The Heart Surgery Forum #2004-1070
7 (5), 2004 [Epub September 2004]
doi:10.1532/HSF98.20041070

Online address: www.hsforum.com/vol7/issue5/2004-1070.html

The Clinical and Fiscal Impact of Endovascular Repair of Abdominal Aortic Aneurysms

Dr. Watson

Daniel R. Watson, MD, Thomas Tan, Lori Wiseman, Gary M. Ansel, MD, Chip Botti, MD, Barry George, MD, Richard Snow, DO

Division of Endovascular Medicine and Surgery, Riverside Methodist Hospital, Columbus, Ohio, USA

ABSTRACT

Purpose: This study analyzed cost, reimbursement, application, and outcome differences between endovascular (ER) and open repair (OR) of abdominal aortic aneurysms (AAA) in a community hospital.

Method: A total of 187 consecutive elective AAA repairs by both methods (69 ER, 118 OR) performed at a single center between July 2001 and March 2003 were analyzed. Average values in postoperative clinical and fiscal demographics were calculated for this period.

Results: The average length of stay was higher for OR than ER (9.38 days versus 1.94 days, $P < .001$). Significant reductions in operative time (4 hours versus 2.67 hours) and intensive care unit use (100% versus 4.05%) were seen in the ER population. Total hospital costs were slightly higher for OR than ER ($21,989 versus $19,668) despite a considerable difference in cost of the grafts (>$11,000 for ER versus <$500 for OR). However, hospital charges were much lower for ER than OR ($32,660 versus $48,877), and there was an average loss of $4986 on ER cases versus a profit of $2064 on OR procedures. Thirty-day mortality was not significantly improved in the ER population (1.45% versus 2.54%, $P = .05$).

Conclusions: Our data suggest that ER offers improvements in hospital convalescence and operating room times but no improvements in fiscal impact or overall morbidity/mortality rates when similar preoperative medical risks exist.

INTRODUCTION

Resource utilization improvement, in the form of decreased inpatient and intensive care unit (ICU) stay, resulting from endovascular repair (ER) rather than traditional open repair (OR) of abdominal aortic aneurysms (AAA) has been demonstrated in numerous studies [Blum 1997, Mialhe 1997, Zarins 1999, Clair 2003]. These reports have documented the safety and efficacy of endovascular aneurysm repair using US Food and Drug Administration-approved, currently available, commercially produced grafts. Minimizing the therapeutic footprint via significant reductions in blood use, ICU care, and hospital stay improve patient recovery time and offer the potential opportunity to realize significant reduction in the cost of AAA repair.

Several studies have documented the significant economic burden associated with the traditional OR of AAAs [Johnston 1989, Gold 1996]. More recently, Holzenbein et al [1997] suggested that potential cost savings may be realized through the use of endovascular techniques to repair AAA. The present study was undertaken to evaluate the clinical and financial impact of endovascular devices on health care costs, clinical outcomes, and discharge disposition at a community hospital.

METHODS

Sixty-nine patients were identified from a registry of patients undergoing surgical ER of AAA at Riverside Methodist Hospital. Riverside Methodist Hospital is a large community hospital with a 25-member, multidisciplinary division dedicated to catheter-based approaches to vascular disease. Informed consent was obtained from each patient. All procedures were performed in a catheterization lab according to operating department sterility specifications. Cardiothoracic surgeons and interventional cardiologists were involved with all 69 cases. Industry-related proctors were present in all cases.

The endografts used were AneuRx (Medtronic, Santa Rosa, CA, USA), Ancure (Guidant, Menlo Park, CA, USA), and Zenith (Cook, Bloomington, IN, USA). Prophylactic antibiotics were administered at the time of induction of anesthesia. All patients underwent anticoagulation with 10,000 U heparin administered intravenously after the access artery was exposed. Monitoring of the anticoagulation status was not used, and full reversal with protamine was administered immediately following femoral artery repair. Access was restricted to the femoral arteries in all 69 patients. Fluoroscopic monitoring was used in the delivery and deployment

Presented at the 10th Annual CTT Meeting 2004, Miami Beach, Florida, USA, March 10-13, 2004.

