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Cost-effectiveness of abdominal aortic aneurysm repair: A systematic review

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Objectives: A systematic review of the cost-effectiveness of abdominal aortic aneurysm (AAA) repair was conducted. Although open surgery has been considered the gold standard for prevention of AAA rupture, emerging less-invasive endovascular treatments have led to increased interest in evaluating the cost and cost-effectiveness of treatment options.
Methods: A systematic review of studies published in MEDLINE between 1999 and 2005 reporting the cost and/or cost-effectiveness of endovascular and/or open surgical repair of nonruptured AAAs was conducted. Case series studies with less than fifty patients per treatment were excluded.
Results: Of twenty eligible articles, three were randomized controlled trials, twelve case series, four Markov models, and one systematic review. Regardless of time frame, all studies found that endovascular repair costs more than open surgery. Although the high cost of the endovascular prosthesis was partially offset by reduced intensive care, hospital length of stay, operating time, blood transfusions, and perioperative complications, hospital costs were still greater for endovascular than open surgical repair. For patients medically fit for open surgery, mid-term costs were greater for endovascular repair with no difference in overall survival or quality of life. For patients medically unfit for open surgery, endovascular repair costs more than no intervention with no difference in survival.
Conclusions: Although conclusions regarding the cost-effectiveness of AAA treatment options are time dependent and vary by institutional perspective, from a societal

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perspective, endovascular repair is not currently cost-effective for patients with large AAA regardless of medical fitness.

Keywords: Aortic aneurysm, Abdominal, Cost-effectiveness, Systematic review, Blood vessel prosthesis, Surgical procedures, Operative

Ruptured abdominal aortic aneurysm (AAA) is the thirteenth leading cause of death in the United States and tenth among older men (20;21), accounting for approximately 9,000 deaths annually (16). Some 30,000–40,000 patients undergo elective repair of the asymptomatic AAA to prevent rupture, with perioperative mortality ranging from 2–8 percent (19;25).

Most AAAs remain asymptomatic for years, although the risk of rupture and death increases with AAA diameter. Management options include no treatment, active surveillance and delayed repair, immediate open surgical repair, and endovascular repair. Management is based on AAA diameter defined for entry criteria into randomized trials as small (AAA <5.5 cm in diameter) and large (AAA ≥5.5 cm), as well as patient's life expectancy and operative risk. Recommendations for AAA screening in high-risk populations along with emerging less-invasive treatments have led to increased interest in evaluating the cost and cost-effectiveness of treatment options for unruptured AAA.

Although open surgery has been considered the gold standard for prevention of AAA rupture, an estimated 20–50 percent of AAA could be amenable to endovascular repair based on AAA size, morphology, and patient risk characteristics (7;11;34). Open surgery has the mortality risk of major vascular surgery with perioperative complications, including myocardial and spinal cord ischemia, respiratory and renal failure, ischemic colitis, and prosthetic graft infection (27). Nevertheless, because the risk of rupture may be less than the risk of intervention, early repair may not always be indicated. Equally effective management options in preventing rupture and prolonging survival with lower morbidity and similar or reduced healthcare costs have been sought. As part of a larger evidence report for the Agency for Healthcare Research and Quality, this study assesses the cost and benefits for elective treatment options for unruptured AAA and focuses on the relative costs and cost-effectiveness of open surgery and endovascular repair (36).

MATERIALS AND METHODS

Literature Search

MEDLINE was searched for articles published between 1999 and 2005. Search terms included abdominal aortic aneurysm combined with economics, nursing economics, pharmaceutical economics, cost, pharmacoeconomics, cost analysis, cost allocation, cost-benefit analysis, cost control, cost savings, cost of illness, cost sharing, deductibles and coinsurance, medical savings accounts, healthcare costs, direct service costs, drug costs, employer health costs, hospital costs, health expenditures, capital expenditures, hospital economics, hospital charges, hospital costs, medical economics, and medical fees.

Selection Criteria

Studies were eligible if they reported on the cost and/or cost-effectiveness of endovascular and/or open surgery for elective repair of nonruptured AAA. Case series studies with less than fifty patients per treatment were excluded. Study type, intervention(s), main cost results, and measures of effectiveness data were extracted by a trained abstractor and reviewed with study authors.

