

# Editor's Choice — Endovascular Aneurysm Repair Versus Open Repair for Patients with a Ruptured Abdominal Aortic Aneurysm: A Systematic Review and Meta-analysis of Short-term Survival

CME



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## WHAT THIS PAPER ADDS

There is a clinical equipoise about the best treatment for a patient with a ruptured abdominal aortic aneurysm: endovascular (EVAR) or open repair (OR). The results of the present systematic review indicate that endovascular aneurysm repair is not inferior to open repair with regard to short-term survival. This supports the use of EVAR in suitable patients and OR as a reasonable alternative. Possible future directions are centralisation of care in high-volume hospitals, 'EVAR-first'/hybrid repair, or an 'EVAR-only' approach.

**Background:** There is clinical equipoise between open (OR) and endovascular aneurysm repair (EVAR) for the best treatment of ruptured abdominal aortic aneurysm (RAAA).

**Objective:** The aim of the study was to perform a systematic review and meta-analysis to estimate the short-term (combined 30-day or in-hospital) survival after EVAR and OR for patients with RAAA. Data sources included Medline, Embase, and the World Health Organization International Clinical Trials Registry until 13 January 2014. All randomised controlled trials (RCTs), observational cohort studies, and administrative registries comparing OR and EVAR of at least 50 patients were included. Articles were full-length and in English.

**Methods:** Standard PRISMA guidelines were followed. The methodological quality of RCTs was assessed with the Cochrane Collaboration's tool for assessing risk of bias. The quality of observational studies was assessed with a modified Cochrane Collaboration's tool for assessing risk of bias, the Newcastle—Ottawa Scale, and the Methodological Index for Non-Randomized Studies. The results of the RCTs, of the observational studies, and of the administrative registries were pooled separately and analysed with the use of a random effects model.

**Results:** From a total of 3,769 articles, three RCTs, 21 observational studies, and eight administrative registries met the inclusion criteria. In the RCTs, the risk of bias was lowest and the pooled odds ratio for death after EVAR versus OR was 0.90 (95% CI 0.65—1.24). The majority of the observational studies had a high risk of bias and the pooled odds ratio for death was 0.44 (95% CI 0.37—0.53). The majority of the administrative registries had a high risk of bias and the pooled odds ratio for death was 0.54 (95% CI 0.47—0.62).

**Conclusion:** Endovascular aneurysm repair is not inferior to open repair in patients with a ruptured abdominal aortic aneurysm. This supports the use of EVAR in suitable patients and OR as a reasonable alternative.

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<sup>\*</sup> **Appendix 1:** protocol, quality assessment RCTs, quality assessment observational studies and administrative registries, search PubMed, search Embase, Figs. 7—10.

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## INTRODUCTION

The death rate in all patients with a ruptured abdominal aortic aneurysm (RAAA) is around 80%.<sup>1</sup> One-third of all patients with RAAA do not reach the hospital alive, and one-third do not have an intervention. Of the patients having an intervention, only half survive intervention and admission. The traditional intervention is open surgical repair (OR) with exclusion of the aneurysm with a synthetic tube or bifurcated graft. Endovascular aneurysm repair (EVAR) was developed in the 1990s. The experience with elective EVAR has led to its increasing use in the emergency setting. Between 46% and 64% of patients with RAAA have suitable aortic anatomy for EVAR.<sup>2,3</sup>

Observational studies have reported improved short-term survival after EVAR compared with OR. Observational studies however have methodological limitations, leading to biased estimates of outcome. Randomised controlled trials are regarded as providing the best evidence for the relative efficacy of interventions. An early trial from the UK did not show any benefit of EVAR in patients with RAAA.<sup>4</sup> Recently, the results of two larger RCTs have been published.<sup>2,3</sup> These new studies might help to better determine whether EVAR improves short-term survival when compared with open repair, which in turn might help caregivers to decide on the best treatment strategy.

## OBJECTIVE

The aim of this study was to perform a systematic review and meta-analysis to obtain the best estimates of the short-term (combined 30-day or in-hospital) survival after endovascular repair compared with open repair for patients with a RAAA in randomised controlled trials and observational studies.