Address correspondence and reprint requests to: Daniel R. Watson, MD, Medical Director, Division of Endovascular Medicine and Surgery, Riverside Methodist Hospital, Columbus, Ohio 43214, USA (e-mail: drwatson@columbus.rr.com).

of all endografts. On-table completion angiography was performed in all patients.

A total of 118 patients undergoing traditional surgical OR of an AAA between July 1, 2001, and March 31, 2003, were identified from a separate prospective vascular surgical registry comprising all vascular procedures performed at Riverside Methodist Hospital. The vascular surgical department consisted of 6 cardiothoracic and vascular surgeons performing procedures at the main facility. All patients in this study were treated by these physicians. Patients undergoing emergent repair for ruptured aneurysms or repair of aneurysms involving visceral branch vessels were excluded from this cost evaluation.

Nearly all (99.1%) of the operative AAA procedures were performed with general endotracheal anesthesia and the conventional OR technique, usually together with epidural analgesia for postoperative pain management. Although a midline transperitoneal incision was used preferentially, a retroperitoneal approach through the left flank was used whenever the surgeon deemed it to be more appropriate because of a "hostile" abdomen secondary to multiple previous celiotomies, functioning colostomy, truncal obesity, serious chronic obstructive pulmonary disease, or the possibility that suprarenal cross-clamping might be necessary for construction of a juxtarenal aortic graft. (Our database does not contain specific information regarding the choice of incisions or clamp placement.) Collagen-impregnated Hemashield knitted Dacron grafts (Meadox Medical; Boston Scientific, Maple Grove, MN, USA) were implanted in all cases. Straight grafts were feasible in 55 patients (46.6%), but aortobiiliac (n = 60), aortobifemoral (n = 2), or aortoiliac/femoral (n = 1) bifurcation grafts were used in 63 cases (53.4%).

Comparative demographic data were assembled from these 2 registries and included in the study if a case-respective comprehensive financial profile was available. Additionally, evaluations of operative time (total case time), shed blood loss, ICU time, hospital length of stay, and morbidity and mortality rates were compiled from registry and hospital records. When appropriate these data were compared with 2 statistics or the Student *t* test to assess differences between the 2 groups.

A pulmonary complication was defined as a need for intubation/reintubation or pulmonary embolus proven by ventilation-perfusion scan or pulmonary angiogram. Cerebrovascular accident persisting >72 hours was considered a neurologic deficit. Renal complications were deemed present when there was an elevation of the serum creatinine level greater than 2 mg/dL or >50% over abnormal baseline during the postoperative period.

Data regarding direct and indirect costs for care of patients and mean expected revenue were compiled using the accounting department database of Riverside Methodist Hospital. This system accrues cost data on all patients admitted and maintains data on those costs for each hospital admission. To assess costs related to different working areas in the hospital, costs were calculated in 9 different cost centers: anesthesia, emergency department, laboratory medicine, ICU, operating room materials (operating-room technical), regular nursing floor materials, catheters and other miscellaneous materials (catheters/other), pharmacy, and radiology. Costs were calculated overall and in the different cost centers on a per case basis and then averaged to obtain an average cost per case associated with each of the 2 types of repairs. The Student *t* test was used to compare the costs for the 2 different types of repairs. Costs calculated included only in-hospital costs. This study did not include out-of-hospital costs related to the different types of aneurysm repair. Additionally, physician charges and rehabilitation facility costs were not evaluated.

RESULTS

There were 184 patients who underwent nonemergent repair of infrarenal AAA, had a completed clinical and financial profile, and had documented 30-day follow-up during the 33-month study period. Of these patients, 118 underwent OR and 69 patients underwent ER. Patients in the ER group were older than those in the OR group (Table 1) and had a statistically significant higher incidence of diabetes and peripheral vascular disease. All other demographic variables were similar in the 2 groups. Operative times, use of ICU, and shed blood loss were all markedly decreased in the ER group (Table 2).

