Cost-effectiveness of conventional and endovascular repair of abdominal aortic aneurysms

Prinssen, Monique; Buskens, Erik; de Jong, Sjors E.; Buth, Jacob; Mackaay, Albert J.; Sambeek, Marc R.; Blankensteijn, Jan D.; null, null

Published in:
JOURNAL OF VASCULAR SURGERY

DOI:
10.1016/j.jvs.2007.07.033

Publication date:
2007

Cost-effectiveness of conventional and endovascular repair of abdominal aortic aneurysms: Results of a randomized trial

Monique Prinssen, MD, PhD,[a] Erik Buskens, MD, PhD,[b] Sjors E. de Jong, MD, PhD,[c] Jacob Buth, MD,[d] Albert J. Mackaay, MD, PhD,[e] Marc R. Sambeek, MD, PhD,[f] and **Jan D. Blankensteijn, MD, PhD,[c] for the DREAM trial participants,*** *Utrecht, Groningen, Nijmegen, Eindhoven, Amersfoort, and Rotterdam, The Netherlands*

Background: **Two randomized trials have shown similar mid-term outcomes for survival and quality of life after endovascular and conventional open repair of abdominal aortic aneurysms (AAA). With reduced hospital and intensive care stay, endovascular repair has been hypothesized to be more efficient than open repair. The Dutch Randomized Endovascular Aneurysm Management (DREAM) trial was undertaken to assess the balance of costs and effects of endovascular vs open aneurysm repair.**

Methods: **We conducted a multicenter, randomized trial comparing endovascular repair with open repair in 351 patients with an AAA and studied costs, cost-effectiveness, and clinical outcome 1 year after surgery. In addition to clinical outcome, costs and quality of life were recorded up to 1 year in 170 patients in the endovascular repair group and in 170 in the open repair group. Incremental cost-effectiveness ratios were estimated for cost per life-year, event-free life-year, and quality adjusted life-year (QALY) gained. Uncertainty regarding these outcomes was assessed using bootstrapping.**

Results: **Patients in the endovascular repair group experienced 0.72 QALY vs 0.73 in the open repair group (absolute difference, 0.01; 95% confidence interval [CI], −0.038 to 0.058). Endovascular repair was associated with additional €4293 direct costs (€18,179 vs €13.886; 95% CI, €2,770 to €5,830). Most of the bootstrap estimates indicated that endovascular repair resulted in slightly longer overall and event-free survival associated with respective incremental cost-effectiveness ratios of €76,100 and €171,500 per year gained. Open repair appeared the dominant strategy in costs per QALY.**

Conclusion: **Presently, routine use of endovascular repair in patients also eligible for open repair does not result in a QALY gain at 1 year postoperatively, provides only a marginal overall survival benefit, and is associated with a substantial, if not prohibitive, increase in costs. (J Vasc Surg 2007;46:883-90.)**

Endovascular repair of abdominal aortic aneurysms (AAA) has been demonstrated to reduce death and complication rates in the first month after the procedure compared with open repair.[1,2] Subsequent longer term analysis of these randomized trials showed a sustained benefit in terms of aneurysm related mortality up to 4 years, but the difference in overall survival did not persist beyond the first 2 postoperative years.[3,4] Consequently, only a very limited overall difference in expected survival time remained. Clearly, incorporating other factors such as economics and health-related quality of life (HRQOL) becomes imperative to assess and compare both treatment options.

Several studies, including the two randomized trials, have documented reduced hospital stay and intensive care unit (ICU) stay after endovascular repair compared with open repair.[1,2,5-7] These reductions, together with improvement of patient recovery time, might result in reduced immediate costs of AAA repair. However, this initial cost advantage may be offset by life-long and frequent follow-up imaging as recommended after endovascular repair.[8] We have shown that the costs associated with the mandatory long-term surveillance are considerable.[9]

In addition to cost advantages, other reports have suggested that the minimally invasive nature of endovascular repair may be associated with better quality of life after the operation.[10-12] We have previously addressed this issue by specifically looking at HRQOL in patients randomized to endovascular repair or open repair.[13] Only in the early postoperative period could we demonstrate a minimal QOL advantage of endovascular repair vs open repair. In the second half of the first year, however, better QOL was actually reported after open repair than after endovascular repair. This might further limit the possible advantage of endovascular repair compared with open repair.

From the Division of Vascular Surgery, Department of Surgery, University Medical Center Utrecht[a]; Julius Center for Health Sciences and Primary Care, University Medical Center Utrecht, and Department of Epidemiology, University Medical Center Groningen, University of Groningen[b]; the Department of Vascular Surgery, Radboud University Nijmegen Medical Center[c]; the Department of Surgery, Catharina Hospital Eindhoven[d]; the Department of Surgery, Meander Medical Center[e]; and the Division of Vascular Surgery, Department of Surgery, Erasmus Medical Center Rotterdam.[f]

Additional material for this article may be found online at www.jvascsurg.org.

Competition of interest: none.

*The members of the DREAM trial group are listed in the Appendix (online only), which may be found online at www.jvascsurg.org.

Reprint requests: Erik Buskens, MD, PhD, Department of Epidemiology, University Medical Center Groningen, University of Groningen, PO Box 30,001, 9700 RB Groningen, The Netherlands (e-mail: e.buskens@epi.umcg.nl).

