.0001$). The percentage of CABGs involving one or more arterial conduits rose from

Figure 1) Age distribution of all coronary revascularization procedures performed on British Columbia residents between 1995 and 2001. CABG Coronary artery bypass graft surgery; PCI Percutaneous coronary intervention

72% in 1995 to 84% in 2001 ($P<0.001$), while the percentage of off-pump cases rose from 0.1% to 7.6% ($P<0.0001$).

Mortality after revascularization

There were no trends over time for unadjusted overall mortality after PCI (30-day $P=0.11$, one-year $P=0.78$) (Table 1). However, excluding emergent cases (9.0% of PCI cases), there was a statistically significant trend toward improvement over time for 30-day mortality (1.8% in 1995 to 1.1% in 2001; $P=0.021$ for trend) (Table 2). Following CABG, the overall 30-day mortality decreased from a high of 2.5% in 1995 to 1.4% in 2001 ($P<0.001$) (Table 1). Overall mortality at one year also decreased from 5.0% to 3.5% ($P<0.001$). Excluding emergent cases (2.7% of CABG cases), the mortality rates after CABG improved at 30 days (from 1.8% in 1995 to 1.2% in 2001; $P=0.011$ for trend) and one year (from 4.3% to 3.3%; $P=0.012$) (Table 2).

Emergent procedures

Emergent cases (9.0% of PCIs and 2.7% of CABGs) were more frequently treated with PCI, the percentage increasing from 85.5% to 92.5% during the study period ($P<0.001$) (Table 3). The 30-day mortality after emergent PCI did not change over time, being 11.7% overall (95% CI 10.3% to 13.3%). The 30-day mortality after emergent CABG improved from 28.1% to 10.0% ($P=0.003$ for trend). The mean age of patients treated by emergent PCI was 61.9 years, while it was 65.0 years in those treated by emergent CABG, with no significant trends between 1995 and 2001.

Survival free from repeat revascularization after PCI

As a result of restenosis, repeat procedures are often required after PCI, although much less often following CABG surgery. This is one of the major differences in outcome between the two modalities; therefore, mortality, as well as survival free from repeat procedures, were examined. For patients whose first revascularization procedure was PCI, 17.7% underwent repeat revascularization within one year (13.5% repeat PCI; 4.1% CABG) and 4.9% did so within 30 days. The percentage requiring repeat revascularization within one year was highest in 1995 (22.9%) and decreased annually until 2001 (13.0%).

TABLE 2
Unadjusted mortality rates after first coronary revascularization procedures on British Columbia residents, 1995–2001 (non-emergent cases)

Year	Number of cases		Mortality postprocedure, %			
			30-day		One-year	
	PCI	CABG	PCI	CABG	PCI	CABG
1995	1964	1305	1.83	1.84	3.46	4.29
1996	2087	1360	1.01	2.65	2.97	4.34
1997	2297	1414	1.48	1.63	3.40	3.25
1998	2618	1584	1.26	1.52	3.09	3.47
1999	2481	1511	1.01	1.46	3.31	2.65
2000	2735	1493	0.95	1.34	3.25	2.88
2001	3160	1300	1.08	1.23	3.29	3.31
Overall	17,342	9967	1.21	1.66	3.25	3.43

CABG Coronary artery bypass graft surgery; PCI Percutaneous coronary intervention

TABLE 3
Unadjusted mortality rates after first coronary revascularization procedures on British Columbia residents, 1995–2001 (emergent cases)

Year	Number of cases		Mortality postprocedure, %			
			30-day		One-year	
	PCI	CABG	PCI	CABG	PCI	CABG
1995	189	32	13.2	28.1	16.4	34.4
1996	226	54	8.85	27.8	11.9	29.6
1997	168	49	14.9	16.3	17.3	18.4
1998	193	52	14.5	17.3	16.6	23.1
1999	252	34	11.9	14.7	17.5	26.5
2000	316	25	13.0	4.00	16.8	12.0
2001	368	30	8.70	10.0	11.7	10.0
Overall	1712	276	11.7	18.1	15.1	22.8

CABG Coronary artery bypass graft surgery; PCI Percutaneous coronary intervention