Statistical Analysis

Due to heterogeneity in study design, interventions, outcomes and the type of costs (direct and indirect) reported, explicit inclusion of cost categories, and the use of charges versus costs, pooled data synthesis was not performed. Cost estimates from randomized controlled trials and case series are presented followed by the results of the Markov models used to estimate the cost-effectiveness of open surgery versus active surveillance for small AAA and endovascular versus open surgery or endovascular versus no intervention for large AAA.

RESULTS

Of the twenty included articles, four were Markov models (5;28;29;32), three were randomized controlled trials (2;14;15), twelve were case series studies (1;4;6;8;10;13;18;20;23;24;30;33), and one was a systematic review (26) (Table 1). Twelve of the articles reported on a comparative analysis of endovascular and open surgical repair (1;5;6;10;13;14;18;23;26;28;29;33). Two reported on endovascular repair compared with no intervention (one of which also reported on endovascular and open surgery) (15;28), three on endovascular repair only (4;24;30), two on open surgery versus active surveillance with selective open surgery (2;32), and two on open surgery only (8;20).

Of the fifteen studies reporting cost data, four reported direct variable costs only; (1;2;10;33) nine included both direct and indirect costs (4;6;8;13;18;20;23;24;30) and the remaining two did not explicitly state whether indirect costs were included (14;15). Four studies used a timeframe of at least 1 year (14;15;18;28).

Summarizing costs for these two procedures is complicated, because these studies used different cost reporting strategies (Table 2). AAA repair costs should include

Table 1. Overview of Studies

Procedures	Author (reference)	Study type	Publication year	Cohort year	Country	Sample size (n)	Timeframe	Main cost results
EVAR, OSR	Bosch (5)	Markov model	2002	NA	USA	NA	Lifetime	$EVAR > $OSR
	Patel (29)	Markov model	1999	NA	USA	NA	Lifetime	$EVAR > $OSR
	Michaels (28)	Markov model	2005	NA	UK	NA	10 years	$EVAR > $OSR
	EVAR-1 (14)	RCT	2005	1999	UK	543, 539	4 years	$EVAR > $OSR
	Angle (1)	Retrospective	2004	2000–01	USA	55, 64	Initial hospitalization	$EVAR > $OSR
	Bosch (6)	Retrospective	2001	1997–99	USA	181, 273	Initial hospitalization	$EVAR > $OSR
	Clair (10)	Retrospective	2000	1998	USA	45, 94	Initial hospitalization	$EVAR > $OSR
	Dryjski (13)	Retrospective	2003	2000	USA	73, 57	Initial hospitalization	$EVAR > $OSR
	Hayter (18)	Retrospective	2005	1995–2004	Australia	55, 140	Hospital + 1-year follow-up	$EVAR > $OSR
	Lee (23)	Retrospective	2004	2001	USA	2565, 4607	Initial hospitalization	$EVAR > $OSR
	Sternbergh (33)	Retrospective	2000	1996–97	USA	131, 49	Initial hospitalization	$EVAR > $OSR
	Maher (26)	Systematic review	2003	NA	NA	NA	NA	$EVAR > $OSR
EVAR, NT	Michaels (28)	Markov model	2005	NA	UK	NA	10 years	$EVAR > $AS
	EVAR-2 (15)	RCT	2005	1999	UK	166, 172	4 years	$EVAR > $AS
EVAR only	Prinssen (30)	Retrospective	2004	1994–2000	Netherlands	77	Follow-up surveillance	$EVAR only
	Bertges (4)	Retrospective	2003	2000–01	USA	221	Initial hospitalization	$EVAR only
	Lester (24)	Retrospective	2001	1994–99	USA	91	Initial hospitalization	$EVAR only
OSR, AS	UK SAT (2)	RCT	1998	1991–95	UK	563, 527	18 months postrandomization	$OSR > $AS
	Schermerhorn (32)	Markov model	2000	NA	UK	NA	lifetime	$OSR > $AS
OSR only	Brox (8)	Retrospective	2003	1997–2000	USA/Canada	297/176	Initial hospitalization	$OSR only
	Huber (20)	Retrospective	2001	1994–96	USA	16450	Initial hospitalization	$OSR only

Note. EVAR, endovascular repair; OSR, open surgical repair; NT, no treatment; AS, active surveillance; RCT, randomized controlled trial; NA, not applicable; UK SAT, United Kingdom Small Aneurysm Trial; $EVAR and $OSR, costs associated with EVAR and OSR, respectively.

