Hospital volume, calendar age, and short term outcomes in patients undergoing repair of abdominal aortic aneurysms: the Ontario experience, 1988–92

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Abstract

Objective – To determine, for abdominal aortic aneurysm surgery, whether a previously reported relationship between hospital case volume and mortality rate was observed in Ontario hospitals and to assess the potential impact of age on the mortality rate for elective surgery.

Design – Population based observational study using administrative data.

Setting – All Ontario hospitals where repair of abdominal aortic aneurysm as a primary procedure was performed during 1988–92.

Patients – These comprised 5492 patients with unruptured abdominal aortic aneurysms and 1203 patients with ruptured abdominal aortic aneurysms admitted to hospital between 1988–92 for repair of abdominal aortic aneurysm as a primary procedure.

Main outcomes – In-hospital death and length of in-hospital stay.

Results – The case fatality rate was 3·8% for unruptured abdominal aortic aneurysms and 40·0% for ruptured abdominal aortic aneurysms. For unruptured cases, after adjustment for patient and hospital covariates, each 10 case per year increase in hospital volume was related to a 6% reduction in relative odds of death (odds ratio (OR) 0·94, 95% confidence intervals 0·88, 0·99) and 0·29 days reduction (95% CI −0·22, −0·35) in postoperative in-hospital stay. Female sex (OR 1·53, 95% CI 1·08, 2·18) and transfer from another acute care hospital (OR 4·37, 95% CI 2·62, 7·29) were associated with increased case fatality rates among patients in the unruptured category. For ruptured cases, neither the case fatality rate nor postoperative in-hospital stay were significantly related to hospital volume. The case fatality rates increased linearly and substantially with advancing age both for unruptured and ruptured aneurysms, and the excess risk of postoperative death in ruptured as compared to unruptured aneurysms was substantially higher in older patients.

Conclusion – The relationship between hospital volume and mortality or morbidity was very modest and observed only for elective surgery. Case fatality rates in patients with ruptured abdominal aortic aneurysms remained 10 times higher than for patients with unruptured abdominal aortic aneurysms, despite improvements in overall mortality in comparison to previously published data. More effective detection of aneurysms, including elective repair for those once considered "high risk" older patients, might further reduce the toll from ruptured aortic aneurysms.

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Abdominal aortic aneurysm results in about 1000 deaths each year among Canadian men 65 years or older[1] and Health Canada has identified this disorder as a priority public health issue.[2] Surgical repair of the dilated aorta remains the cornerstone of management but surgery carries definite risks. Published series from population based studies report the short term postoperative case fatality rate (CFR) at 4·7% to 8·2% for unruptured aneurysms. On the other hand, the CFR ranges from 43·6% to 60·2% for ruptured aneurysms.[3–7] The skills of the surgical team are considered important determinants of postoperative mortality and morbidity.[8–11] Several studies have found that high volume hospitals typically had lower postoperative mortality than low volume hospitals, presumably because the higher volume either leads to or reflects improved patient care.[6–8 12–14] The relationship between hospital volume and length of in-hospital stay (LHS) for patients who have survived the surgery has not been examined. Demonstrating volume-mortality and/or morbidity relationships has important policy implications: if an inverse relationship between hospital volume and postoperative mortality and/or morbidity is persistently observed, a strong argument might be made for restricting these operations to regional referral centres with specialised surgical teams.

Since the risk of postoperative death in ruptured aneurysms substantially exceeds the risk of death in elective surgery for intact aneurysms, some risks in undertaking elective surgery for aneurysms are acceptable to prevent eventual complications and death from rupture.[15–22] However, indications for this preventive procedure remain controversial.[16–21] It seems logical that elective procedures would pose more risks to older patients than younger ones,[23–25] but two recent hospital based studies[24 25] did not find an increased risk of death with advancing age in unruptured

aortic abdominal aneurysms. Although the authors[24][25] accordingly suggested that elective surgery should not be withheld from older patients, the sample sizes in these studies were small and they analysed only patients with unruptured aneurysms. Since the elective operation trades off the small immediate risk of surgery against the very high risk of death from ruptured aneurysm, a parallel analysis of age specific case fatality rate (CFR) for ruptured and unruptured aneurysms is needed. Dramatically lower death rates for unruptured compared with ruptured aortic abdominal aneurysms in older patients can be taken as affirming the potential preventive value of elective surgery among the elderly (except, of course, where life expectancy is seriously foreshortened for other reasons).