Survival free from repeat revascularization increased in a step-wise fashion from 1995 to 2001 ($P<0.001$ for trend, Figure 2A). The need for surgery within 30 days of PCI decreased from 1.6% in 1995 to 1.0% in 2001 ($P<0.001$), and the need for repeat PCI within 30 days also decreased from 4.6% in 1995 to 2.5% in 2001 ($P<0.001$). The bulk of repeat revascularization in the PCI group occurred in the first year in all cohorts (Figure 2C). By two years following the index procedure, examination of the hazard rates showed no difference in risk of repeat revascularization or death between the PCI cohorts (note, there was no follow-up beyond two years for the 2001 cohort).

Survival free from repeat revascularization after CABG

Among patients having their first CABG during the study period, the percentage who required a repeat revascularization by one year was 1.9% (PCI in 1.7% of cases and repeat CABG in 0.2%) and 0.4% within 30 days. Survival free from repeat revascularization after CABG at one year improved from 93.6% in 1995 to 94.9% in 2001 ($P=0.005$ for trend,

Figure 2) Curves of survival without repeat revascularization showing annual improvements at one year after percutaneous coronary intervention PCI (A) and coronary artery bypass graft surgery (CABG) (B). Medium-term outcomes following both PCI (C) and CABG (D) are also shown. Numbers in parentheses represent the number of cases

Figure 2B). Few patients had repeat CABG; most repeat procedures performed were PCI. Again, examination of the hazard rates after the first year following the index CABG showed no difference in survival free from repeat revascularization (Figure 2D).

DISCUSSION

The present study examined all adult BC residents who had a first revascularization procedure between 1995 and 2001. These data have the advantage that they include all procedures, both emergent and non-emergent, performed on patients living in one province under a single, publicly-funded health care system. The population denominator is therefore the same for both PCI and CABG. There are few published studies that have captured all cardiac procedures from the same population in this fashion (3-5,12-14). The number of revascularization procedures is increasing, mainly due to an increase in PCI, as has been reported in Canada and elsewhere (3-6,12,14-19).

Characteristics of patients treated with PCI are different from those of patients treated with CABG. Most procedures,

both PCI and CABG, were performed on men, a gender difference that has previously been noted (6,15-18). The percentage of female CABG patients was lower than that of PCI patients, and decreased further during the study period. Although we did not observe any significant differences in mean age, higher proportions of patients younger than 50 years of age and older than 80 years of age were treated with PCI. In the former case, this likely reflects limited disease, while in the latter, the desire to avoid CABG may be more important. A higher and increasing proportion of emergent procedures (eg, acute STEMI, shock) was treated by PCI. As noted by other investigators, a greater degree of revascularization was performed during CABG than PCI (3,12). Although this may reflect more widespread coronary artery disease leading to the choice of surgical therapy, we were unable to confirm this because coronary angiograms were not reviewed. We were also unable to determine any differences in comorbidities (see 'Study limitations'). These data cannot, therefore, be used to compare outcomes of the two modalities, which are applied selectively to different

patient populations based on clinical and angiographic assessments, as well as patient and physician preferences. Rather, the data emphasize different and changing referral patterns and demonstrate the complementary roles of the two strategies.

Changes in mortality rates

There were improvements in unadjusted one-year mortality rates for non-emergent procedures, both PCI and CABG, mainly due to decreased 30-day mortality rates. For CABG, this likely resulted from a combination of improved anesthetic and operative techniques, and for PCI, improved interventional technologies and the use of concomitant medications. These data suggest that the improvements demonstrated in clinical trials, when extrapolated to the entire cohort of patients undergoing revascularization in BC, have translated to improvements overall. This finding is consistent with that of other studies (3,4,12,14,19) and is important because it demonstrates the generalizability of the clinical trial results in an unselected population. Similar patterns have been noted elsewhere in Canada (15-19).