0741-5214/$32.00

doi:10.1016/j.jvs.2007.07.033

Until recently, only a few nonrandomized studies comparing costs of endovascular and open aneurysm repair have been published, and results were conflicting.[14-18] The largest trial thus far reported no advantage of endovascular repair in terms of HRQOL and costs.[4] A full economic evaluation using trial based data is lacking, however. This would appear to hamper a truly considered policy decision on the issue. We anticipated that health economics might be required to finalize the discussion and conducted a comprehensive economic evaluation in parallel to our multicenter randomized trial, the Dutch Randomized Endovascular Aneurysm Management (DREAM) trial. Thus a head-to-head comparison of the balance between costs and effects after elective endovascular and open AAA repair was obtained.

METHODS

Study design and patients. A detailed description of the design and methods of the DREAM trial has been presented elsewhere.[19] In brief, patients diagnosed with an AAA of ≥5 cm in diameter who were considered suitable for both techniques were randomly assigned to endovascular repair or open repair, after giving written informed consent. The study excluded patients requiring emergency AAA repair and patients with inflammatory aneurysms, anatomic variations, connective tissue disease, previous organ transplantation, and a life expectancy of <2 years. The study was performed according to the principles of the Declaration of Helsinki. The Institutional Review Boards of all participating hospitals approved the protocol. The present analyses are limited to patients with complete 1-year data on costs and effects by fall 2005.

End points. Complications were classified and graded according to the reporting standards of the Ad Hoc Committee for Standardized Reporting Practices in Vascular Surgery of The Society for Vascular Surgery/International Society for Cardiovascular Surgery.[20,21] A committee blinded to the treatment allocation evaluated the clinical outcomes. Three severity grades—mild, moderate, and severe—were distinguished. Only severe events were considered for the present analyses.

Quality of life. HRQOL was assessed with the Dutch language version of the EuroQol 5 Dimensions questionnaire (EQ-5D) using the summary score based on the tariffs by Dolan.[22] The EQ-5D questionnaire is a multiattribute instrument reflecting the societal preferences and values for the five domains discerned and their mutual interdependence. Value judgments have been derived previously, independent of potential (economic) cost consequences for current patients. At different points in time, utility scores were obtained by means of EQ-5D. The EQ-5D results in a single numeric score that represents the societal valuation of the actual health status. A value of 1 represents optimal health, and 0 represents death.

Questionnaires were sent to patients at baseline (upon randomization), at 3 and 6 weeks, and at 3, 6, and 12 months postoperatively. Using linear interpolation for the periods between measurements, we calculated the quality-adjusted survival time in terms of quality-adjusted life-years (QALY) by determining the individual area under the curve. These results were previously reported.[13] For the present analyses, the results of the remaining patients that completed their 1-year follow-up were added. We used simple imputation based on clinical outcome to obtain a "complete" data set. Baseline and other (outcome) characteristics of the patients with missing data were no different from those with complete data.

Costs. Medical costs associated with treatment and follow-up until 1 year after inclusion were assessed in Euros. Costs per patient were calculated by multiplying individual resource use with unit costs. The volume of the resource use during admission and follow-up (out-patient visits) was recorded in the case record forms and completed by means of patient diaries. The latter were specifically designed to capture additional resource use such as consultations of a physiotherapist or family physicians, home care, medication used, and other admissions, such as for rehabilitation. Additional examinations specifically performed for study purposes and not serving any clinical purpose, such as additional computed tomography angiography follow-up in the open repair group, were not included in the analysis. Where unavailable from existing sources, unit costs were determined in two academic and two peripheral hospitals.

Notably, the costs of the devices were based on the actual purchasing prices (inclusive of value added taxes and shipping). Personnel costs comprised all individuals involved, inclusive of specialists and operating room staff. A weighted mean of costs per item was calculated by using the ratio of the patients treated in academic and peripheral settings.

We based our estimates of average costs per hospital day (ICU and ward) on a study previously performed in the Netherlands.[23] Costs of outpatient visits, visits to family physicians, and home care were calculated from unit costs reported by the Dutch Costing Manual issued by the National Health Insurance Council.[24] Costs of medication were estimated using the Dutch Formulary (Pharmacotherapeutic Compass 2003) and included the pharmacist's charges. Costs of rarely performed interventions were based on national tariffs (College Tarieven Gezondheidszorg (CTG), http://www.ctg-zaio.nl). Where necessary, unit costs were adjusted to 2003 values according to National Health Service Costs Index issued by the National Bureau for Statistics Netherlands.

We also assessed costs due to losses in productivity associated with sick leave and travel as well as other private costs incurred by patients and their families. Time costs were valued using the friction cost method.[25] The Health and Labour Questionnaire[26] was used to assess actual sick leave.

Cost-effectiveness. For the economic evaluation, the estimates of QALY were chosen as the primary measure of effect. The balance between costs and effects of endovascular repair compared with open repair was expressed in terms of incremental costs per QALY gained using a societal perspective. The incremental cost-effectiveness ratio was

calculated by dividing the difference in costs incurred during a 1-year period by the difference in QALYs. The incremental costs per year without severe complications and per life-year gained were estimated as secondary outcome measures.

The time horizon considered for the current analyses was 1 year. Accordingly, the time preference for any of the outcomes was considered negligible, thus obviating discounting of costs and effects.

Statistical analysis. Patients were classified according to the original treatment allocated for all analyses (as randomized). Mortality and complication rates at 1 year were compared between the two trial arms using the χ^2 test.