We accordingly analysed hospital discharge abstracts from Ontario (average population 9·7 million) for the fiscal years 1988–92 to examine the relationship between hospital volume and short term treatment outcomes, and the relationship between patient's age and postoperative mortality in patients undergoing repair of abdominal aortic aneurysm as a primary procedure.

Methods

DATA SOURCES, INCLUSION, AND EXCLUSION CRITERIA

In the province of Ontario, discharge abstracts for all acute care hospital separations (discharges, transfers or in-hospital deaths) are computerised by the Hospital Medical Records Institute (now the Canadian Institute for Health Information). Discharge summaries, operative notes, and pathology reports were coded by qualified technicians; diagnoses followed the *International Classification of Diseases*, 9th rev (ICD-9)[26] and procedure coding followed the *Canadian Classification* (CC).[27]

We included all Ontario residents admitted to an Ontario acute hospital with a principal diagnosis of unruptured (ICD-9 code 441·4) or ruptured (ICD-9 code 441·3) abdominal aortic aneurysm who underwent abdominal aortic aneurysm surgery with either replacement, anastomosis, or aorta-iliac-femoral bypass as the primary procedure (CC code 5034 or 5024 or 5125) from fiscal 1988 (01/04/1988) to fiscal 1992. For ruptured cases, an additional procedure code of laparotomy (CC code 661) was added to the inclusion criteria, because some of these patients died before completion of aneurysm surgery and were therefore recorded simply as laparotomy. Patients were excluded if they underwent a secondary procedure involving any operations on the heart – for example coronary vessels, pericardium, valves, or septa (CC codes 47–49). Also excluded were patients with the following secondary diagnoses: dissecting aneurysm (ICD-9 code 4410) or thoracic aneurysm (ICD-9 codes 4411–4412); aneurysm of unspecified site, ruptured (ICD-9 code 4415); aortic aneurysm of unspecified site, without mention of rupture (ICD-9 code 4419); arterial embolism and thrombosis of abdominal (ICD-9 code 4440) or thoracic aorta (ICD-9 code 4441); congenital anomalies of aorta (ICD-9 code 7472) including coarctation (ICD-9 code 7471); or injury to abdominal aorta (ICD-9 code 9420).

The patient's age, sex, occurrence of in-hospital death, main secondary diagnoses (co-existing diseases), whether transferred from another hospital, and LHS were abstracted from the database as needed. Analysis on LHS was restricted to non-fatal cases. We calculated the postoperative LHS by the difference between date of surgery and date of discharge. The postoperative LHS thus calculated was further validated by comparing its value with preoperative LHS and the entire LHS. If the sum of postoperative LHS and preoperative LHS was not equal to the entire LHS, the postoperative LHS was assigned as missing. One unruptured case and none of the ruptured cases was assigned a missing value on postoperative LHS by this rule. All postoperative LHSs that exceeded the 95th centile (27 days for unruptured and 51 days for ruptured aneurysms, respectively) were assigned the value of the 95th centile to limit the influence of a few patients with excessively long LHS. To mitigate the confounding effects on outcomes of diseases other than abdominal aortic aneurysms, a comorbidity index for each patient was calculated using a validated ICD-9-CM-based adaptation[28] of a clinical system described by Charlson *et al.*[29] Ontario discharge abstracts permit full calculation of this comorbidity index in nearly all cases.[30] Information on hospital bed-size, and teaching status (presence or absence of house staff) was taken from the *Canadian Hospital Directory, 1991–1992.*[31]

ANALYSIS

To consider the fundamental differences in the natural history of the disease and clinical management issues involved, the two categories of aneurysm (ruptured and unruptured) were analysed separately throughout. Yearly number of operations, number of hospitals performing the procedure, number of deaths, and mean postoperative LHS were determined first; hospital and patient characteristics for the overall five fiscal years were then determined for the two categories of aneurysm. Surgeon identifying codes in the discharge abstracts were inconsistent, hence volume-outcome relationships could only be examined by centre, not by surgeon.