Mortality rates for emergent procedures were substantially higher than for non-emergent procedures, as would be anticipated. In contrast to the observed improvement in mortality rates after non-emergent cases, there was no improvement in mortality rates after emergent PCI. Following emergent CABG, there was a disproportionately large improvement in mortality, which was statistically significant despite the relatively small numbers. This improvement contributed significantly to the improvement in overall surgical mortality. Although other contemporary studies noted reductions in surgical mortality for emergent cases (20,21), they were not as dramatic as those observed in the present study, suggesting that improvements in surgical and anesthetic techniques were not alone responsible. However, it is important to bear in mind that the determination of what constituted an emergent case was made by staff at the time of the procedure, and although the guidelines for what constituted an emergency did not change during the study period, it is possible that their application may have varied.

We have previously reported (6) an increase in the rate of diagnostic coronary angiography during this six-year period, the indications for which have expanded, being increasingly mandated for the management of acute coronary syndromes, including STEMI, and shock (20,22). The number of emergent revascularization procedures has increased concomitantly. However, rather than a proportionate increase in both modalities, as may have been anticipated, the increase was almost entirely in the number of PCIs, such that the percentage of emergencies treated with surgery decreased by almost one-half over the study period. It is therefore likely that the improvement in surgical mortality relates, at least in part, to the application of PCI to high-risk patients, who were formerly referred for CABG. The failure of emergent PCI mortality to improve, despite the improved mortality after non-emergent PCI, likely reflects not only increased treatment of high-risk patients who were formerly treated surgically, but also those who were formerly treated medically. These include patients in shock and those with acute STEMI who are ineligible for lysis or, increasingly, as primary therapy. Thus, interpretation of outcomes must take into account not simply improvements in techniques, but also changing patterns of application and, possibly, different determination of what constitutes an emergency, even though the BCCR definitions did not

change during the study period. This emphasizes the importance of reporting the results of the two revascularization modalities simultaneously.

Repeat revascularization

The need for repeat revascularization in BC decreased between 1995 and 2001, primarily due to a reduced need for repeat revascularization after PCI. CABG was associated with a very high one-year survival free from repeat revascularization, which increased modestly throughout the study period and is similar to that of other published data (1-4,7,12,14,21,23). Following PCI, the need for repeat revascularization reduced significantly year by year from 1995 to 2001, despite an increase in multivessel procedures. Most repeat revascularization procedures occurred within the first year of the index procedure, reflecting restenosis. As mentioned previously, this increased requirement for repeat procedures after PCI compared with surgery is well recognized (4,12). Coronary stenting and improved adjunctive therapy have increased the safety and efficacy of angioplasty, and we had previously reported increased stent use in BC, which increased dramatically from 25% of PCI procedures in 1995 to 90% in 2001 (6,24). The present study confirms that this finding has been accompanied by a significant improvement in survival free from repeat revascularization at one year.

These data were collected during a period when only bare metal stents were in use. Although in randomized clinical trials the low medium-term need for repeat revascularization after CABG has remained the 'gold standard', the advent of drug-eluting stents promises to further reduce the incidence of restenosis and consequent need for repeat procedures post-PCI, particularly within the first year. It is anticipated that drug-eluting stents, combined with other improvements in adjunctive therapies, will facilitate greater application of percutaneous revascularization to multivessel disease (5). Drug-eluting stents will likely help to bridge the remaining gap between PCI and CABG, in terms of the need for repeat revascularization. The data in the present report serve as a baseline to compare possible future changes in revascularization patterns and outcomes in BC.

Study limitations

We have not reported on comorbid conditions. Although these data have been collected by the BCCR for CABG patients since 1994, data concerning comorbidity for PCI patients have only been collected prospectively in the registry since 1999. We examined Canadian Institutes for Health Information data, but found discrepancies between these data and those of the BCCR which were larger for PCI than for CABG and rendered unclear the outcome of any analysis. In previous work (24), we did not find an association between comorbid conditions and improved outcomes post-PCI. In addition, we did not include postprocedural myocardial infarctions within our outcomes because cardiac enzymes were not routinely measured at all the institutions following PCI, and quantification of infarcts following CABG is problematic. We were reluctant to depend on discharge coding, which fails to distinguish between small postprocedural enzyme increases and more significant infarctions, and for the discrepancies already noted. Similarly, we did not examine the long-term occurrence of angina or subsequent myocardial infarction. It is possible that there may be a difference in these outcomes between the groups, such as a high re-referral rate after PCI because of

clinical suspicion of restenosis, but a low re-referral rate of patients who had what was perceived as definitive surgery.

