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A cost-effectiveness analysis of standard versus endovascular abdominal aortic aneurysm repair

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Objective: To compare endovascular and standard open repair of abdominal aortic aneurysms in terms of initial in-hospital costs and the costs of secondary interventions and surveillance. **Design:** A retrospective study. **Setting:** A university-affiliated tertiary care medical centre. **Patients:** Seven patients who underwent elective endovascular (EV) repair of an abdominal aortic aneurysm in 1998 and 31 patients anatomically suitable for endovascular repair who underwent standard (STAN) elective repair. Follow-up ranged from 2 to 14 months. **Interventions:** Elective repair of an abdominal aortic aneurysm with use of the standard technique or endovascular technology. **Outcome measures:** Costs common to both groups were not determined. Costs were determined for total hospital stay, preoperative or postoperative embolization, grafts, additional endovascular equipment, and follow-up computed tomography. **Results:** Groups were similar with respect to demographic data and aneurysm size (EV = 6.23 cm v. STAN = 6.05 cm). All patients were in American Society of Anesthesiologists class III or IV. Vanguard bifurcated grafts and extensions were used in the EV group. The total cost for both groups in Canadian dollars included: cost of stay (EV, 5.6 d, $2092.63 v. STAN, 10.7 d, $4449.19; p = 0.009); cost of embolization (EV, n = 3; $900 / procedure); cost of follow-up CT (EV, 5.4 per patient; $450 / CT); cost of grafts (EV = $8571.43, STAN = $374); additional radiologic equipment costs (EV = $1475). The mean total cost differed significantly between the 2 groups (EV = $14 967.63 v. STAN = $4823.19; p = 0.004). The additional cost associated with a reduction in hospital stay was calculated by determining the incremental cost-effectiveness ratio (ICER: difference in mean costs / difference in mean length of stay = $1604.51). **Conclusions:** Endovascular repair continues to be more expensive than standard open repair determined according to procedural and follow-up costs. The technology is still in the developmental stage, but as it evolves and follow-up protocols are streamlined, it is hoped that there will be an eventual reduction in the costs associated with the endovascular procedure.

Objectif : Comparer, dans la réparation des anévrismes de l'aorte abdominale, l'intervention endovasculaire avec la chirurgie effractive habituelle, aux chapitres des coûts initiaux à l'hôpital et des coûts des interventions secondaires et du suivi. **Conception :** Étude rétrospective. **Contexte :** Centre médical de soins tertiaires affilié à une université. **Patients :** Sept patients qui ont subi une chirurgie endovasculaire (EV) élective pour un anévrisme de l'aorte abdominale en 1998 et 31 patients, dont l'anatomie se prêtait à une intervention endovasculaire, qui ont subi une chirurgie élective standard (STAN). Le suivi variait de 2 à 14 mois. **Interventions :** Intervention élective de réparation d'un anévrisme de l'aorte abdominale faisant appel à la technique habituelle ou à la technologie endovasculaire. **Mesures de résultats :** Les coûts communs aux deux groupes n'ont pas été calculés. On a établi les coûts de l'hospitalisation totale, de l'embolisation préopératoire et postopératoire, des greffons, du matériel endovasculaire supplémentaire et de la tomodensitométrie de suivi. **Résultats :** Les données sur les caractéristiques démographiques et la taille d'anévrisme étaient semblables dans les deux groupes (EV = 6,23 cm c. STAN = 6,05 cm). Tous les patients faisaient partie des classes III ou IV de l'American Society of Anesthesio-

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logists. Des extensions et greffons bifurqués d'avant-garde ont servi dans le groupe de traitement EV. Dans les deux groupes, le coût total, établi en dollars canadiens, comprenait : le coût de l'hospitalisation (EV, 5,6 j, 2092,63 $ c. STAN, 10,7 j, 4449,19 $; *p* = 0,009); le coût de l'embolisation (EV, *n* = 3; 900 $ / intervention); le coût de la tomodensitométrie de suivi (EV, 5,4 par patient; 450 $ / tomodensitométrie); le coût des greffons (EV = 8571,43 $ STAN = 374 $); les coûts liés au matériel de radiologie supplémentaire (EV = 1475 $). Le coût total moyen différait considérablement entre les deux groupes (EV = 14 967,63 $ c. STAN = 4823,19 $; *p* = 0,004). La détermination du rapport coût-efficacité différentiel (RCED : différence entre les coûts moyens / différence entre les durées moyennes d'hospitalisation = 1604,51 $) a permis de calculer le coût supplémentaire qu'occasionne la réduction de la durée d'hospitalisation. **Conclusions :** L'intervention endovasculaire demeure plus coûteuse que la chirurgie effractive habituelle, selon les coûts d'intervention et de suivi. La technologie est encore en cours de mise au point, mais on espère qu'à mesure qu'elle évoluera et que les protocoles de suivi seront mis à jour, les coûts associés à l'intervention endovasculaire diminueront.