Table 2. Cost Analyses Findings

Study (reference)	EVAR-1 (14)		Angle (1)		Bosch (6)		Clair (10)		Dryjski (13)		Hayter (18)		Lee (23)	
Type of cost data (source)	Hospital costs (UK NHS)		Hospital costs (unspecified)		Hospital costs (TSI)		Hospital costs (TSI)		Hospital costs (unspecified)		Hospital costs (Medicare rates)		Hospital charges (National Inpatient)	
Type of study	RCT		Retrospective		Retrospective		Retrospective		Retrospective		Retrospective		Retrospective	
Direct and/or indirect costs	Unclear		Direct only		Direct & indirect		Direct only		Direct & indirect		Direct & indirect		Direct & indirect	
Currency	UK pound		US dollar		US dollar, 1999		US dollar		US dollar		US dollar, 2003/04		US dollar, 2001	
Cohort	1999–2003, UK		2000–01		1997–99		1998		2000		1995–2004		2001	
	EVAR	OSR	EVAR	OSR	EVAR	OSR	EVAR	OSR	EVAR	OSR	EVAR	OSR	EVAR	OSR
Initial ER evaluation	N		N		?		Y		N		N		N	
Preop/preop diagnostics	N		N		?		N		N		Y		N	
Total preop	N		N		?		N		N		$733	$663	N	
Prosthetic device	Y		Y		$7,000	$600	$8,976	$597	$12,974	$750	$7,765	$363	$10,000 –$12,000	?
% Costs due to prosthesis	?		58%	6%	34%	3%	?		78%	8%	49%	3%	?	
Operating room	Y		Y		Y		Y		Y		Y		?	
Surgeon fees	?		?		N		N		N		Y		?	
Nursing	?		Y		Y		Y		Y		Y		?	
Anesthesia	?		?		Y		Y		N		Y		?	
Medical/surgical supplies	?		Y		Y		Y		?		Y		?	
Respiratory/ventilation	?		Y		?		?		N		Y		?	
Pharmacy	?		Y		?		Y		N		Y		?	
Radiology	?		Y		Y		Y		N		Y		?	
Blood/transfusion	Y		?		?		Y		?		?		?	
Laboratory	?		Y		?		Y		N		?		?	
Postop ICU	Y		Y		Y		Y		Y		Y		?	
Postop ward	Y		Y		Y		?		Y		Y		?	
Post diagnostic	?		N		?		?		?		Y		?	
Patient cost-time, morbidity	N		N		N		N		N		N		N	
"Other"	Y		?		?		Y		?		?		N	
Total hospitalization	£10,819	£9,204	EVAR = 1.7∗OSR		$20,716	$18, 484	EVAR = OSR + $7205		$16,731	$9,042	$15,898	$13,400	$50,346	$47,009
Total preop + hosp.	N		N		N		N		N		$16,631	$14,063	N	
Radiology follow-up	Y		N		N		N		N		Y		N	
Endoleak repair	Y		N		N		N		N		Y		N	
Conversion to OSR	Y		N		N		N		N		None needed		N	
"Adverse events"	Y		N		N		N		N		Y		N	
Patient cost-time, morbidity	Y		N		N		N		N		Y		N	
Total follow-up	£2,439	£741	N		N		N		N		$2,013	$59	N	
Grand total	£13,258 at 4 years	£9,945 at 4 years	N		N		N		N		$18,644 at 2 years	$14,122 at 2 years	N	

Y and N, explicitly included/not included cost; ?, cost not mentioned or inclusion/exclusion uncertain; EVAR, endovascular repair; OSR, open surgical repair; AS; active surveillance; TSI, Transition System, Inc., hospital accounting system; UK NHS, United Kingdom National Health Service; RCT, randomized controlled trial; UK SAT, United Kingdom Small Aneurysm Trial; ICU, intensive care unit.

Table 2. Cost Analyses Findings (cont.)