## METHODS

The present review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.<sup>5</sup> The objectives, the methodology, and the inclusion criteria were prespecified in a protocol ([Appendix 1](#)).

### Search strategy

A systematic search in Medline through Pubmed and in Embase through Ovid was conducted with the assistance of a clinical librarian. The search strategy was built around the participants, intervention, comparison, outcomes, and study design (PICOS) framework ([Appendix 1](#)). Additionally, the World Health Organization International Clinical Trials Registry Platform (WHOICTRP) was searched for relevant RCTs.

The last search was done on the 13 January 2014. Two authors (SvB, AC) independently screened the titles and abstracts of the identified articles for relevance. Subsequently, the relevant full length articles were assessed by two authors (SvB, AC) to check if they met the inclusion criteria. Disagreements were resolved by discussion with two other authors (MK, RB). The reference list of the included articles was checked for other eligible articles and a cited reference search in the Web of Science was done.

### Eligibility criteria

All RCTs comparing OR and EVAR, and all observational studies comparing OR and EVAR that included at least 50 patients were included. Observational studies that included patients based on the International Classification of Diseases (ICD) or other forms of coding were analysed separately, and are referred to as administrative registries. Studies were included if they were full length and in English. Studies reporting more than once on the same patient population were included only once, based on relevance

and size. Studies were excluded if they did not allow extraction of two-by-two contingency tables for the endpoint 30-day or in-hospital death rate.

### Assessment of study quality

The methodological quality of the included articles was independently assessed by two authors (SvB, AC). For the RCTs, The Cochrane Collaboration's tool for assessing risk of bias was used ([Appendix 1](#)). For the observational studies and administrative registries, a tool based on the Cochrane Collaboration's tool for assessing risk of bias, the Newcastle–Ottawa Scale, and the Methodological Index for Non-Randomized Studies (MINORS) was used ([Appendix](#)). Again, disagreements were resolved by discussion with two other authors. The risk of bias within studies was reported as an [online supplement \(Appendix 1, Figs. 7–9\)](#).

### Data collection

Data were extracted independently by two authors (SvB, AC) with use of a standardised form in Microsoft Office Access 2003 (Microsoft Corporation, Redmond, WA, USA). The following data were collected: study design (RCT, observational study or administrative registry), study period, study size, country, and rejection rate. For the included RCTs, the number of events and the total number of patients per type of intervention were extracted based on intention-to-treat analysis. For the included observational studies, the number of events and the total number of patients per type of intervention were extracted based on as-treated analysis. Authors were contacted to obtain missing data if necessary. When the authors were unable to provide missing data, the study was excluded from the analysis.

### Statistical analysis

The primary endpoint was the combined 30-day and in-hospital death rate. If not reported, the 30-day or in-hospital death rate was used instead. For the observational studies, a secondary endpoint was the odds ratio of EVAR on death rate after adjustment for age, sex, and hemodynamic stability. The statistical analysis was performed using Review Manager 5.2 (Copenhagen: The Nordic Cochrane Centre, The Cochrane Collaboration) and Stata/SE 11.0 (StataCorp, College Station, TX, USA). Three meta-analyses were done. The first meta-analysis included all RCTs, the second all observational studies, and the third all administrative registries. Pooled effects of EVAR and OR were presented as odds ratios with 95% CI. Because heterogeneity was expected, the meta-analyses were done a priori with the use of a random effects model. A pre-specified sensitivity analysis of observational studies was done by pooling the odds ratios of EVAR versus OR adjusted for at least, age,<sup>6</sup> sex,<sup>7</sup> and hemodynamic stability.<sup>8</sup> Heterogeneity between studies was determined with the  $I^2$  statistic. An  $I^2$  between 30% and 50% was considered moderate heterogeneity and between 60% and 90% as substantial heterogeneity. Funnel plots were created and

inspected for the presence of publication bias if more than 10 studies were included.