There is little doubt that the introduction of endovascular technology in the early 1990s revolutionized the treatment of abdominal aortic aneurysms (AAAs).[1] Use of endovascular repair has many potential advantages over standard open repair, including possible decreased morbidity and mortality in high-risk patients and technical advantages in certain clinical and anatomic situations. As with any new technique there are a number of ongoing controversies and unresolved issues. The debate regarding the significance of endoleaks[2] and endotension[3] continues, and there is concern regarding postimplantation reintervention rates.

Today the cost of any new technology is often initially prohibitive. It is important for surgeons to be fluent in the language of economists so that they can best represent their patients' interests in the ongoing discussions with hospital administrations, insurance companies and government agencies with respect to other new treatments. Economic evaluations have been under-utilized in surgical studies. Until recently there were relatively few economic analyses comparing endovascular and standard aortic aneurysm repair.[4–9] These studies concentrated on initial hospital costs with few of them[10] incorporating the cost of postimplantation surveillance after endovascular repair. The purpose of our study was to compare the costs of standard and endovascular repair of AAAs during initial hospitalization and follow-up. The assumption was that the higher technical and equipment costs of the endovascular technique would be, at least partially, offset by a shorter hospitalization period.

Patients and methods

We reviewed all elective infrarenal AAAs repaired at our institution in 1998. This was early in the development of our endovascular program when the technique was reserved for high-risk patients with appropriate aortic anatomy. This period was chosen so as to include the costs of postoperative surveillance. During this period 169 elective infrarenal aneurysms were repaired with the standard open approach at our institution. Patients were not randomized to either group and there were no conversions from endovascular to open repair. For the purpose of this economic analysis the standard repair (STAN) group was restricted to those who would have been anatomically suitable for endovascular repair (with adequate infrarenal neck [> 15 mm long] and appropriate iliac anatomy) and were in the same high-risk category as determined by the American Society of Anesthesiologists' (ASA) Physical Status Classification. Patients who underwent mesenteric or renal revascularization at the time of standard aneurysm repair were excluded from the study. These criteria resulted in the exclusion of 138 patients from the STAN group. The final study population comprised 7 patients in the endovascular (EV) group and 31 patients in the STAN group.

All endovascular repairs were performed in the operating room under general anesthesia. Open repair was performed via the transperitoneal route. Postoperatively patients were monitored in the vascular surgery observation unit with continuous ECG monitoring and frequent noninvasive blood pressure determinations. Only those patients who required invasive hemodynamic monitoring or ventilatory support were admitted to the intensive care unit. Most patients were admitted to hospital on the day of surgery. The date of discharge was determined at the discretion of the attending surgical staff.

Several basic assumptions were made before this economic evaluation. Costs were determined from the hospital's perspective and costs common to both techniques were not included in the analysis. It was determined that the difference in costs between the 2 techniques was more important than the absolute costs. Also, microcosting was not undertaken. That is, for the 2 techniques, a hospital day was viewed as equivalent in cost without determining the cost of various investigations such as blood work or intravenous administration of fluids. Also, to evaluate the cost of follow-up only patients who survived the postoperative period were included in the study.

The first part of the study involved a direct cost comparison between the 2 groups. Costs, determined from our hospital cost centre, included beds on the ward and in the intensive care unit, a standard Dacron graft, a Vanguard endovascular graft (Boston Scientific, Natick, Mass.), embolization procedures, contrast enhanced computed tomography and additional radiologic equipment for the endovascular procedure (Table 1). The χ^2 test or the Student's *t*-test was used to assess differences between the 2 groups when appropriate. A probability value less than 0.05 was considered statistically significant.

The second part of the study looked at the ICER (incremental cost-effectiveness ratio). The ICER represents the added cost of an additional unit of benefit and allows the comparison of different programs. In this case, length of stay was used as the outcome measure. The ICER in this study represents the additional cost of a reduction in hospital stay per day.

Results

The STAN and EV groups did not differ in age (71.7 v. 70.8 yr) or mean aneurysm diameter (6.2 v. 6.1 cm). All patients were ASA class III or IV. Four patients in the STAN group (none in the EV group) requiring invasive hemodynamic monitoring or ventilatory support were admitted to the intensive care unit. Two patients in the EV group were admitted the day before surgery in order to undergo internal iliac artery embolization. Although this can be achieved as an outpatient, our practice has been to perform this procedure the day before surgery. Total length of stay was significantly longer in the STAN group (10.7 d v. 5.6 d: $p = 0.04$) than the EV group (Table 2). There was minimal use of the ICU with both groups. One patient in the EV group underwent postoperative embolization of a lumbar artery for a type 2 endoleak. Preoperative arteriography was performed in all patients as is our usual practice. The endovascular patients underwent preoperative CT as well as postoperative CT at 48 hours, 1 month, 3 months and then every 3 months for the first year. This surveillance program resulted in a mean of 5.4 CT investigations per endovascular patient. Follow-up ranged from 2 to 14 months.