The incidence of myocardial infarction (diagnosed by enzymes) was similar in both groups. Renal complications occurred with a frequency that was not statistically different. Dysrhythmia, wound infection, and pulmonary complications

Table I. Demographic Data

	Stent Grafting/Open (n = 69/118)	*P*
Mean age, y	72.3/70.4	NS
Age range	47-91/42-89	NS
Male	89.8%/83.8%	NS
Smoking, present	21.7%/21.2%	NS
Smoking, former	33.3%/38.1%	NS
Chronic obstructive pulmonary disease	31.8%/32.2%	NS
Hypertension	69.6%/68.6%	NS
History of myocardial infarction	31.8%/27.1%	NS
Cerebrovascular accident	7.2%/11%	NS
Diabetes mellitus, oral medication	14.4%/5.08%	< .04
Diabetes mellitus, insulin	2.9%/2.54%	NS
Congestive heart failure	11.6%/7.62%	NS
Renal insufficiency	10.1%/5.08%	NS
Hyperlipidemia	43.5%/40.6%	NS
Peripheral vascular disease	30.4%/16.9%	< .008
Coronary artery disease	50.7%/50%	NS
Alcohol use	4.8%/7.62%	NS
American Society of Anesthesiologists risk category		
I-II	4.8%/5.08%	NS
III	74.9%/74.6%	NS
IV	20.3%/20.3%	NS
Aneurysm size, mean	5.3 cm/6.3 cm	NS
Range of size, cm	4.9-7.5/4.6-9.7	NS

Table 2. Shed Blood Loss, Anesthesia, Procedure Time, Intensive Care Unit Use

	Stent Grafting/Open	*P*
Shed blood loss, mean, mL	379/1930	<.001
Shed blood loss, range, mL	30-2200/50-10000	
Anesthesia, general/spinal	85.5/14.5 (59/10) 99.1/0.9 (117/1)	<.001
Procedure time, h	2.67/4.28	.005
Intensive care unit use	4.05%/100%	

were significantly increased in the OR group. Wound hematoma was significantly more common in ER patients. The endoleak rate for patients in the ER group was evaluated by computed tomographic (CT) scanning and found to be approximately 22% at 30 days (Table 3).

Considerable differences were found in discharge disposition, as outlined in Table 4. The ER group had significantly higher numbers of patients discharged to home. OR patients

Table 3. Complications

	Stent Grafting (n = 69)/ Open (n = 118)	*P*
Hematoma	5.80%/0.8%	.007
Pseudoaneurysm	0.0%/0	NS
Thrombosis	4.32%/1.6%	NS
Acute myocardial infarction	1.44%/4.23%	NS
Retroperitoneal bleed	1.44%/0.8%	NS
Dysrhythmia	2.88%/9.32%	<.005
Ileus	1.44%/16.9%	<.0001
Dissection	1.44%/0.0%	NS
Incisional hernia/dehiscence	0.0%/0.8%	NS
Infection	0.0%/9.3%	<.0007
Surgical wound	/1.44%	
Respiratory	/4.33%	
Urinary tract infection	/1.9%	
Other	/0.48%	
Cerebrovascular accident	1.44%/0.0%	NS
Endoleak TII	21.43%	
Endoleak TIII	0.79%	
Death	1.44%/2.54%	NS
Respiratory complications	2.88%/12.7%	<.0003
Renal complications	1.44%/5.08%	NS
Paralysis	0%/0%	NS
Paresthesia	2.88%/0.0%	NS
Perforation	1.44%/0.0%	NS
Sepsis	0%/0.8%	NS
Seroma (see below)	2.38%/0.0%	NS
Intent to treat/abandon	1.44%/0.0%	NS
Congestive heart failure	1.44%/3.4%	NS
Late conversion	2.88%/NA	NS
Convert to open repair	0.0%/NA	NS
Length of stay, d	1.94/9.38	

Table 4. Discharge Status

	Stent Grafting (n = 69)/Open (n = 118)	*P*
Home	84.06%/50.8%	<.0001
Home health	7.25%/18.6%	.0025
Skilled/extended care	7.25%/28%	.0007
Died	1.44%/2.54%	NS
30-Day follow-up	100%/100%	

required significantly more utilization of home-health nursing and rehabilitation center facilities at the time of discharge, 18.6% versus 7.25% and 28% versus 7.25%, respectively. The mortality rates for the 2 groups were similar.