## RESULTS

### Literature search

3,769 unique articles were identified from Medline and Embase, of which 123 were retrieved for more detailed evaluation and 30 met the inclusion criteria (Fig. 1). Two additional RCTs<sup>2,9</sup> were identified from the WHO ICTRP, of which one was published<sup>2</sup> and included. One additional administrative registry<sup>10</sup> was identified from the cited reference search. Of 32 included studies, three articles were RCTs,<sup>2–4</sup> 21 were observational studies,<sup>6,11–30</sup> and eight were administrative registries.<sup>10,31–38</sup> Table 1 summarises their main characteristics.

### Study quality

The quality assessment of the included studies is summarised in Figs. 2–4 and in Figs. 6–9 of the appendix. The risk of bias was lowest in the RCTs, whereas the observational studies suffered from all forms of bias. In >75% of observational studies the representativeness of the cohort, the blinding of outcome assessment and the baseline equivalence of groups was considered to have a high risk of bias. In all observational studies, patient selection for EVAR and OR was considered to have a high risk of bias because treatment was based on the preference of caregivers or a clinical algorithm. The administrative registries also suffered from all forms of bias. In more than 50% of the registries the representativeness of the cohort was considered to have a high risk of bias, mostly because of lack of information about the type of hospitals (secondary, tertiary) included.