Combination of Tables 1 and 2 gave rise to the cost data in Table 3. Not surprisingly, the cost of the hospitalization period is twice as expensive in the STAN group given the longer length of stay. The cost of embolization and additional radiology equipment contributes to the cost of the endovascular technique. The cost of the endovascular graft accounted for 57.3% of the total cost of endovascular repair and 80.8% of the difference in costs between the 2 procedures ($10 144.44). Also, it is evident that as the surveillance period is lengthened, the cost of the endovascular procedure from the hospital perspective grows as more CT investigations are performed.

The ICER was the difference between the mean costs of the initial hospitalization and treatment ($C^{EV} – C^{STAN}$) divided by the difference between the mean length of stay ($LOS^{STAN} – LOS^{EV}$). With this calculation the cost of reducing the hospital stay by 1 day by performing endovascular repair is $1604.51. This is one form of analysis that allows us to compare different pro-

Table 1

Costs in Canadian Dollars Associated With Abdominal Aortic Aneurysm Repair

Item	Costs, $
Ward bed/d	375.60
ICU bed/d	966.96
STAN graft	374.00
Vanguard bifurcated graft (EV)	7000.00
Vanguard extension (EV)	2500.00
Embolization	900.00
Computed tomography	450.00
Additional radiology equipment for EV	1475.00

ICU = intensive care unit, STAN = standard, EV = endovascular.

Table 2

Comparison of Characteristics Associated With Standard and Endovascular Repairs for Abdominal Aortic Aneurysm

	STAN repair		EV repair		
Category	Mean	Median/range	Mean	Median/range	*p* value
Time on ward, d	9.9	9/14	5.6	4/6	0.04
Time in ICU, d	0.74	0/17	0	0/0	0.1
Length of hospital stay, d	10.7	9/21	5.6	4/6	0.04
No. of embolization procedures	0	0/0	3	0/1	0.04
No. of CT investigations	0	0/0	5.4	5/5	0.02

STAN = standard, EV = endovascular, ICU = intensive care unit, CT = computed tomography.

Table 3

Comparison of the Costs in Canadian Dollars of Standard and Endovascular Repairs for Abdominal Aortic Aneurysm

	STAN repair, $		EV repair, $		
Category	Mean	Median/range	Mean	Median/range	*p* value
Length of hospital stay	4 449.19	3 380.40/17 940.72	2 092.63	1 502.40/2 253.60	0.009
Embolization	0	0/0	385.71	0/900	0.01
Computed tomography	0	0/0	2 442.86	2 250/2 250	0.009
Grafts	374.00	374.00/0	8 571.43	7 500/5 000	0.007
Radiology equipment	0	0/0	1 475.00	1 475.00/0	0.008
Total	4 823.19	37 54.40/17 940.72	14 967.63	15 129.80/4 303.60	0.004

STAN = standard, EV = endovascular.

grams with respect to their economic impact on the hospital.

Discussion

Until recently, economic evaluations have been under-utilized in surgical studies. They are especially important with new technology or procedures, which must not be just beneficial but beneficial enough to offset the often higher costs.[11] In this era of limited health care resources, new and expensive technology is reviewed closely by government agencies and hospital administrations in the Canadian health care system. With this in mind we set out to determine the difference in cost to the hospital between endovascular and standard elective aortic aneurysm repairs. A period of postoperative surveillance was included in cost determination.

Several cost comparisons between endovascular and open aneurysm repair have been reported by surgeons from various countries.[4–9] Hölzenbein and associates[4] reported higher costs with standard repair than endovascular repair as a result of a longer hospitalization. Unlike other studies, the cost of the endovascular grafts was not included in the overall costs, and this explains these somewhat atypical results. Two further studies found no difference in hospital costs between the 2 techniques.[6,9] Ceelen and associates[6] reported their experience in Belgium where the reduction in hospital stay offset the high cost of the endovascular graft. This was not the case in 2 American studies where endovascular repair proved much more costly.[5,8] Clair and colleagues,[5] describing the Cleveland Clinic experience, reported that endovascular repair was more expensive than standard repair unless the endovascular graft cost less than US$6000; this is despite a 6.5-day reduction in hospital stay with endovascular repair (9.7 v. 3.2 d). Sternbergh and Money[8] reported a similar experience in which, unless the endovascular graft cost less than US$5000, endovascular repair was more expensive than open repair. All of these studies involved in-hospital costs only and did not include the cost of postoperative surveillance. Like our study, Birch and associates[10] did include surveillance and reintervention costs in their analysis. In this Australian study the authors estimated that lifelong surveillance after endovascular repair would cost an additional $4120 per patient.