Because the distribution of costs across individuals tends to be skewed, calculating conventional confidence intervals (CI) is hampered because these are based on the assumption of normal distribution. Furthermore, the concept of a 95% CI pertaining to a ratio of incremental costs and effects is problematic as such. A negative incremental cost-effectiveness ratio may imply a negative cost difference (cost savings) and positive health effects, or a positive cost difference (extra costs) and negative health effects. The first would obviously be an outcome leading to immediate implementation, whereas the latter would call for immediate halt to the experimental method. Likewise, positive incremental cost-effectiveness ratios may be attained by positive cost differences and positive health effects, or negative cost differences and negative health effects. These situations might also have quite different implications; therefore, a single point estimate of average incremental cost-effectiveness with pertaining 95% CI a priori is a useless concept.

Accordingly, it has become customary in health economics to depict the joint distributions of incremental costs and effects with their pertaining uncertainty in a "cost-effectiveness plane," where incremental costs are on the y-axis and incremental effects are on the x-axis. To evaluate the joint uncertainty in trial data while maintaining the underlying correlation between costs and effects, a bootstrap procedure may be applied.[27] Patients are randomly drawn from the original trial data set, without being excluded for subsequent sampling, until the original number of participants is reached. This process is typically repeated several 1000 times, and for each trial replicate, the incremental costs and effects are calculated, to be depicted in the cost-effectiveness plane. Then, nonparametric 95% CI for the incremental costs can be calculated, and the density distribution of the incremental cost-effectiveness ratio appears in the cost-effectiveness plane.

Thus, our analysis presents costs and health outcomes as the means per patient inclusive of 95% CIs. From the original data set, 10,000 bootstrap replicates were drawn and the incremental costs for each replicate were plotted against the incremental effects representing the uncertainty surrounding the incremental cost-effectiveness ratio.

RESULTS

Characteristics of the patients and treatment assignments. Details of the clinical study results were previously reported.[1,19] Briefly, between November 2000 and December 2003, 351 patients were randomly assigned to endovascular repair or open repair. Six patients did not undergo aneurysm repair after randomization: four declined treatment (1 assigned to endovascular repair and 3 to open repair), and one patient in each group died. Five patients were lost to follow-up in the first year. This resulted in a study group of 340 patients, with 170 open repairs and 170 endovascular repairs. Five crossovers occurred: one patient assigned to endovascular repair had open repair, and four patients assigned to open repair had endovascular repair.

Table I. Baseline characteristics*

*Characteristic**	*OR (n = 170)*	*EVAR (n = 170)*
Age, y	69.4 ± 6.8	70.7 ± 6.6
Male sex	154 (91)	158 (93)
SVS/ISCVS risk-factor score, %†		
Diabetes mellitus	8.8	10.0
Tobacco use	55.3	64.7
Hypertension	54.7	58.2
Hyperlipidemia	53.7	47.3
Carotid disease	15.3	13.5
Cardiac disease	46.5	41.2
Renal disease	7.6	7.6
Pulmonary disease	18.2	27.1
Total†	4.5 ± 2.5	4.4 ± 2.5
FEV_1, L/s	2.6 ± 0.7	2.5 ± 0.7
Body mass index, kg/m^2	26.5 ± 4.0	26.3 ± 3.4
ASA class		
I—healthy status	41 (24)	37 (22)
II—mild systemic disease	105 (62)	119 (70)
III—severe systemic disease	24 (14)	14 (8)
Maximum AAA diameter, mm	60.0 ± 8.5	60.6 ± 9.0

OR, Open repair; *EVAR,* endovascular repair; *SVS/ISCS,* Society for Vascular Surgery/International Society for Cardiovascular Surgery; *FEV_1,* forced expiratory volume in 1 second; *ASA,* American Society of Anesthesiologists; *AAA,* Abdominal aortic aneurysm.

*Continuous data are presented as means ± SD, and categoric data as number (%) and percentages (because of rounding not all percentages total 100).

†Mild, moderate, or severe risk-factor SVS/ISCS score ranges for each of eight domains from 0 (no risk factors) to 3 (severe risk factors).[20] Total scores can range from 0 to 24, with higher scores indicating more risk factors.

Baseline characteristics of patients and aneurysms are given in Table I. The two groups had similar demographic characteristics, comorbid conditions, cardiovascular risk profile, American Society of Anesthesiologists classifications, and aneurysm characteristics.

End points. In the first postoperative year, one or more severe complications occurred in 33 patients in the endovascular repair group and in 37 in the open repair group ($P = .6$). Death (all causes) occurred in 10 patients in the endovascular repair group and 12 in the open repair group ($P = .7$). Aneurysm related events occurred in two patients in the endovascular repair group and nine in the open repair group ($P = .03$). Detailed results were previously reported.[3]

Quality of life. A marginal and nonsignificant benefit of open repair compared with endovascular repair was

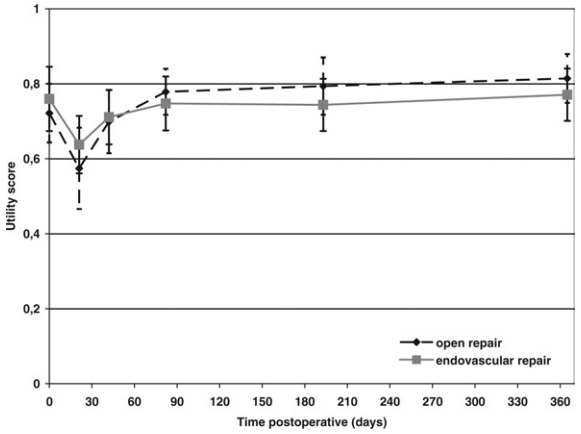

Fig 1. Utility score over time in the first postoperative year after endovascular repair *(gray line)* and open repair *(dashed line)* with 95% confidence intervals. Area under the curve equals quality-adjusted life years.