Study (reference)	Sternbergh (33)		EVAR-2 (15)		Prinssen (30)	Bertges (4)	Lester (24)	Brox (8)		UK SAT (2)		Huber (20)
Type of cost data (source)	Hospital costs (unspecified)		hospital costs (UK NHS)		Hospital costs	Hospital costs	Hospital costs (TSI)	Hospital costs (TSI)		Hospital cost (UK NHS)		Hospital charges
Type of study	Retrospective		RCT		Retrospective	Retrospective	Retrospective	Retrospective		RCT		Retrospective
Direct and/or indirect costs	Direct only		Unclear		Direct & indirect	Direct & indirect	Direct & indirect	Direct & indirect		Direct only		Direct & indirect
Currency	US dollars		UK pound		US dollar	US dollar	US dollar	US dollar, 2000		UK pound		US dollar 1996
Cohort	1996–97		1999–2003, UK		1994–2000	2000–01	1994–99	1997–2000		Unknown		1994–96
	EVAR	OSR	EVAR	AS	EVAR	EVAR	EVAR	OSR-USA	OSR-Canada	AS	OSR	OSR
Initial ER evaluation	?		N		N	?	Y	?		?		N
Preop/preop diagnostics	Y		N		N	?	?	?		?		N
Total preoperative	$1,100	$644	N		N	?	?	?		?		N
Prosthetic device	$10,200	$653	Y		N	$13,191	N	Y		?		?
% Costs due to prosthesis	51%	6%	?		?	57%	?	?		?		?
Operating room	Y		Y		N	Y	Y	Y		?		?
Surgeon fees	N		?		N	N	N	N		?		?
Nursing	?		?		N	Y	Y	Y		?		?
Anesthesia	Y		?		N	Y	Y	Y		?		?
Medical/surgical supplies	Y		?		N	Y	Y	Y		?		?
Respiratory/ventilation	?		?		N	Y	?	Y		?		?
Pharmacy	Y		?		N	Y	Y	Y		?		?
Radiology	?		?		N	Y	Y	Y		Y		?
Blood/transfusion	Y		Y		N	Y	Y	Y		?		?
Laboratory	?		?		N	Y	Y	Y		?		?
Postoperative ICU	Y		Y		N	Y	Y	Y		?		?
Postoperative ward	Y		Y		N	Y	Y	Y		Y		?
Post diagnostic	Y		?		N	Y	Y	Y		?		?
Patient costs-time, morbidity	N		N		N	N	N	N		N		N
"Other"	?		Y		N	?	Y	?		Y		?
Total hospitalization	$20,150	$11,698	£11,016	£3,518	?	$23,042	Y	$19,000	$16,000	£3,914	£4,978	$35,681
Subtotal	$21,250	$12,342	N		N	N	$11,842	?		?		N
Radiology follow-up	N		Y		Y	N	N	?		?		N
Endoleak repair	N		Y		Y	N	N	?		?		N
Conversion to OSR	N		Y		Y	N	N	?		?		N
"Adverse events"	N		Y		?	N	N	?		?		N
Patient costs-time, morbidity	N		Y		N	N	N	?		?		N
Total follow-up	?		£2,616	£1,465	$9,729 - 5 year	N	N	?		?		N
Grand total	?		£13,632 at 4 years	£4,983 at 4 years	?	N	N	?		?		N

Y and N, explicitly included/not included cost; ?, cost not mentioned or inclusion/exclusion uncertain; EVAR, endovascular repair; OSR, open surgical repair; AS; active surveillance; TSI, Transition System, Inc., hospital accounting system; UK NHS, United Kingdom National Health Service; RCT, randomized controlled trial; UK SAT, United Kingdom Small Aneurysm Trial; ICU, intensive care unit.

preoperative costs, surgical team and hospitalization costs associated with the initial procedure, the costs of the endovascular repair prosthesis and subsequent postoperative surveillance, interventions, hospitalizations, and drug treatment. However, the majority of the studies did not include pre- or postoperative costs (beyond 30 days of the initial hospitalization) and did not include surgeon fees within the cost of the initial hospitalization.

Small AAAs <5.5 cm

In a randomized controlled trial conducted in the United Kingdom, the mean cost of treatment for patients in the early immediate open surgery group was significantly higher than that for ultrasonographic surveillance with delayed open surgery (£4,978 and £3,924, respectively) (2). No reduction in all-cause mortality was realized (2;22). Outcomes did not differ significantly by treatment according to age, gender, or aneurysm diameter, although few women were enrolled.