CFR and mean postoperative LHS were first compared after grouping hospitals according to hospital volume for the entire five years: <50, 50–100, 101–200, and >200 cases for unruptured aneurysm, and <10, 10–20, 21–40, >40 cases for ruptured aneurysm. Corresponding annual volumes are readily determined by dividing by five. In choosing these cut off points, we aimed to create sufficient gradients in hospital volume groups, so that the volume effects could be assessed, while at the same time maintaining large enough sample sizes in each group for statistical stability. Sensitivity analyses were done to evaluate moving

the five year volume cut off points for each category up or down by one case from the original cut off points, and the results were stable.

Stepwise multiple logistic regression analysis was used to examine the volume–mortality relationship, and stepwise multiple linear regression was used to examine the volume–postoperative LHS relationship at the individual patient level. Potential confounding factors included in the models were bed size and teaching status of the admitting hospital, patient's sex and age, comorbidity index, and whether the patient had been transferred from another hospital. As the primary factor of interest, hospital volume was kept in the model regardless of significance; other factors were excluded at a threshold significance level of 0·10. Hospital volume, bed size, and teaching status were assigned to each patient according to the hospital to which he or she was admitted. Avoidable deaths for unruptured cases in low volume hospitals (using the 75th centile, or 40 cases per year as the cut off point) were also estimated by applying the ORs obtained from the multiple logistic regression model.

To frame the age specific CFR analysis, ruptured and unruptured abdominal aortic aneurysms were compared after dividing the patients into six groups according to their calendar age (<60, 60–64, 65–69, 70–74, 75–79, and ≥80 years, respectively). Again, cut off points reflected a balance between creation of gradients to examine age effects, while maintaining statistical stability. Sensitivity analyses evaluating the impact of moving cut points up or down one year showed no change in results or conclusions. To examine whether there was any age dependent differential excessive risk of postoperative deaths in ruptured aneurysms, age specific rate differences (CFR in ruptured aneurysms – CFR in unruptured aneurysms) and their 95% confidence intervals were estimated using the method described by Fleiss.[32] Differences in numbers of deaths (number of deaths in ruptured aneurysms – number of deaths in unruptured aneurysms) were also calculated to describe the actual age specific differences in attributable deaths for the two types of aneurysms in the province of Ontario.

Ideally, all deaths occurring in aneurysm patients should be tallied in assessing the preventive value of elective surgery. However, in an analysis based on administrative data, we are unable to obtain information on deaths in aneurysm patients that occurred before surgery or after discharge from hospital. This limitation will be discussed later.

Several sensitivity analyses were performed. First, regression analyses were repeated after excluding patients admitted to extremely low volume hospitals (fewer than 10 cases for unruptured aneurysms, or fewer than five cases for ruptured aneurysms, respectively, for the entire five year period). Secondly, the analyses were repeated by including cases with a diagnosis of aneurysm of unspecified site, ruptured (ICD-9 code 4415) in the ruptured aneurysm category, and by including cases with a diagnosis of aortic aneurysm of unspecified site,

without mention of rupture (ICD-9 code 4419) or arterial embolism and thrombosis of abdominal aorta (ICD-9 code 4440) in the unruptured category. Finally, to assess the impact of delayed discharge for administrative reasons on the results, the analyses for postoperative LHS were repeated by excluding those patients transferred to another acute or chronic care center.

Results

OVERALL PROFILE

During the five years, there were 5837 operations on patients with unruptured abdominal aortic aneurysms and 1288 operations for ruptured aneurysms in Ontario hospitals. Altogether 321 unruputured cases and 32 ruptured cases were excluded either because they were out-of-province residents, or their demographic data were missing. Twenty four unruptured cases and 53 ruptured cases were further excluded because of the co-existence of another aneurysm or other major procedures in the heart or thoracic cavity which might complicate the comparisons, leaving 5492 unruptured cases and 1203 ruptured cases for analysis. The overall CFR was 3·8% for unruptured and 40·0% for ruptured abdominal aortic aneurysms.

The annual number of operations rose moderately during the period analysed (table 1). Postoperative LHS decreased moderately both in ruptured and unruptured aneurysms, but no consistent temporal trend of CFR was observed for either category (table 1).