Table II. Main unit costs based on cost study

Variable	*Unit costs (€)*
Preoperative	
Workup, inclusive examinations and visits	493
Intraoperative	
Operation room per hour	15
Anesthesia, excluding personnel	
OR: university hospital	436
OR: general hospital	316
EVAR: university hospital	206
EVAR: general hospital	75
Inpatient hospital days*	
Ward: university hospital	330
Ward: general hospital	240
Medium care unit	735
Intensive care unit	1140
Investigations	
Angiography	662
CT angiography	183
Duplex scanning	84

OR, Open repair; *EVAR,* endovascular repair; *CT,* computed tomography.
*From Oostenbrink, et al.[23]

observed in QALYs, defined as the primary health outcome for the economic evaluation 1 year after randomization. Patients who underwent endovascular repair experienced 0.72 QALYs (95% CI, 0.29 to 1.14), and patients that underwent open repair experienced 0.73 QALYs (95% CI, 0.27 to 1.19); that is, a nonsignificant 0.01 QALY loss (95% CI, −0.038 to 0.058) was observed after endovascular repair (Fig 1).

Costs. The estimates of the main unit costs are presented in Table II. Actual averages of total costs per patient according to treatment at 1 year are presented in Table III. The estimated difference, as estimated with bootstrap replicates of the trial, amounted to €4300 per patient (95% CI, €2770 to €5830) in favor of open repair (€13,886 for open repair vs €18,179 for endovascular repair). The greater part of the cost difference was attributable to the costs of the endoprosthesis, which was only partly compensated for by savings in admission costs ensuing from shorter lengths of stay in the ICU and on the regular ward. The costs of surveillance of the endovascular repair group also contributed to the difference. Only 24 patients reported paid employment, resulting in only minimal costs associated with loss in productivity (Table III). Focusing on these 24 patients, the mean costs due to sick leave were €3820 in 11 patients (95% CI €1509 to €6131) in the endovascular repair group and €4,662 for 13 patients (95% CI, €2511 to €6812) in the open repair group.

Cost-effectiveness. In terms of QALYs, open repair appeared to be the dominant strategy; that is, costs were lower and better results were observed, albeit marginal and nonsignificant. The incremental cost-effectiveness ratio in terms of costs per year without severe complications was €76,100 and was €171,500 for costs per life-year gained.

Results of the bootstrapping are depicted in cost-effectiveness planes in Fig 2. The QALYs gained panel (Fig 2, *A*) shows that 65% of replicates fall into the left upper quadrant, indicating that we can be 65% certain that open repair yields a marginally better outcome in terms of QALYs at 1 year. Note that all replicates lie above the x-axis, indicating that with 100% certainty endovascular repair is more costly. The oblique line indicates a (rather arbitrary) societal willingness to pay a threshold of €25,000 per QALY. All replicates lie above this threshold, indicating that with 100% certainty open repair can be considered the preferred strategy at a societal €25,000 per QALY willingness to pay threshold. Note that even if a threshold of €50,000 per QALY gained would be considered acceptable, still >99% of estimates would lie above this threshold. Fig 2, *B* (event-free years gained) and Fig 2, *C* (life-years gained) show that, respectively, 95% and 85% of the replicates fell into in the right upper quadrant. This indicates that with high certainty that endovascular repair had favorable health outcomes but against higher costs.

DISCUSSION

Sound evidence shows that early survival after endovascular repair is better; however, within a few years, the frail survivors of endovascular repair seemed to have died just the same, leaving on average an overall benefit of only just >11 days. Because this almost negligible survival advantage comes at considerable financial costs, it is clear that major shifts in endograft pricing and follow-up protocols are mandatory before health care payers would consider reimbursement of endovascular repair money well-spent. Moreover, in terms of costs per QALY gained, there was an indication of open repair being the dominant strategy. The costs after endovascular repair were higher, and in terms of QALYs, a net loss was observed.

Similar to our findings in terms of utility scores beyond the sixth postoperative month, the EndoVascular Aneurysm Repair-1 (EVAR-1) trial showed a nonsignificant difference in favor of open repair.[4] Forbes et al[28] performed a cost-effectiveness analysis and reported comparable re-

Table III. Average costs per patient per treatment group in the first postoperative year

	OR (n = 170)		*EVAR (n = 170)*	
Variable	*Costs (€)*	*95% CI*	*Cost (€)*	*95% CI*
Direct costs in hospital	11,975	10,674-13,277	14,915	14,283-15,546
Operation	5672	5416-5928	12,679	12,292-13,066
Use of operating room	540	533-547	308	293-323
Operating room personnel, inclusive of specialists	4256	4093-4420	3775	3579-3970
Conventional prosthesis	488	477-500	9	0-19
Endovascular prosthesis	193	2-385	7857	7572-8143
Other materials	195	131-258	730	635-824
Admission (ward + ICU)	6011	4828-7195	2136	1705-2567
Additional costs*	291	108-475	100	44-155
Direct costs during 1-year follow-up	1651	1334-1969	3618	3301-4160
Standard follow-up	266	249-283	829	807-850
Complications	291	265-317	1320	971-1669
Sick leave	356	120-593	247	56-438
Outpatient health care†	729	494-964	1295	983-1607
Total‡	13,627	12,297-14,957	18,595	17,835-19,335
Estimate total direct costs using bootstrap‡	13,886		18,179	