In the present study we set out to compare the costs associated with endovascular and standard aneurysm repairs during the hospital and postoperative surveillance periods. This occurred early in our endovascular experience, so the number of patients is small. In an attempt to more accurately document the cost of endovascular repair to the hospital the cost of postoperative CT examinations was included in the analysis. Costs common to both procedures were not determined, because we were most interested in the difference in costs between the 2 techniques. As in other studies, length of hospitalization was reduced with endovascular compared with standard aneurysm repair (10.7 v. 5.6 d; p = 0.04). Further reduction in length of stay after endovascular repair can be achieved with more aggressive discharge planning as is evident in the Cleveland Clinic experience.[5]

The cost of the endovascular device continues to account for a large component of the total cost of endovascular repair. The cost in our study (57.3% of the total cost of endovascular repair) is in keeping with that found by others.[8] In previous studies the cost of postoperative CT was not included in the cost of endovascular repair. In our study, with a follow-up ranging from 2 to 14 months, CT accounted for 16.3% of the cost of endovascular repair. This contribution to total cost would continue to increase as the follow-up period lengthened. The optimal postimplantation surveillance program of endovascular grafts remains unknown. Radiographic surveillance of aortic grafts placed during open repair is not routine, although some authors have recommended CT after 5 years.[12,13]

The further reduction of costs associated with endovascular repair will require cooperation between industry and medicine.[14] Although shortening hospital stay can reduce total costs, the extent of cost reduction may not be as significant as is widely believed. The reduction in hospital stay on a trauma service by 1 full day reduces total cost of care by 3% or less.[15] As experience with endovascular repair increases, the frequency of endoleaks should decrease, resulting in fewer secondary interventions and allowing some cost savings. Postoperative surveillance will continue to be necessary with endovascular repair and may vary among the different available endografts. Although we have continued to use CT, the frequency has been reduced. Any cost savings resulting from this reduction have yet to be determined. As surveillance programs are continually streamlined and alternative investigations, such as duplex ultrasonography, are used, further cost reductions will be achieved. The majority of the associated increased cost of endovascular repair continues to be that of the device. It is imperative that industry and medicine continue to work together to reduce these costs so that this technology is available to the patients who will benefit.

A direct cost comparison is just one possible component of an economic evaluation. A method of comparing both costs and health effects of competing programs or techniques is the ICER.[16] In general, this represents the added cost of an additional unit of benefit. In the present study, the additional cost associated with a reduction in hospital stay by 1 day was found to be Can$1604.51. In comparison, an ICER can be extrapolated from a paper describing the early experience with laparoscopic cholecystectomy.[17] By using the data from this paper the cost of reducing hospital stay by 1 day by using the laparoscopic approach is approximately $485.25.

Our study has several limitations. We attempted to analyze our early experience with endovascular aneurysm repair, so the numbers are small. However, the data obtained is indicative of a Canadian centre's early experience with the endovascular technique. To obtain a general idea of the difference in costs between the 2 techniques several assumptions were made. Although analysis of all variables and the use of microcosting may have resulted in more accurate total cost data, it would not have altered the study's conclusions. With larger numbers of patients a sensitivity analysis could be performed to analyze the role of complications, different graft costs, and various surveillance schedules on total procedure cost.

Of more value may be an economic evaluation associating cost with a measure of health-related quality of life (QOL). Endovascular aneurysm repair has the potential advantage of decreasing the degree of morbidity previously associated with open repair. Several studies have compared prospectively obtained QOL measures between endovascular and open repair.[18,19] With a cost utility analysis, a standard unit such as quality adjusted life years (QALYs) could be used as the measure of health benefit. By achieving a measure of cost per QALY comparisons between different programs could be made, and the overall economic attractiveness of different programs could be assessed and compared. It would be of value for any prospective study of a new technology or treatment to include cost and QOL data such that a cost utility analysis could be performed.

Conclusions

From the hospital perspective the elective endovascular repair of aortic aneurysms is more expensive than standard open repair, with the majority of the increased costs accounted for by device costs and surveillance. Endovascular technology is still in the developmental stage and as follow-up protocols are streamlined it is hoped that there will be an eventual reduction in endovascular costs. Economic evaluations should prove to be an integral part of prospective studies of this technology as cost could continue to be a significant factor in limiting the widespread utilization of this currently attractive technology.

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