Patients with unruptured abdominal aortic aneurysms tended to be younger and were less likely than ruptured cases to be transferred from another hospital. On the other hand, there were no important differences in size or teaching status of the hospitals, sex ratio, or comorbidity index. As expected, both the CFR and postoperative LHS in non-fatal cases were substantially higher in ruptured than in unruptured abdominal aortic aneurysms (table 2).

HOSPITAL-LEVEL CROSS TABULATION

For the entire five years, the hospital volume for unruptured aneurysms ranged from 1 to 415, while that for ruptured aneurysms ranged from 1 to 64. There was a moderate decline in CFR with rising hospital volumes for both unruptured and ruptured abdominal aortic aneurysms (table 3) but this did not reach statistical significance. The volume–postoperative LHS relationship was weak and inconsistent in the crude comparison (table 3).

RESULTS OBTAINED FROM STEPWISE REGRESSION ANALYSIS

In the multivariate analyses, each 10 case per year increase in hospital volume was related to a 6% reduction in odds of death and a 0·29 day reduction in postoperative LHS in unruptured cases. On the other hand, there was no significant relationship between either CFR or

Table 1   Yearly statistics on repair of abdominal aortic aneurysms performed as primary procedures in Ontario hospitals, 1988–92

Year	Unruptured aneurysm					Ruptured aneurysm				
	No of operations	No of hospitals	Average no per hospital	CFR (%)	Mean (SD) LHS	No of operations	No of hospitals	Average no per hospital	CFR (%)	Mean (SD) LHS
1988	1022	60	17·0	4·1	12·1 (5·4)	229	55	3·8	45·0	19·6 (12·1)
1989	971	63	15·4	3·5	11·6 (5·2)	268	54	4·6	40·0	18·0 (11·4)
1990	1112	65	17·1	4·2	11·2 (5·1)	241	55	4·1	33·2	19·1 (13·3)
1991	1163	62	18·8	3·3	10·7 (4·7)	265	56	4·3	44·5	18·1 (13·1)
1992	1224	62	19·7	4·0	10·4 (5·1)	253	54	4·3	42·3	18·3 (13·3)

CFR = case fatality rate; LHS = length of hospital stay.

Table 2   Hospital and patient characteristics for abdominal aortic aneurysms in Ontario, 1988–92

Characteristics	Unruptured aneurysm	Ruptured aneurysm
Mean (SD) number of cases per year per hospital	15·6 (18·2)	3·1 (3·3)
Mean (SD) of bed size	236 (160)	225 (158)
Teaching hospital (%)	44·3	44·0
Female patients (%)	16·3	17·0
Patient's age (y):		
<60 (%)	8·9	6·5
60–64 (%)	14·8	12·2
65–68 (%)	24·5	20·9
70–74 (%)	24·6	22·7
75–79 (%)	17·6	20·6
≥80 (%)	9·6	17·2
Comorbidity index:		
0 (%)	59·6	62·2
1 (%)	28·2	24·4
≥2 (%)	12·2	13·4
Transferred from another hospital (%)	4·1	26·4
In-hospital death (%)	3·8	40·0
Mean (SD) LHS	11·2 (5·1)	18·6 (12·6)

Aneurysm surgery volume, bed size, and teaching status were obtained from the HMRI database and published sources. Age, sex, comorbidity index, admission status, transferred from another hospital, death rates, and length of hospital stay (LHS) were determined for patients admitted to each hospital.

AGE-SPECIFIC RATE DIFFERENCE AND DIFFERENCE IN NUMBER OF DEATHS

For patients aged 60 years or less, the CFRs were 19·23% and 1·03%, and the numbers of deaths 5 and 15 respectively for ruptured and unruptured aneurysms. The corresponding rate difference is 18·20%, and the absolute difference in number of deaths 10 (or 2 per year). As shown in table 6, whether measured by rate difference or difference in actual number of deaths, the risk of postoperative death in ruptured abdominal aortic aneurysms markedly exceeded the risk of surgery in unruptured aneurysms. Moreover, the excessive risk of death from ruptured aneurysms was highest in older patients.

postoperative LHS and hospital volume in the ruptured cases. The CFR increased linearly with age both for unruptured and ruptured aneurysms: ORs for CFR for each 10 year age increase obtained from multiple logistic regression models were 1·75 (95% CI 1·52, 2·01) for ruptured abdominal aortic aneurysms and 2·10 (95% CI 1·74, 2·54) for unruptured aneurysms. Transfer from another hospital was associated with increased odds of death among unruptured cases (OR 4·37, 95% CI 2·62, 7·29) as was female sex (OR 1·53, 95% CI 1·08, 2·18). Comorbidity was also a predictor of outcomes (table 4).