OR, Open repair; *EVAR*, endovascular repair; *CI*, confidence interval; *ICU*, intensive care unit.
*Investigations, medications, etc.
†Open repair, n = 149; EVAR, n = 156.
‡The actual trial-based absolute difference in costs is almost €5000. An accurate estimate of the absolute difference and pertaining 95% CI was obtained using 10,000 bootstrap replications of the trial. The resulting estimate of the absolute difference was €4,393 (95% CI, €2,770 to 5,830: €13,886 versus €18,179).

sults that were based on a retrospective analysis of 40 patients (7 endovascular repairs, 31 open repairs) electively treated for an AAA. Other studies using a Markov-model suggested that endovascular repair was cost-effective compared with open repair.[17,18]

These results are in marked contrast with our findings showing that the incremental costs associated with endovascular repair are considerably higher compared with open repair in the first year after surgery. Among the plausible explanations for these contradicting findings are that Patel et al[17] used a combined and lasting mortality and severe morbidity rate of 1.1% for endovascular repair vs 9.1% for open repair, which was later shown to be too optimistic for endovascular repair. Even at that time, it was concluded that the cost-effectiveness of endovascular repair would critically depend on its potential to reduce morbidity and mortality rates.

In this respect, the two randomized trials (EVAR-1 and DREAM) provided sound evidence of a short-term benefit of endovascular repair vs open repair for operative mortality and complications.[1,2] Both trials also reported a significant reduction in hospital length of stay, ICU use, systemic complications, and use of other resources such as productivity losses due to sick leave. As a result, endovascular repair was expected to lead to significant savings in hospital and other costs; however, the use of actual cost data and accounting for longer-term results challenged this expectation.

The savings realized seem to be largely offset by the costs of the endoprostheses, which are eight to ten times more expensive than conventional prostheses. Sternberg and Money[14] found that the costs of an endoprosthesis accounted for 52% of the total cost of endovascular repair. Likewise, in the study by Berman et al,[15] 70% of the costs of endovascular repair were attributed to the endoprosthesis, whereas in the open repair group 75% of the costs were accounted for by hospital care outside the operating room.

A drawback of these two studies, and also other studies on costs of endovascular repair and open repair, is that none had a randomized design. This may have introduced selection bias, especially because endovascular repair was initially intended for use in patients unfit for open repair. Nevertheless, the data of the present randomized trial show similar results for initial intervention related costs, thus confirming that the costs of the devices, apart from the cost of long-term surveillance and possible complications, represent a major part of the cost difference.

With regard to additional costs, another flaw of most available economic studies is that they focused on in-hospital costs only.[16,28] A comprehensive economic analysis should also include the costs of preoperative and postoperative radiologic studies, the costs of preoperative and secondary interventions, the costs of the procedure itself, and finally the costs associated with regular follow-up. It is well known that endovascular repair sometimes results in specific complications, including endoleak and endograft migration, kinking, and rupture.[29-31] These complications are rare or impossible after open repair.[31]

Despite decreased endograft-specific complication rates with newer endovascular devices, life-long follow-up is still considered mandatory after endovascular repair. For centers that have also implemented an elaborate long-term follow-up protocol for open repair patients, the cost disadvantage of endovascular repair would be somewhat smaller. However, because the current analyses focus on short-term outcomes, the impact of accounting for routine follow-up

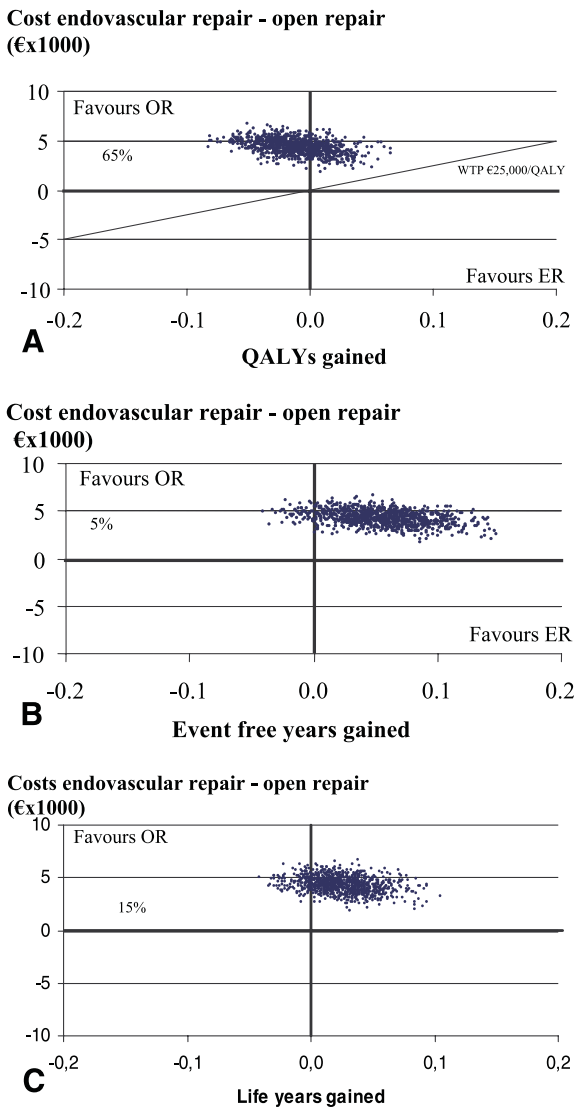

Fig 2. Cost-effectiveness planes for **(A)** quality-adjusted life years, **(B)** event-free years gained, and **(C)** life-years gained for costs of endovascular repair *(ER)* and open repair *(OR)*. The cost-effectiveness plane consists of four quadrants. A dot to the right of the y-axis means that ER yields a better outcome, whereas a dot on the left side means the OR yields a better outcome. Likewise, a dot above the x-axis means that the costs of ER are higher, whereas a dot below the x-axis implies that OR is more expensive. The lower right and upper left quadrant would indicate that both costs and effects are favorable (dominant) for ER and OR, respectively. The percentages represent the proportion of bootstrap replication in which the clinical outcome is favorable for open repair. **A,** The oblique line indicates a societal willingness to pay a threshold of €25,000 per quality-adjusted life year.