Despite these published findings, another study used a Markov model based on the UK trial data and concluded that early open surgery was modestly cost-effective for patients with small AAAs ($10,800/quality-adjusted life-year [QALY]), particularly among younger patients (<72 years of age) (32). However, because the UK trial found that active surveillance with delayed open surgery resulted in approximately one-third fewer surgical repairs as well as similar survival and quality of life and fewer complications at lower cost compared with early open surgery, it is difficult to conclude that early open surgery may be cost-effective.

Large AAAs ≥5.5 cm

Although the studies had no uniform size criteria, most patients included in studies evaluating endovascular and open surgical repair (and all but one of the Markov model reports) involved large AAAs ≥ 5.5 cm in diameter. Hospitalization costs for the initial endovascular procedure ranged from $16,000 to $23,000 (4;22), whereas open surgical repair costs ranged from $9,000 to $18,500 (4;13). Studies explicitly excluding several care categories from the cost analyses led to relatively low hospitalization cost estimates (e.g., anesthesia, respiratory care, pharmacy, radiology, and laboratory tests (13)), whereas those including a very comprehensive list of categories report higher hospitalization costs. The two British endovascular randomized trials report relatively high hospitalization costs of £10,819 (14) and £11,016 (15) for endovascular repair and £9,204 for open surgical repair. As hospital charges are generally higher than costs, studies relying on hospital charges reported more expensive hospitalizations than those relying on costs (20;23).

Cost estimates for the endovascular prosthesis range from $7,000 reported for a 1997–99 patient cohort to $13,000 reported for a patient cohort from 2000 (6;13). The prosthesis accounts for 34 percent and 78 percent of the total hospitalization costs reported in these two studies, respectively, with the differences in percentages largely a reflection of how comprehensively the authors itemized costs. Bosch et al. (6) relied on prosthesis costs near the time of commercialization and estimated a low price for the prosthesis relative to the cost of the hospitalization. Thus, total hospitalization costs for endovascular repair, the difference in the cost of endovascular repair relative to open surgery, and the percentage of total hospitalization costs attributable to the prosthesis were underestimated. In contrast, Dryjski et al. (13) excluded several categories of necessary hospital services from the cost estimate and underestimated the cost of the hospitalization relative to the prosthesis.

None of the studies reported on the cost of the training required by surgeons to perform endovascular repair or to acquire new equipment. This training can include attending 1- to 3-month training courses at a cost of $30,000 and purchasing portable fluoroscopy units that cost approximately $250,000 (9).

Although the initial hospitalization for endovascular repair results in shorter length of stay (LOS) (14) and less intensive care unit (ICU) use (10;13) than open surgery (1;33) (Table 3), all of the studies found that the cost of the initial hospitalization was higher for endovascular repair, primarily due to the high cost of the prosthesis.

Two randomized controlled trials provide evidence that there is no difference in overall survival between endovascular repair and open surgery 2 years following the initial hospitalization. Although differences in health-related quality of life favored endovascular repair, they were small and disappeared after 3 months. Nevertheless, postoperative complications, including endovascular prosthesis-related ruptures, infections, endoleaks, thrombosis, or other surgery requiring re-exploration of open surgery, were five times more common with endovascular repair as with open surgery (14). Reinterventions occurred three times as often in the endovascular repair group. As a result, endovascular repair costs were higher than open surgical costs at 4 years (£13,258 versus £9,945) (14). A retrospective review from Australia also reported greater costs at 2 years of follow-up for patients treated with endovascular repair ($18,644) than open surgery ($14,122) (18).

Only one randomized controlled trial evaluated costs and outcomes of endovascular repair versus no intervention for patients with large AAAs who were judged medically unfit for open surgery (15). Endovascular repair resulted in a 30-day mortality of 9 percent, did not improve all-cause or AAA survival compared with no intervention at 4 years, did not improve health-related quality of life, was associated with a need for continued surveillance and reinterventions, and resulted in higher costs. Endovascular repair substantially increased the cost of the primary hospital admission (£11,016 versus £3,518) and at 4 years (£13,632 versus £4,983).