AVOIDABLE DEATHS FOR UNRUPTURED ANEURYSMS IN LOW VOLUME HOSPITALS

Approximately 40 deaths (8 deaths/year) in the low volume (<40 cases/year) hospitals might be avoidable if all of their surgery had been transferred to high volume hospitals (table 5).

SENSITIVITY ANALYSIS

Sensitivity analyses showed that results for both outcomes were stable after including cases with ambiguous diagnostic codes (see methods section) or excluding patients admitted to very low volume hospitals (fewer than five ruptured cases or fewer than 10 unruptured cases in the entire five years). Results for postoperative LHS were stable after excluding patients transferred to other acute or chronic institutions (data on request).

Discussion

Case fatality rates in patients undergoing abdominal aortic aneurysm repair surgery in the province of Ontario during 1988–92 were the lowest in recently reported series.[3-7] We applied more exclusion criteria than other studies in an effort to reduce the misclassification of procedures that can occur with administrative data. However, exclusions resulted in less than a 0·5% reduction of the study sample (from 5516 to 5492 for unruptured and from 1256 to 1203 for ruptured cases), and the overall CFR was basically unchanged even after adding these

Table 3   Distribution of in-hospital death rate of postoperative in-hospital stay by level of hospital-volume of abdominal aneurysm surgery in Ontario, 1988–92

Volume level per y	Unruptured aneurysm					Ruptured aneurysm				
	<10	10–20	21–40	>40	p value	<2	2–4	4·1–8	>8	p value
No hospitals	35	17	12	6		40	19	12	7	
No patients	696	1179	1683	1934		150	288	373	392	
CFR (%)	4·6	4·0	3·8	3·5	0·59	44·7	40·6	38·6	39·0	0·82
Mean (SD) LHS	11·6 (5·4)	11·2 (5·0)	11·0 (5·1)	11·1 (5·1)	0·06	17·4 (13·0)	17·7 (12·1)	19·7 (13·5)	18·6 (12·0)	0·33

CFR = case fatality rate; LHS = length of hospital stay.

Table 4   Adjusted odds ratios (95% confidence interval) for in-hospital death and adjusted linear regression coefficients for length of postoperative stay for patients undergoing abdominal aortic aneurysm surgery in Ontario, 1988–92

Determinants	Unruptured aneurysm		Ruptured aneurysm	
	In-hospital death (%)	Length of stay (d)	In-hospital death (%)	Length of stay (d)
Aneurysm surgery volume – 10 case/y increase for unruptured and 2 case/y increase for ruptured	0·94 (0·88, 0·99)	−0·29 (−0·22, −0·35)	0·97 (0·91, 1·03)	−0·12 (−0·46, +0·22)
Bed size – 30 bed increase	NS	0·11 (0·08, 0·13)	NS	0·14 (0·06, 0·22)
Teaching hospital – yes = 0; no = 1	NS	−0·46 (−0·14, −0·78)	NS	NS
Age – 10 y increase	2·10 (1·74, 2·54)	1·39 (1·23, 1·55)	1·75 (1·52, 2·01)	1·84 (1·14, 2·54)
Sex – male = 0; female = 1	1·53 (1·08, 2·18)	0·47 (0·11, 0·83)	NS	NS
Comorbidity index – none = 0; 1 = 1; ≥2 = 2	2·12 (1·77, 2·53)	1·05 (0·87, 1·23)	NS	0·92 (0·04, 1·78)
Transferred from another hospital – no = 0; yes = 1	4·37 (2·62, 7·29)	1·62 (0·92, 2·32)	NS	NS

NS: not significant; nos in brackets represent 95% confidence intervals.

excluded cases back to the sample (4·0% *v* 3·8% for unruptured cases and 40·9% *v* 40·0% for ruptured cases).