after open repair would be marginal. Still, in addition to the accumulating costs of follow-up, costs associated with re-interventions occurring at a rate as high as 10% per annum after endovascular repair should be anticipated.[32] It would appear that a less intensive follow-up protocol or one using less costly diagnostic techniques is not justified before the currently available or next generation devices are proven to require fewer secondary interventions or to lead to reduced long-term complication rates.[33] In the future, this could overcome part of the cost disadvantage of endovascular repair; however, our economic evaluation suggests that only a substantial drop in the price of the devices could really tilt the balance.

A possible limitation of our study may be the restriction to 1-year data. We would like to stress, however, that the two randomized trials showed about 13% reinterventions at 2 years and 20% at 4 years after endovascular repair.[3,4] Similarly, Laheij et al[32] showed that the reintervention rate does not decrease up to 4 years after endovascular repair in a large observational study using European Collaborators on Stent-Graft Techniques for AAA and Thoracic Aortic Aneurysm and Dissection Repair (EUROSTAR) data. As a result, we maintain that the present 1-year analysis, if anything, yields an underestimation of the cost advantage of open repair. Moreover, the limited initial benefit in terms of survival time may ultimately vanish altogether because of longer-term complications occurring. Clearly, long-term cost-effectiveness will be driven by the need for long-term surveillance, reinterventions with possible complications, and even occasional aneurysm rupture.

Future generations of less costly and more effective and reliable endografts may render the present analysis obsolete. We claim, however, that until sound evidence is presented that indeed devices have improved and reintervention rates have dropped considerably, meticulous follow-up remains required. Even a slightly higher reintervention rate after endovascular repair will retain the cost advantages of open repair.

It is well known that item costs may differ across national borders. In fact, the price paid in the United States for a similar health care service may be up to twice that paid in a typical Western European setting. This obviously has implications for the incremental cost-effectiveness ratio. In this case, the incremental cost difference is likely to increase because costs in both arms of the trial would increase more or less proportionally. The incremental effects, however, likely would remain similar. Accordingly, the ratio of incremental costs and effects as calculated for the Netherlands might be an underestimate of that attained in a United States setting. On the other hand, if in alternative settings postoperative monitoring routines or long-term follow-up schemes after endovascular repair would be less strict than currently used in the Dutch setting, the incremental cost-effectiveness might become somewhat less unfavorable.

We note again that the present analyses derive from short-term data, and that therefore long-term follow-up protocols make up only a minute part of the overall costs. In the long run, these savings might result in an incremental cost-effectiveness ratio somewhat less unfavorable for endovascular repair, yet only if this would not be counterbalanced by an increased complication rate.

CONCLUSION

The results of the present economic and cost-effectiveness analyses demonstrate that a policy in which endovascular repair is offered routinely to all eligible patients is associated with considerable financial costs.[3] As long as the risk of death in the first year after endovascular repair cannot be predicted more accurately or prevented by more aggressive risk-factor management, the extra costs incurred may not be justified by the benefit of general implementation of endovascular repair.

Whether endovascular repair will become cost-effective in the near future remains to be seen. Long-term data from the randomized trials may shed new light on the issue. We believe that only if quality of life, complication rates, and survival after endovascular repair were to improve and the costs of the devices would come down considerably, the cost-effectiveness might change in favor of endovascular repair.

Finally, routine use of endovascular repair in patients also eligible for open repair does not result in QALY-gain at 1 year postoperatively and provides only a marginal overall survival benefit while it is associated with a substantial if not prohibitive increase in costs.

AUTHOR CONTRIBUTIONS

Conception and design: EB, JB
Analysis and interpretation: MP, EB, JB
Data collection: MP, SJ, JB, AM, MS, JB
Writing the article: MP, EB, JB
Critical revision of the article: MP, EB, SJ, JB, AM, MS, JB
Final approval of the article: MP, EB, SJ, JB, AM, MS, JB
Statistical analysis: MP, EB, JB
Obtained funding: EB, JB
Overall responsibility: EB was coprincipal investigator of the DREAM trial and had overall responsibility for the economic evaluation, and JD was the principal investigator of the DREAM trial.