Summation of cost center data was completed for each group and is presented in Table 5. Aggregate amounts from each of the separate cost centers are shown for the 2 groups, resulting in total direct, indirect, and overall costs. Costs for the ER group exceeded those for the OR group in only 2 cost centers of the 9 into which items were broken down (cath/other, operating-room technical). The largest difference between the groups was noted in the operating-room technical costs. These costs reflected the cost of implantable items as well as those materials needed for placement of the device. The cost difference in this cost center was driven by the difference in the costs of the prostheses, approximately $11,000 in the ER group and less than $500 in the OR group in our study. This difference drove the direct cost of ER to be greater than that of OR and resulted in a greater than 50% of the total cost of that procedure.

DISCUSSION

Endovascular repair represents a dramatic technical advance in the management of infrarenal AAAs and already provides a relatively safe alternative to traditional open operations in truly high-risk surgical candidates. Namely, ER offers significant reductions in hospitalization and recovery times. However, patients undergoing this procedure often require significant additional imaging beforehand and more significant imaging afterward. The current study was limited to an analysis of inpatient hospital costs only; expenses incurred after discharge were not included or studied. Although OR requires little ancillary follow-up, close CT evaluation is required for ER. At present, a minimum of 3 postoperative CT scans are performed within the first year, the first within the first month and then at 6 and 12 months after repair. Endoleaks that do not spontaneously resolve generally require expensive interventional treatment. Thus, the follow-up for ER for AAA is certainly more expensive than OR, further widening the global economic cost between them. Conversely, OR requires greater costs for structured rehabilitation programs following discharge.

Although these costs represent an addition to the overall costs of this type of repair, this study shows that ER incurs greater health care institution costs during hospitalization for repair. Supplementary costs related to preoperative and postoperative evaluation and endograft maintenance will fur-

Table 5. Hospital-Based Financial Outcomes, July 1, 2001-March 31, 2003

	Projected Revenue	Direct Cost	Total Cost	Contribution Margin	Profit or (Loss)
Surgery (n=118)	$21,732	$11,220	$19,668	$10,512	$2064
Stent graft (n = 69)	$17,002	$13,002	$21,989	$3999	($4987)

*Values are means.

ther increase the cost difference between these 2 types of repair and may ablate any fiscal benefits relative to accelerated functional recovery, especially in the eyes of third-party payers.

Our report presents a comparison of concurrent groups of patients who underwent 2 different methods of AAA repair. These were consecutive patients undergoing placement by the same set of operators of a variety of stent-graft systems at a single institution, approximately 2 years after the initiation of an ER program. This scenario theoretically eliminated any confounding effects from multiple operators or interval learning of new skill sets as a learning curve was negotiated.

The 2 groups created from the patient population were well matched in all aspects, although the ER group had relatively more significant comorbidities than the OR group, including advanced age, diabetes, and peripheral vascular disease. Perhaps a reason for the greater number of comorbidities in the endograft group was an implicit bias to direct ER therapy to the relatively sicker or older patient, leaving healthier or younger patients to choose between conventional or endovascular repair. Because of the advanced age and more comorbidities in the ER group, higher pharmacy, laboratory, and floor nursing care costs might be expected. However, patients in the ER group had lower costs in all these areas. In spite of reduced costs in these areas, the overall direct cost of patient care was significantly higher than in the OR group.

Aneurysm morphology, which can present particular challenges to the operator and requires optimum preoperative imaging, was similar in both groups. Although gross assessments of proximal neck angulation and iliac tortuosity can be made from axial images alone, volumetric rendering of axial CT data creates a virtual aortoiliac luminal cast that can be rotated in space and visualized from all angles to give the operator a better perspective of the aneurysm morphology than conventional angiograms.