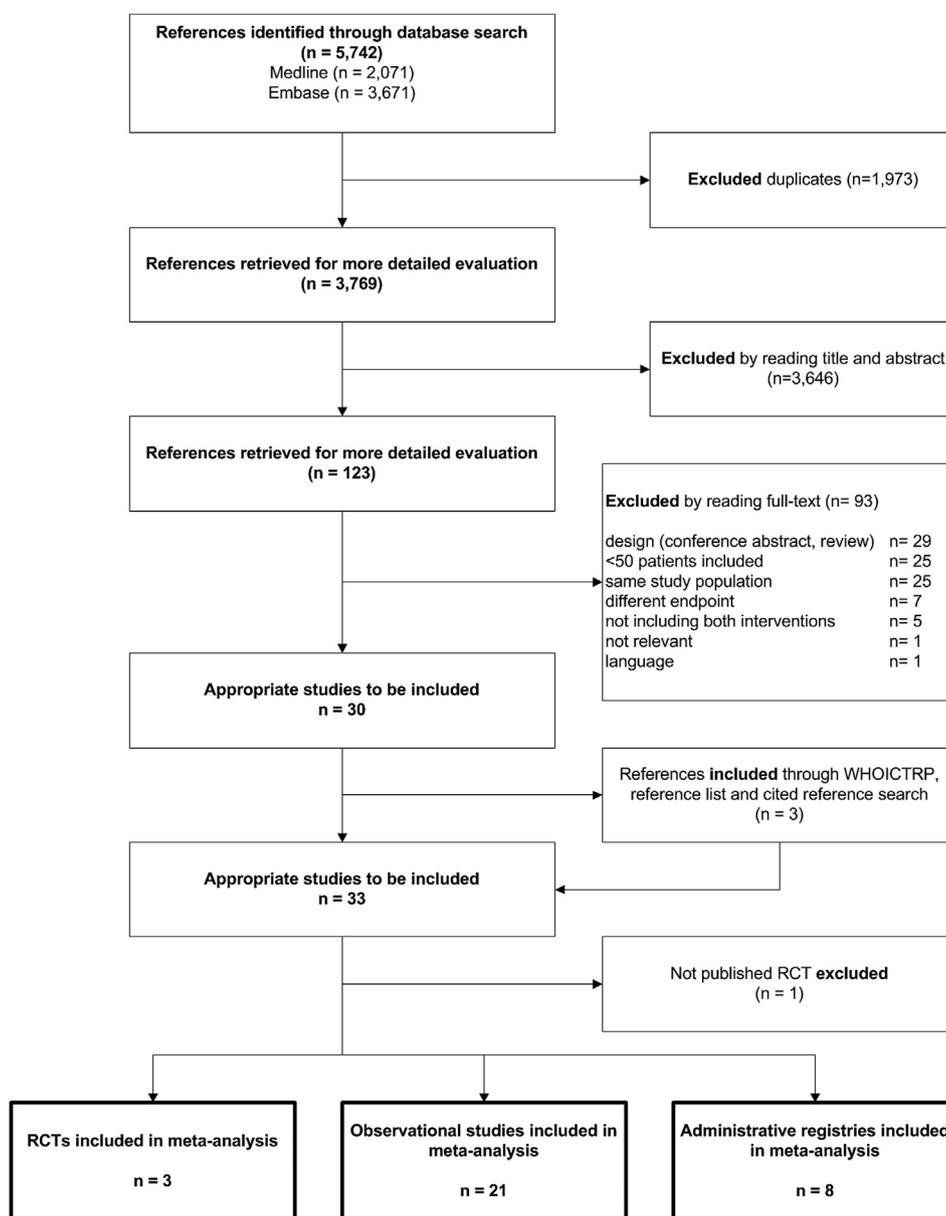


Figure 1. Flowchart of in- and exclusion.

**Table 1.** Characteristics of studies included in the meta-analyses evaluating the outcome after endovascular and open repair of a ruptured abdominal aortic aneurysm.