REFERENCES

1. Prinssen M, Verhoeven EL, Buth J, Cuypers PW, Van Sambeek MR, Balm R, et al. A randomized trial comparing conventional and endovascular repair of abdominal aortic aneurysms. N Engl J Med 2004;351:1607-18.
2. Greenhalgh RM, Brown LC, Kwong GP, Powell JT, Thompson SG. Comparison of endovascular aneurysm repair with open repair in patients with abdominal aortic aneurysm (EVAR trial 1), 30-day operative mortality results: randomised controlled trial. Lancet 2004;364:843-8.
3. Blankensteijn JD, De Jong SECA, Prinssen M, van der Ham AC, Buth J, van Sterkenburg SMM, et al. Two-year outcomes after conventional or endovascular repair of abdominal aortic aneurysms. N Engl J Med 2005;352:2398-405.
4. Endovascular aneurysm repair versus open repair in patients with abdominal aortic aneurysm (EVAR trial 1): randomised controlled trial. Lancet 2005;365:2179-86.
5. Adriaensen ME, Bosch JL, Halpern EF, Myriam Hunink MG, Gazelle GS. Elective endovascular versus open surgical repair of abdominal aortic aneurysms: systematic review of short-term results. Radiology 2002;224:739-47.
6. Lee WA, Carter JW, Upchurch G, Seeger JM, Huber TS. Perioperative outcomes after open and endovascular repair of intact abdominal aortic aneurysms in the United States during 2001. J Vasc Surg 2004;39:491-6.
7. Anderson PL, Arons RR, Moskowitz AJ, Gelijns A, Magnell C, Faries PL, et al. A statewide experience with endovascular abdominal aortic aneurysm repair: rapid diffusion with excellent early results. J Vasc Surg 2004;39:10-9.
8. Geller SC. Imaging guidelines for abdominal aortic aneurysm repair with endovascular stent grafts. J Vasc Interv Radiol 2003;14:S263-4.
9. Prinssen M, Wixon CL, Buskens E, Blankensteijn JD. Surveillance after endovascular aneurysm repair: diagnostics, complications, and associated costs. Ann Vasc Surg 2004;18:421-7.
10. Aquino RV, Jones MA, Zullo TG, Missig-Carroll N, Makaroun MS. Quality of life assessment in patients undergoing endovascular or conventional AAA repair. J Endovasc Ther 2001;8:521-8.
11. Lloyd AJ, Boyle J, Bell PR, Thompson MM. Comparison of cognitive function and quality of life after endovascular or conventional aortic aneurysm repair. Br J Surg 2000;87:443-7.
12. Lottman PE, Laheij RJ, Cuypers PW, Bender M, Buth J. Health-related quality of life outcomes following elective open or endovascular AAA repair: a randomized controlled trial. J Endovasc Ther 2004;11:323-9.
13. Prinssen M, Buskens E, Blankensteijn JD. Quality of life endovascular and open AAA repair. Results of a randomised trial. Eur J Vasc Endovasc Surg 2004;27:121-7.
14. Sternbergh WC 3rd, Money SR. Hospital cost of endovascular versus open repair of abdominal aortic aneurysms: a multicenter study. J Vasc Surg 2000;31:237-44.
15. Berman SS, Gentile AT, Berens ES, Haskell J. Institutional economic losses associated with AAA repair are independent of technique. J Endovasc Ther 2002;9:282-8.
16. Dryjski M, O'Brien-Irr MS, Hassett J. Hospital costs for endovascular and open repair of abdominal aortic aneurysm. J Am Coll Surg 2003;197:64-70.
17. Patel ST, Haser PB, Bush HL Jr, Kent KC. The cost-effectiveness of endovascular repair versus open surgical repair of abdominal aortic aneurysms: a decision analysis model. J Vasc Surg 1999;29:958-71.
18. Bosch JL, Kaufman JA, Beinfeld MT, Adriaensen ME, Brewster DC, Gazelle GS. Abdominal aortic aneurysms: cost-effectiveness of elective endovascular and open surgical repair. Radiology 2002;225:337-44.
19. Prinssen M, Buskens E, Blankensteijn JD. The Dutch Randomised Endovascular Aneurysm Management (DREAM) trial. Background, design and methods. J Cardiovasc Surg (Torino) 2002;43:379-84.
20. Rutherford RB, Baker JD, Ernst C, Johnston KW, Porter JM, Ahn S, et al. Recommended standards for reports dealing with lower extremity ischemia: revised version. J Vasc Surg 1997;26:517-38.
21. Chaikof EL, Blankensteijn JD, Harris PL, White GH, Zarins CK, Bernhard VM, et al. Reporting standards for endovascular aortic aneurysm repair. J Vasc Surg 2002;35:1048-60.
22. Dolan P. Modeling valuations for EuroQol health states. Med Care 1997;35:1095-108.
23. Oostenbrink JB, Buijs-Van der Woude T, van Agthoven M, Koopmanschap MA, Rutten FF. Unit costs of inpatient hospital days. Pharmacoeconomics 2003;21:263-71.
24. Oostenbrink JB, Koopmanschap MA, Rutten FFH. Standardisation of costs - The Dutch manual for costing in economic evaluations. Pharmacoeconomics 2002;20:443-54.
25. Koopmanschap MA, Rutten FF, van Ineveld BM, van Roijen L. The friction cost method for measuring indirect costs of disease. J Health Econ 1995;14:171-89.
26. van Roijen L, Essink-Bot ML, Koopmanschap MA, Bonsel G, Rutten FF. Labor and health status in economic evaluation of health care. The Health and Labor Questionnaire. Int J Technol Assess Health Care 1996;12:405-15.
27. Efron B, Tibshirani RJ. An introduction to the bootstrap. New York, NY: Chapman & Hall; 2003.
28. Forbes TL, DeRose G, Kribs S, Harris KA. A cost-effectiveness analysis of standard versus endovascular abdominal aortic aneurysm repair. Can J Surg 2002;45:420-4.
29. Becquemin JP, Lapie V, Favre JP, Rousseau H. Mid-term results of a second generation bifurcated endovascular graft for abdominal aortic

aneurysm repair: the French Vanguard trial. J Vasc Surg 1999;30: 209-18.
30. Zarins CK, White RA, Hodgson KJ, Schwarten D, Fogarty TJ. Endoleak as a predictor of outcome after endovascular aneurysm repair: AneuRx multicenter clinical trial. J Vasc Surg 2000;32:90-107.
31. Rutherford RB. Structural failures in abdominal aortic aneurysm stent-grafts: threat to durability and challenge to technology. Semin Vasc Surg 2004;17:294-7.
32. Laheij RJ, Buth J, Harris PL, Moll FL, Stelter WJ, Verhoeven EL. Need for secondary interventions after endovascular repair of abdominal aortic aneurysms. Intermediate-term follow-up results of a European collaborative registry (EUROSTAR). Br J Surg 2000;87:1666-73.
33. Torella F. Effect of improved endograft design on outcome of endovascular aneurysm repair. J Vasc Surg 2004;40:216-21.