Evaluation of the cost difference between the 2 groups revealed a significantly lower direct cost difference for those patients in the OR group ($1800). These costs do not account for reduction in hospitalization time or potential savings in indirect costs that may be generated by the ER group. Indirect cost difference between the 2 groups should take some account of this. Indirect cost remains a difficult quantity to calculate without complex formulas relating cost of care to fixed institutional costs. Additionally, patients may use the items contained in these costs to varying degrees. When one calculates the difference in total cost (direct and indirect) between the 2 groups, the difference is approximately $2300. Given the cost of implantable items ($10,000) for the ER group, one can see that bringing the total costs of the groups to parity will require the cost of the graft to be limited to approximately $7000. Although this figure would better equate the costs of the 2 procedures, this preliminary finding clearly needs to be studied further, and additional costs (eg, outpatient and rehabilitative costs) for the 2 types of repair also need to be assessed as part of a more definitive analysis.

Numerous authors have evaluated hospital costs as related to AAA repair [Breckwoldt 1991, Benzaquen 1998] These authors have calculated overall costs with a formula that derived cost associated with indirect cost of care for these patients. Although investigators effectively evaluate costs associated with AAA repair in these studies, they do not evaluate direct costs of care. Moreover, the model does not allow an evaluation of how changing trends in patient care can modify the cost of treating a medical problem.

Holzenbein et al [1997] reported on a study of cost comparison between endovascular and open surgical repair of AAAs. With 22 patients in each group, these authors sought to determine if it was economically sensible to pursue ER of AAAs. In their study, the authors found that the cost of ER was substantially less than that of standard surgical repair. In the calculation of costs for the hospital stay of these patients, however, a calculated cost of hospitalization was computed for time spent in the ICU and on the hospital ward. These calculations were based on relatively arbitrary assumptions of the standard costs of patient care resource use. This methodology ignores those costs that are related to the particular intervention under question. For instance, the cost of the endovascular prosthesis is not included. When such costs are included in the analysis, as it was done in the present study, the economic impact of endovascular aortic repair is quite different. More recently, Clair and coworkers [Clair 2003] studied 139 AAA patients and found a direct cost difference of $7000 when the endograft expense was included in the analysis.

Although a feasible and promising alternative, endovascular stenting of AAAs imposes a significant economic burden on health care institutions without a commensurate improvement in morbidity and mortality. Further reductions in length of stay, improvement in operating time, and refinement of the use of diagnostic tests with endovascular repair may produce greater cost savings than are reflected in the current data. However, as long as the disparity in the cost of the respective AAA grafts remains excessively high, with concomitant similar clinical outcomes, the financial feasibility of endovascular techniques is questionable. The resulting contradiction is unfortunate, wherein a procedure of potentially great benefit to many patients may potentially be denied on the basis of a prohibitive fiscal impact on providers.

REFERENCES

Benzaquen BS, Eisenberg MJCR, Nguyen T, Brown KJ, Topol EJ. 1996. Correlates of in-hospital cost among patients undergoing abdominal aortic aneurysm repair. Am Heart J 136:696-702.

Blum U, Voshage G, Lammer J, et al. 1997. Endoluminal stent-grafts for infrarenal abdominal aortic aneurysms. N Engl J Med 336:13-20.

Breckwoldt WL, Mackey WC, O'Donnell TFJ. 1991. The economic implications of high-risk abdominal aortic aneurysms. J Vasc Surg 13:798-804.

Clair DG, Gray B, O'Hara, et al. 2000. An evaluation of the costs to health care institutions of endovascular aortic repair. J Vasc Surg 32: 148-52.

Gold MR, Siegel JS, Russell LB, Weinstein MC, the Panel on Cost-Effectiveness in Health and Medicine. 1996. Cost-effectiveness in health and medicine. New York: Oxford University Press.

Holzenbein J, Kretschmer G, Glanzl R, et al. 1997. Endovascular AAA treatment: expensive prestige or economic alternative? Eur J Vasc Endovasc Surg 14:265-72.

Johnston KW. 1989. Multicenter prospective study of nonruptured abdominal aortic aneurysm; part II: variables predicting morbidity and mortality. J Vasc Surg 9:437-47.

Mialhe C, Amicabile C, Becquemin JP. 1997. Endovascular treatment of infrarenal abdominal aneurysms by the Stentor system: preliminary results of 79 cases. J Vasc Surg 26:199-209.

Zarins CK, White RA, Schwarten D, et al. 1999. AneuRx stent graft versus open surgical repair of abdominal aortic aneurysms: multicenter prospective clinical trial. J Vasc Surg 29:292-308.