Patients were followed in the present study for a mean of four years and a maximum of eight. This is a medium-term rather than long-term follow-up, but reflects the earliest period for which PCI data were collected within the registry. Because the need for repeat procedures after CABG tends to increase with diminishing vein graft patency, typically after eight years (9,25,26), longer follow-up would be required to determine the long-term difference in survival free from repeat revascularization between the CABG and PCI modalities.

We did not examine whether repeat revascularization following PCI was performed on the same lesion or even on the same target vessel. Although this conservative method underestimates the effectiveness of PCI on an individual lesion, it is a more pragmatic approach to the durability of the procedure to relieve symptoms. It also takes into account the difficulties in identifying the so-called 'culprit' lesions at time of PCI and the potential for re-presentation due to stenosis at non-target lesion segments as a consequence of instrumental injury during the initial procedure. A similar approach has been used by other investigators (4). Only the first repeat coronary revascularization procedure was taken into account in the analysis, and we did not include details of any subsequent procedures.

CONCLUSIONS

The number of first revascularization procedures in BC increased from 1995 to 2001, chiefly reflecting the increasing use of PCI. Unadjusted mortality rates at 30 days following

non-emergent revascularization procedures improved in both modalities. For emergent procedures, changes in mortality must be interpreted in light of the changing patterns of application of PCI and CABG. Following PCI, there were significant stepwise improvements in one-year survival free from repeat revascularization over the seven years of the study. However, the one-year period freedom from repeat procedure after PCI in the final year of the study was still lower than that of CABG. If improved PCI techniques, particularly drug-eluting stents, further reduce this difference, PCI may offer as durable a result as surgery. These data confirm that the improvements noted in clinical trials have been borne out in clinical practice and emphasize the complementary nature of these revascularization modalities. Furthermore, they serve as a benchmark to examine the effects of future treatments, such as drug-eluting stents, both on the durability of PCI procedures and on how this durability impacts upon the application of surgery.