Table 3. Studies Reporting Hospital and ICU Length of Stay

Author (reference)	Treatment arm	Total *N*	Hospital LOS Mean days	Hospital LOS Range or SD	ICU LOS Mean days	ICU LOS Range or SD
EVAR-1 (14)	EVAR	543	10.3	17.8 SD	.7	3.8 SD
	OSR	539	15.7	16.9 SD	2.4	5.9 SD
Angle (1)	EVAR	55	1.96 (median = 1)	1.5 SD	.09	.29 SD
	OSR	64	7.3 (median = 6)	8.3 SD	3.5	7.36 SD
Bosch (6)	EVAR	181	NR	NR	1.2[a] (median = 1)	.4 SD; 1 to 2
	OSR	273	NR	NR	2.3[a] (median = 1)	2.1 SD; 1 to 12
Clair (10)	EVAR	45	3.2	1.4 SD	.06	.25 SD
	OSR	94	9.7	4.8 SD	2.97	3.02 SD
Dryjski (13)	EVAR	73	4.9	13.4 SD	1.4	7.1 SD
	OSR	57	12.6	14.8 SD	5.0	6.1 SD
Hayter (18)	EVAR	55	6 (median)	4 to 24	0 (median)	0 to 3
	OSR	140	10 (median)	6 to 46	1 (median)	1 to 19
Lee (23)	EVAR	2,565	3.6 (median = 2)	5.9 SD	NR	NR
	OSR	4,607	8.8 (median = 7)	7.8 SD	NR	NR
Sternbergh (33)	EVAR	131	3.9	3.6 SD	1.1	2.0 SD
	OSR	49	8.0	5.8 SD	2.0	2.3 SD
Bertges (4)	EVAR	221	2.4	NR	NR	NR
Lester (24)	EVAR	91	3.5	2.3 SD	NR	NR
Huber (20)	OSR	16,450	10 (median = 8)	8.1 SD	NR	NR

[a] Includes only subjects staying 1 day or longer.
EVAR, endovascular repair; OSR, open surgical repair; AS, active surveillance; NR, not reported; LOS, length of stay; ICU, intensive care unit; SD, standard deviation.

The authors saw no reason to pursue cost-effectiveness modeling.

Markov Methodologies

Table 4 summarizes studies that used Markov methodologies to analyze differences in the cost and effectiveness of endovascular repair and open surgery over a patient's lifetime (5;28;29). All three found that endovascular repair was more expensive. As reported for the case series studies, the Markov studies were inconsistent in terms of enumerating what categories of care were considered in evaluating costs.

Two of the Markov studies comparing endovascular repair and open surgery were based on U.S. costs and outcomes and report a higher quality of life with endovascular repair (5;29). The incremental cost-effectiveness ratios were $9,905 per QALY and $22,826 per QALY. Using assumptions of effectiveness based on case series data, Patel et al. (29) concluded that the benefits were worth the cost with the qualification that their results were highly dependent on their assumptions regarding mortality and morbidity. They reported that endovascular repair may be more cost-effective than open surgery if endovascular repair operative mortality rates were less than 1.2 percent and the open surgery mortality rates were higher than 1.7 percent. Bosch et al. (5) also used case series data as the basis for their model; they reported the sensitivity of their conclusions to endovascular prosthesis performance in terms of long-term failure and rupture rates. Although both authors varied analytical assumptions and conducted sensitivity analyses, they did not vary their assumptions simultaneously by using probabilistic sensitivity analyses to fully test the robustness of their findings (12;17;35).

In a more recent and rigorous approach to Markov modeling, Michaels et al. (28) used probabilistic sensitivity analyses and used short-term, but not mid-term, outcome data from the UK trials. With an incremental cost-effectiveness ratio well above accepted norms (£110,000 per QALY), they concluded that endovascular repair was not a cost-effective alternative to open surgery (17;37). Regardless of the time frame, the cost-effectiveness of endovascular repair and open surgery was sensitive to assumptions regarding lower early morbidity for endovascular repair, higher open surgery operative mortality rate, increased need for follow-up care for endovascular repair, higher reintervention/complication rates for endovascular repair, and higher healthcare costs.

Michaels et al. (28) also reported that endovascular repair was cost-effective compared with no intervention in individuals with large AAAs who were judged unfit for open surgery. However, they did not use the previously described 4-year outcomes and cost results from the UK trial that directly compared endovascular repair with no intervention (15).