The CFR of 3·8% for unruptured aneurysm observed in our study sample reflects, at least partly, the continuous improvement in the treatment outcomes for this surgical procedure.[6 7 11] Another possible reason for the low mortality rate is a surgeon training effect. We estimate that more than 80% of abdominal aortic aneurysm patients were treated in Ontario hospitals with a trained vascular surgeon on staff. However, inconsistent identifying factors on the data for individual surgeons prevented us from exploring further the relationship between a surgeon's training and outcomes.

Previous analyses showing an inverse volume and mortality relationship[6–8 12–14] have generated support for the view that stricter regionalisation of this procedure will lead to better treatment outcomes. We too found a volume-mortality relationship but it was modest. Similarly, there was a modest relationship between hospital volume and postoperative LHS in non-fatal cases, presumably caused, at least partly, by increased complication rates in low volume hospitals. As shown in table 5, in the unlikely event that all unruptured cases now treated in low volume hospitals were transferred to the high volume hospitals and achieved the same CFR as high volume hospitals, only 40 deaths for the entire five years (or 8 deaths per year) could be avoided. This is dramatically fewer than suggested in a similar analysis by Maerki *et al*[13] using 1972 data; however, their series had a much higher overall mortality (resulting in a greater potential for saving). Hannan *et al* analysed more recent (1985–1987) New York State data separating unruptured aneurysms from ruptured aneurysms and, similar to our findings, showed an inverse relationship between hospital volume and CFR for unruptured aneurysm surgery but not for ruptured aneurysms.[7] Hannan *et al* used a log transformation for hospital volume in their logistic regression analysis, which precludes a direct comparison between their study and the current one.

On balance, it seems reasonable to infer that as surgical skill and care has improved (reflected by a continuous decrease in overall CFR), the impact of hospital volume on mortality might have diminished. Moreover, there are many factors affecting surgical care, and hospital volume itself is only an indirect marker for surgical care. For example, as Pilcher *et al* have pointed out,[8] surgeons in large volume hospitals who perform vascular surgery occasionally may not do as well as those who perform vascular surgery more frequently, and some smaller community hospitals with one or two well trained, busy vascular surgeons can produce results comparable to those in large centres.[8] These observations, coupled with the limited volume-outcome relationship seen in this study, cast doubt on the policy of regionalisation of abdominal aortic aneurysm care focussing only on hospital volume. Unfortunately, the surgeon identifying codes in the hospital administrative data for Ontario are less reliable than procedure and diagnosis codes, and formal analysis is thereby precluded. However, an informal review of surgeon identifying codes in relation to volumes does suggest very substantial concentration of elective aneurysm surgery in the hands of one or two surgeons in small and medium sized hospitals – a factor that may help explain the weak volume–outcome relationships observed at the hospital level. Further analyses are needed that focus on individual surgical volume, surgical training, and the quality of postoperative care.

Any study drawing on administrative data necessarily suffers from a lack of clinical detail and is subject to vagaries in the coding of diagnoses and procedures. It seems unlikely that the observed excess CFR in women undergoing elective abdominal aortic aneurysm repair can be explained on this basis. However, sex did not significantly affect survival in an earlier Canadian registry study,[4] and independent confirmation of this observation is needed. Unmeasured referral biases are a particular concern in volume–outcomes analyses

Table 5   Avoidable deaths for unruptured abdominal aortic aneurysms in low-volume hospitals (using 40 cases/year as the cut off point) if all patients underwent surgery in high volume hospitals, Ontario, 1988–92

Volume range (per y)	<10	10–20	21–40	>40
Median volume	3·6	15	27	65
Total no of deaths	32	47	64	67
% (95% CI) avoidable deaths*	36·0% (6%, 72%)	30·0% (5%, 60%)	23% (4%, 46%)	NA
No of avoidable deaths	12 (2, 23)	14 (2, 28)	15 (3, 29)	NA

NA: not applicable; *Estimated from the volume–mortality relationship in the multivariate model.