Submitted Jan 18, 2007; accepted Jul 23, 2007.

Additional material for this article may be found online at www.jvascsurg.org.

Appendix (online only)

The members of the Dutch Randomized Endovascular Aneurysm Management Trial Group were as follows:

Steering Committee: Diederik E. Grobbee, MD, PhD, Jan D. Blankensteijn, MD, PhD, Jaap Buth, MD, PhD, Peter M. Pattynama, MD, PhD, Eric LG Verhoeven, MD, PhD, Ad E. van Voorthuisen, MD, PhD, and Annette A. A. Bak, MD, PhD.

Data Monitoring and Ethics Committee: Myriam G. Hunink, MD, PhD, Jos M. A. van Engelshoven, MD, PhD, Michael J. H. M. Jacobs, MD, PhD, and Bas A. J. M. de Mol, MD, PhD.

Site and Device Selection Committee: Hajo J. van Bockel, MD, PhD, Ron Balm, MD, PhD, Jim A. Reekers, MD, PhD, Alexander V. Tielbeek, MD, PhD, Eric L. G. Verhoeven, MD, PhD, and Willem Wisselink, MD, PhD.

Data management: Nicole Boekema, MSc, and Irene Sikking.

Outcome Adjudication Committee: Monique Prinssen, MD, PhD, Ron Balm, MD, PhD, Jaap Buth, MD, PhD, Marc R. H. M. van Sambeek, MD, PhD, Eric L. G. Verhoeven, MD, PhD, and Jan D. Blankensteijn, MD, PhD.

Data analysis: Jan D. Blankensteijn, MD, PhD, Monique Prinssen, MD, PhD, and Erik Buskens, MD, PhD.

Clinical centers in The Netherlands: Catharina Hospital Eindhoven—Jaap Buth, MD, PhD, Alexander V. Tielbeek, MD, PhD; University Medical Center Utrecht—Jan D. Blankensteijn, MD, PhD; Academic Medical Center Amsterdam—Ron Balm, MD, PhD, Jim A. Reekers, MD, PhD; Erasmus Medical Center Rotterdam—Marc R. H. M. van Sambeek, MD, PhD, Peter Pattynama, MD, PhD; University Hospital Groningen—Eric L. G. Verhoeven, MD, PhD, Ted Prins, MD, PhD; St. Franciscus Gasthuis Rotterdam— Arie C. van der Ham, MD, PhD, Jurgen J. I. M. van der Velden, MD, PhD; Rijnstate Hospital Arnhem—Steven MM van Sterkenburg, MD, PhD, Gerard B. ten Haken, MD; Leyenburg Hospital's Gravenhage—Cornelis M. A. Aruijninckx, MD, PhD, Hans van Overhagen, MD, PhD; Albert Schweitzer Hospital Dordrecht—Rudolph P. Tutein Nolthenius, MD, PhD, Tadek R. Hendriksz, MD; Atrium Medical Center Heerlen—Joep A. W. Weijink, MD, PhD, Henk F. Odink, MD, PhD; MC Rijnmond Zuid Rotterdam—André A. E. A. de Smet, MD, PhD, Dammis Vroegindeweij, MD, PhD; Jeroen Bosch Hospital den Bosch—Ruud MM van Loenhout, MD, PhD, Matthieu J. Rutten, MD, PhD; St. Elisabeth Hospital Tilburg—Jaap F. Hamming, MD, PhD, Leo E. H. Hampmann, MD, PhD; Maxima Medical Center Veldhoven—Mart H. M. Mender, MD, PhD, Huub L. Pasmans, MD; OLVG, Amsterdam—Anco C. Vahl, MD, PhD, Cees de Vries, MD; Meander Medical Center Amersfoort—Albert J. C. Cackaay, MD, PhD; Vlietland Hospital Schiedam—Laura MC van Dortmont, MD, PhD; University Medical Center Nijmegen—J. Adam van der Vliet, MD, PhD; Leo Schultze Kool, MD, PhD; Martini Hospital Groningen—Johan H. B. Boomsma, MD, PhD, Herman R van Dop, MD; MC Haaglanden's Gravenhage—J. C. Alexander de Mol van Otterloo, MD, PhD, Theo P. W. de Rooij, MD; Hospital Bernhoven Oss—Taco M. Smits, MD, PhD; Oosterschelde Hospital Goes—E. Neval Yilmaz, MD, PhD; VU Medical Center Amsterdam—Willem Wisselink, MD, PhD, Fred G van den Berg, MD, PhD; and Leiden University Medical Center—Michel J. T. Tisser, MD, PhD, Edwin van der Linden, MD, PhD; University Medical Center Maastricht—Geert Willem H. Schurink, MD, PhD, Michiel de Haan, MD, PhD; Bronovo Hospital' Gravenhage—Harm J. Smeets, MD, PhD;

Centers in Belgium: St Jozef Hospital Turnhout—Paul Stabel, MD; St. Trudo Hospital St. Truiden—Francis van Elst, MD, PhD; University Hospital Antwerpen—Jacek Poniewierski, MD; and University Medical Center Gent—Frank E. G. Germassen, MD, PhD.