DISCUSSION

Conclusions about the cost-effectiveness of AAA repair are time dependent. Studies conducted within a relatively short timeframe fail to adequately address the long-term benefits, harm, or costs associated with endovascular repair. Because open surgery has more frequent and severe early morbidity than endovascular repair, it could result in a longer and

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Table 4. Markov Model Results

Study (reference)	Bosch (5)		Patel (29)		Michaels (28)		Schermerhorn (32)	
Source of costs	Hospital costs, Medicare reimbursement rates		Hospital costs, Medicare reimbursement rates		National Health Service (NHS), Sheffield Teaching Hospitals, NHS Trust		Hospital costs (UK NHS), UK Small Aneurysm Trial	
Direct and/or indirect costs	Direct & indirect		Direct & indirect		Unclear		Direct	
Currency	US dollar, 2000		US dollar, 1997		£UK, 2003–04		£UK ∗1.6 = $US, 1996–97	
Treatment arm	EVAR	OSR	EVAR	OSR	EVAR, OSR	EVAR, AS	OSR	AS
Reference case	70 years old		70 years old		70 years old		60–76 years old	
AAA diameter	5–6 cm		5 cm		5.5 cm		4–5.5 cm	
Risk group	Fit for either treatment		Fit for either treatment		Fit for either treatment		Fit for OSR	
Time horizon	Lifetime		Lifetime		10 years		6 years, lifetime	
Discount rate	3%		3%		3.50%		3%	
Inflation measure	CPI medical care		CPI medical care		?		?	
Baseline operative mortality rate	3%	4%	1.20%	4.80%	1–85%, 5–80%	range 5-80%	5.8% elective	
QOL scores	−10%for 30d	−30%60d	QALY–11d	QALY–47d	QALY–30d, QALY–14d ; base QOL = .8		Baseline QOL = .86	
QOL adjustment for complications	Y		Y		?		Y	
Software	DATA 3.5 (TreeAge)		SMLTREE v2.9		TreeAge Pro		DATA 3.0 (TreeAge)	
Probabilistic sensitivity analyses	No. One & multiple way		No. One & multiple way		Yes		No. One way	
Initial ER evaluation	N		N		?		N	
Preop/preop diagnostics	N		N		?		N	
Total preoperative	N		N		?		N	
Prosthetic device cost	N		$8,000	$650	?		?	
Prosthetic device used	N		10% tube, 90% bifurc	?	?		?	
% Costs due to prosthesis	?		40%	4%	?		?	
Operating room	?		Y		?		Y	
Surgeon fees	Y		Y		?		?	
Nursing	?		?		?		?	
Anesthesia	?		Y		?		?	
Medical/surgical supplies	?		Y		?		?	
Respiratory services/ventilation	?		?		?		?	
Pharmacy	?		?		?		?	
Radiology	?		Y		?		Y	
Blood/transfusion	?		Y		?		?	
Laboratory	?		Y		?		?	
Postoperative ICU	?		Y		?		?	
Postoperative ward	?		Y		?		?	
Post diagnostic	?		Y		?		?	
Patient costs (time, morbidity)	Y		Y		?		?	
Total hospitalization	$19,642	$23,484	$20,083	$16,016	?		?	
Subtotal	N		N		?		?	
Imaging follow-up	Y		Y		Y		?	
Total follow-up	Y		Y		?		?	
Grand total (lifetime)	$39,785	$37,606	$28,901	$19,314	?		$8,000	$6,490
Net cost (costs more)	EVAR $2,179 more		EVAR $9,587 more		EVAR £11,449	EVAR £14,077	Early surgery $1,510 more	
Net benefit (yields more QALYs)	EVAR .22 QALYs more		EVAR .42 QALYs more		EVAR .1 QALYs	EVAR 1.6 QALYs	Early surgery .14 QALYs more	
Incremental cost-effectiveness ratio	$9,905/QALY		$22,826/QALY		£100,000/QALY	£8,579/QALY	$10,800/QALY	

Y and N, explicitly included/not included cost; ?, cost not mentioned or inclusion/exclusion uncertain; EVAR, endovascular repair; OSR, open surgical repair; AS, active surveillance; QOL, quality of life; QALY, quality-adjusted life-year; CPI, Current Price Index; UK NHS, United Kingdom National Health Service; ICU, intensive care unit; AAA, abdominal aortic aneurysm; ER, emergency room.