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REFERENCES

- Birkmeyer JD, Siewers AE, Finlayson EV, et al. Hospital volume and surgical mortality in the United States. *N Engl J Med* 2002;346:1128-37.
- Sabik JF, Blackstone EH, Lytle BW, Houghtaling PL, Gillinov AM, Cosgrove DM. Equivalent midterm outcomes after off-pump and on-pump coronary surgery. *J Thorac Cardiovasc Surg* 2004;127:142-8.
- Mack MJ, Brown PP, Kugelmass AD, et al. Current status and outcomes of coronary revascularization 1999 to 2002: 148,396 surgical and percutaneous procedures. *Ann Thorac Surg* 2004;77:761-6,766-8.
- McCaul KA, Hobbs MS, Knuiman MW, Rankin JM, Gilfillan I. Trends in two year risk of repeat revascularisation or death from cardiovascular disease after coronary artery bypass grafting or percutaneous coronary intervention in Western Australia, 1980-2001. *Heart* 2004;90:1042-6.
- Ulrich MR, Brock DM, Ziskind AA. Analysis of trends in coronary artery bypass grafting and percutaneous coronary intervention rates in Washington state from 1987 to 2001. *Am J Cardiol* 2003;92:836-9.
- Pate GE, Humphries KH, Izadnegahdar M, Gao M, Kiely M, Carere RG. Population rates of invasive cardiac procedures in British Columbia, 1995 to 2001. *Can J Cardiol* 2004;20:712-6.
- Pell JP, MacIntyre K, Walsh D, et al. Time trends in survival and readmission following coronary artery bypass grafting in Scotland, 1981-96: Retrospective observational study. *BMJ* 2002;324:201-2.
- Influence of diabetes on 5-year mortality and morbidity in a randomized trial comparing CABG and PTCA in patients with multivessel disease: The Bypass Angioplasty Revascularization Investigation (BARI). *Circulation* 1997;96:1761-9.
- Lytle BW, Loop FD, Cosgrove DM, Ratliff NB, Easley K, Taylor PC. Long-term (5 to 12 years) serial studies of internal mammary artery and saphenous vein coronary bypass grafts. *J Thorac Cardiovasc Surg* 1985;89:248-58.
- Zacharias A, Habib RH, Schwann TA, Riordan CJ, Durham SJ, Shah A. Improved survival with radial artery versus vein conduits in coronary bypass surgery with left internal thoracic artery to left anterior descending artery grafting. *Circulation* 2004;109:1489-96.
- Parolari A, Alamanni F, Cannata A, et al. Off-pump versus on-pump coronary artery bypass: Meta-analysis of currently available randomized trials. *Ann Thorac Surg* 2003;76:37-40.
- Pell JP, Walsh D, Norrie J, et al. Outcomes following coronary artery bypass grafting and percutaneous transluminal coronary angioplasty in the stent era: A prospective study of all 9890 consecutive patients operated on in Scotland over a two year period. *Heart* 2001;85:662-6.
- Graham MM, Ghali WA, Faris PD, et al; APPROACH Investigators. Population rates of cardiac catheterization and yield of high-risk coronary artery disease. *CMAJ* 2005;173:35-9.
- Bakhai A, Hill RA, Dunder Y, Dickson R, Walley T. Percutaneous transluminal coronary angioplasty with stents versus coronary artery bypass grafting for people with stable angina or acute coronary syndromes. *Cochrane Database Syst Rev* 2005;CD004588.
- Ghali WA, Faris PD, Galbraith PD, et al; Alberta Provincial Project for Outcome Assessment in Coronary Heart Disease (APPROACH) Investigators. Sex differences in access to coronary revascularization after cardiac catheterization: Importance of detailed clinical data. *Ann Intern Med* 2002;136:723-32.
- Jamal SM, Shrive FM, Ghali WA, Knudtson ML, Eisenberg MJ; Canadian Cardiovascular Outcomes Research Team (CCORT). In-hospital outcomes after percutaneous coronary intervention in Canada: 1992/93 to 2000/01. *Can J Cardiol* 2003;19:782-9.
- Higginson LA, Naylor CD. Rates of cardiac catheterization, coronary angioplasty and coronary artery bypass surgery in Canada. *Can J Cardiol* 1997;13(Suppl D):47D-52D.
- Faris PD, Grant FC, Galbraith PD, Gong Y, Ghali WA. Diagnostic cardiac catheterization and revascularization rates for coronary heart disease. *Can J Cardiol* 2004;20:391-7.
- Ghali WA, Knudtson ML. Overview of the Alberta Provincial Project for Outcome Assessment in Coronary Heart Disease. On behalf of the APPROACH investigators. *Can J Cardiol* 2000;16:1225-30.
- Carnendran L, Abboud R, Sleeper LA, et al. Trends in cardiogenic shock: Report from the SHOCK Study. The SHould we emergently revascularize Occluded Coronaries for cardiogenic shock? *Eur Heart J* 2001;22:472-8.

21. Abramov D, Tamariz MG, Fremes SE, et al. Trends in coronary artery bypass surgery results: A recent, 9-year study. *Ann Thorac Surg* 2000;70:84-90.
 22. Ryan TJ, Antman EM, Brooks NH, et al. 1999 update: ACC/AHA Guidelines for the Management of Patients With Acute Myocardial Infarction: Executive Summary and Recommendations: A report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Committee on Management of Acute Myocardial Infarction). *Circulation* 1999;100:1016-30.
 23. Gruberg L, Milo S, Ben Tzvi M, et al; Israel Arterial Revascularization Therapy Study Group. Comparison of bypass surgery and stenting for the treatment of multivessel disease: Results from the ARTS trial in Israel. *Isr Med Assoc J* 2003;5:539-42.
 24. Rankin JM, Spinelli JJ, Carere RG, et al. Improved clinical outcome after widespread use of coronary-artery stenting in Canada. *N Engl J Med* 1999;341:1957-65.
 25. Bourassa MG, Fisher LD, Campeau L, Gillespie MJ, McConney M, Lesperance J. Long-term fate of bypass grafts: The Coronary Artery Surgery Study (CASS) and Montreal Heart Institute experiences. *Circulation* 1985;72:V71-8.
 26. Bourassa MG. Long-term vein graft patency. *Curr Opin Cardiol* 1994;9:685-91.
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