Table 6 A comparison of age specific in-hospital case fatality rate differences (ruptured – unruptured) and differences in the actual number of postoperative deaths (ruptured – unruptured) for patients undergoing abdominal aortic aneurysm surgery

Age (y)	Rate difference in (%) (95% CI)	Difference in no of deaths per year in Ontario
<60	18·2 (8·7, 27·7)	2
60–64	21·0 (13·7, 28·2)	4
65–69	31·8 (25·7, 38·0)	10
70–74	37·5 (31·4, 43·6)	14
75–79	38·9 (32·3, 45·6)	9
≥80	50·2 (42·8, 57·7)	15

based on administrative data. For unruptured aneurysms, it does seem that more complicated and higher risk cases are preferentially referred to large centres, because after age and comorbidity adjustment, the inverse volume-mortality and volume–postoperative LHS relationships became statistically significant. Indeed, as shown by our multivariate analysis, selection factors clearly operate not just through outpatient referrals, but through interinstitutional transfers of inpatients. The effects of these referral or selection biases are unlikely to be totally eliminated by adjustments for age, comorbidity, and transfer status, given the fact that administrative data lack clinical details about many relevant variables. As a result, the volume-outcome relationship in unruptured aneurysms might have been underestimated in our study. On the other hand, it seems likely, considering unadjusted data, that our findings of small effects are real. Earlier studies presented data only on crude comparisons, yet showed a dramatic effect of hospital volume on CFR. For example, Pilcher et al examined the CFR of abdominal aortic aneurysms in Vermont from 1970–1977, and found a 1·5 to 2·5 fold increase in CFR in low volume hospitals compared with high volume hospitals on crude comparisons.[8] Only very dramatic shifts in referral patterns, such as low risk cases being referred to large centres in earlier years and high risk cases being referred to large centres in later years, would explain the large differences in unadjusted results observed in earlier studies when compared with the current one.

The results for ruptured aneurysms are difficult to interpret. Intuitively one would expect high volume centres with sophisticated intensive care units to achieve better outcomes with these critically ill patients. However, apart from age, there were no significant predictors of postoperative mortality. In any event, the emergency nature of this procedure makes regionalisation unrealistic in some parts of Canada where the distance between hospitals would put patients at risk from attempted transfer. Pilcher et al have suggested that resuscitation and selective transfer, as well as emergency operations in selected smaller hospitals, might be effective policies in the management of ruptured aneurysms.[8]

Although the overall CFR in our study sample was low, the rate in ruptured aneurysms remained 10 times higher than that in unruptured aneurysms. This emphasises the need for more effective detection of aneurysms with

elective repair of the dilated aorta. Some authors have argued that with continuing improvement in postoperative mortality and morbidity rates, elective surgery should now be offered to patients at higher risk of postoperative death, including the elderly.[23–25] Our results support this position, in that the absolute excess in numbers of postoperative deaths for ruptured compared with unruptured cases was highest in patients at advanced aged. Moreover, some hospitalised patients with ruptured aneurysms died before surgery was attempted. To assess the potential consequences of nonoperative deaths on the results, we estimated the in-hospital mortality rates for ruptured aneurysms by diagnosis alone. The CFR increased substantially to 54·0% when nonoperative deaths were tallied, underlining the potential advantages of elective surgery. We acknowledge that only short term postoperative mortality was examined and that some deaths related to elective aneurysm repair will occur after discharge but there is no reason for these to be greater among those surviving elective surgery than urgent or emergency surgery for rupture. Our inferences are also supported by the fact that for long term postoperative outcomes a Canadian registry study showed a strong relationship between short term postoperative mortality and long term postoperative mortality.[4] Lastly, some deaths from rupture obviously occur before admission to hospital.[8] This again emphasises the potential yields from elective surgery, especially in older patients who would be less likely to survive rupture and reach the operating room.

There are obviously many factors that affect the preventive value of elective surgery for aneurysms, such as the size of the aneurysm, expansion speed, likelihood of early death from competing causes, and average life expectancy.[16–21] Adequate assessment of the cost effectiveness of elective surgery under various scenarios must therefore integrate these factors with decision analytic techniques.[19] Nonetheless, our results strongly suggest that calendar age per se should not be a reason to withhold elective abdominal aortic aneurysm repair from older patients.

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