more costly hospital stay and subsequent greater duration of impaired functional status and quality of life. Decreased operative mortality rates associated with endovascular repair may be offset by higher complication rates later in life. If follow-up costs associated with complications and reinterventions for endovascular repair are ignored, then endovascular repair's low operative mortality rates favor endovascular repair and may lead to the premature conclusion that endovascular repair is a cost-effective alternative to open surgery. Mid-term results from randomized controlled trials demonstrate that, compared with open surgery, endovascular repair did not improve all-cause mortality or health-related quality of life, costs more, and led to more complications and reinterventions. No studies assessed long-term outcomes for endovascular repair relative to open surgery. Because of the time-dependent nature of these differences in outcomes, the long-term implications of the differences in mortality and morbidity are important for evaluating AAA repair options.

Regardless of the time frame, all studies found that endovascular repair costs more than open surgery. Studies focusing on hospital costs generally found that endovascular repair costs more to perform than open surgery, primarily due to the cost of the prosthesis. Studies accounting for the cost of these prostheses should be aware of the difference between production costs and commercial pricing. Endovascular prostheses first received Food and Drug Administration (FDA) approval in 1999 (3). Once they became commercially available, market prices reflect charges as opposed to production costs. The cost of the prostheses are partially offset by reduced operating room and ICU use, length of stay, blood transfusions, and perioperative complications during the initial hospitalization. Although refinements in endovascular repair technology and operator experience may result in improved outcomes over time, currently, survival associated with AAA repair is generally equivalent over the mid- to long-term. Thus, any potential advantage to endovascular repair versus open surgery lies early in the care process, for example, fewer complications, reduced hospital length of stay, and so on. Hence, from a cost perspective, they have value primarily where early return to work is crucial.

From the perspective of cost, different audiences have different concerns. Traditional economic analyses focus on the cost to the economy of delivering each element of service. However, policy makers may be more interested in the payments they must underwrite than in the economic cost of a procedure. In the United States, where Medicare pays for hospital care using diagnosis-related groups, differences in the costs of the prosthesis or even in lengths of stay may not be relevant to Medicare, because they are all folded into the overall payment. However, those differences are very salient to hospitals that must bear them. Third-party payers, hospitals, and healthcare providers each formulate their own institutional perspective on costs and effectiveness that depends on the extent and duration of their responsibility for the financing and/or provision of care.

Extrapolating the cost experience in one country to another with a different health care and payment system is difficult. No consensus on comparing results of economic analyses across countries exists. Simply factoring in the foreign exchange rate overlooks the variance in utilization and cost estimates across countries due to differences in physician practice patterns, resource valuation, and resource use (31). Although mid-term outcomes from the European randomized controlled trials indicate that endovascular repair is not superior to open surgery and costs more, the cost-effectiveness of endovascular repair relative to other options in the United States awaits the completion of long-term randomized controlled trials.

CONCLUSIONS

For patients with AAA $<$ 5.5 cm, immediate open surgery costs more than active surveillance with selective open surgery with no improvement in survival. Among patients with AAAs $\geq$ 5.5 cm in diameter considered medically fit for open surgery, endovascular repair has greater short- and long-term costs with no improvement in overall survival or quality of life beyond 1 year. Higher costs are attributable to greater long-term complications, need for reintervention, and long-term monitoring than open surgery. Among patients with large AAAs considered medically unfit for open surgery, endovascular repair costs more than no intervention with no improvement in overall or AAA survival.

POLICY IMPLICATIONS

Although conclusions regarding the cost-effectiveness of AAA treatment options vary by institutional perspective and are time dependent, from a societal perspective, current evidence indicates that endovascular repair is not a cost-effective treatment option regardless of medical fitness. However, because the randomized controlled trials evaluating endovascular and open surgical repair were conducted outside of the United States, the endovascular prostheses may not currently have U.S. FDA approval. Future randomized controlled trials conducted in the United States evaluating the long-term effectiveness and cost-effectiveness of endovascular and open surgical repair for medically fit patients and endovascular versus no intervention for patients judged medically unfit for open surgery are needed.

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