| Study                       | Country               | Study design | Study period | Number of patients | Rejection rate            | Type death rate | Death rate EVAR (CI) | Death rate OR (CI) |
|-----------------------------|-----------------------|--------------|--------------|--------------------|---------------------------|-----------------|----------------------|--------------------|
| Nottingham 2006             | United Kingdom        | RCT          | 2002–2004    | 32                 | 54% (55/103)              | 30-day          | 53% (30–75)          | 53% (31–74)        |
| AJAX 2013                   | The Netherlands       | RCT          | 2004–2011    | 116                | 9% (46/520)               | 30-day or IH    | 28% (18–41)          | 29% (19–41)        |
| IMPROVE 2014                | United Kingdom        | RCT          | 2009–2013    | 613                | 23% (299/1275)            | 30-day          | 32% (27–37)          | 35% (30–40)        |
| Coppi 2006                  | Italy                 | OS           | 1999–2006    | 124                | Not reported              | 30-day          | 30% (17–47)          | 46% (36–56)        |
| Peppelenbosch 2006          | Multiple <sup>c</sup> | OS           | 2003–2004    | 100                | Not reported              | 30-day or IH    | 35% (23–49)          | 39% (27–53)        |
| Acosta 2007                 | Sweden                | OS           | 2000–2004    | 162                | 24% (51/213)              | IH              | 34% (23–47)          | 45% (36–55)        |
| Ockert 2007                 | Germany               | OS           | 2000–2005    | 58                 | Not reported              | 30-day          | 31% (17–49)          | 31% (17–49)        |
| Moore 2007                  | Canada                | OS           | 2004–2006    | 56                 | Not reported              | 30-day          | 5% (1–24)            | 25% (14–41)        |
| Sharif 2007                 | United Kingdom        | OS           | 2001–2006    | 126                | 10% (14/140)              | 30-day or IH    | 33% (22–46)          | 51% (40–62)        |
| Lee 2008                    | USA                   | OS           | 2002–2006    | 52                 | Not reported              | 30-day or IH    | 35% (17–59)          | 63% (46–77)        |
| Verhoeven 2009              | The Netherlands       | OS           | 2002–2009    | 159                | 9% (16/175)               | 30-day or IH    | 20% (11–34)          | 35% (27–44)        |
| Chagpar 2010                | Canada                | OS           | 2003–2008    | 167                | Not reported              | 30-day          | 16% (7–32)           | 44% (36–52)        |
| Cho 2010                    | USA                   | OS           | 2001–2008    | 233                | Not reported              | 30-day or IH    | 20% (7–45)           | 38% (32–45)        |
| Sarac 2011                  | USA                   | OS           | 1990–2008    | 160                | Not reported              | 30-day or IH    | 31% (18–49)          | 32% (25–41)        |
| Van Schaik 2011             | The Netherlands       | OS           | 2006–2008    | 56                 | 3% (2/58)                 | 30-day          | 27% (11–52)          | 46% (32–61)        |
| Bosch 2012                  | The Netherlands       | OS           | 2002–2008    | 129                | 4% (6/135)                | 30-day          | 20% (9–39)           | 45% (36–55)        |
| Mayer 2012                  | Multiple <sup>d</sup> | OS           | 1998–2011    | 431                | 10% (42/473)              | 30-day          | 18% (14–23)          | 37% (30–45)        |
| Noorani 2012                | United Kingdom        | OS           | 2006–2010    | 102                | 8% (9/111)                | IH              | 12% (5–23)           | 28% (17–42)        |
| Rödel 2012                  | The Netherlands       | OS           | 2006–2010    | 105                | 10% (12/117)              | 30-day          | 17% (8–33)           | 31% (22–43)        |
| Saqib 2012                  | USA                   | OS           | 2001–2011    | 148                | Not reported              | 30-day or IH    | 22% (11–37)          | 32% (24–41)        |
| Eefting 2013                | The Netherlands       | OS           | 2002–2012    | 195                | Not reported              | 30-day          | 24% (16–35)          | 52% (43–61)        |
| Mehta 2013                  | USA                   | OS           | 2002–2011    | 283                | Not reported              | 30-day          | 24% (17–33)          | 44% (37–52)        |
| Mukherjee 2013 <sup>a</sup> | USA                   | OS           | 2007–2011    | 50                 | Not reported              | 30-day          | 27% (15–43)          | 15% (4–42)         |
| Wallace 2013                | USA                   | OS           | 2007–2012    | 100                | 15% (18/118) <sup>b</sup> | IH              | 16% (9–28)           | 46% (32–61)        |
| Greco 2006                  | USA                   | AR           | 2000–2003    | 5,798              | Not reported              | IH              | 39% (34–45)          | 48% (46–49)        |
| Wanhainen 2008              | Sweden                | AR           | 1994–2005    | 3,516              | Not reported              | 30-day          | 15% (9–24)           | 36% (35–38)        |
| Giles 2009                  | USA                   | AR           | 2005–2007    | 567                | Not reported              | 30-day          | 24% (17–32)          | 36% (32–41)        |
| Holt 2010                   | United Kingdom        | AR           | 2003–2008    | 4,414              | Not reported              | IH              | 32% (27–37)          | 47% (46–49)        |
| Mani 2011                   | Multiple <sup>e</sup> | AR           | 2005–2009    | 7,040              | Not reported              | 30-day or IH    | 20% (17–23)          | 33% (31–34)        |
| Chen 2013                   | Taiwan                | AR           | 1998–2009    | 537                | Not reported              | IH              | 44% (29–59)          | 38% (34–43)        |
| Mohan 2013                  | USA                   | AR           | 2001–2010    | 42,126             | Not reported              | IH              | 26% (25–27)          | 39% (38–40)        |
| Trenner 2013                | Germany               | AR           | 1999–2010    | 4,859              | Not reported              | IH              | 23% (20–26)          | 41% (40–43)        |

USA = United States of America; OS = observational study; RCT = randomised controlled trial; AR = administrative registry; EVAR = endovascular aneurysm repair; IH = in-hospital; OR = open repair; CI = 95% confidence interval.

<sup>a</sup> Patients treated with hybrid repair included in open repair group.

<sup>b</sup> 10 patients died during unknown intervention.

<sup>c</sup> Belgium, Canada, Finland, Italy, Netherlands and Northern Ireland.

<sup>d</sup> Sweden, Switzerland.

<sup>e</sup> Australia, Denmark, Finland, Hungary, Italy, Norway, Sweden, Switzerland, United Kingdom.

### Pooled outcomes

In the RCTs, the reported death rates ranged between 28% and 53% after EVAR and between 29% and 53% after OR. The pooled odds ratio for death after EVAR versus OR was 0.90 (95% CI 0.65–1.24) (Fig. 5). No funnel plot was created because of the low number of included RCTs.

In the observational studies, the death rates after EVAR ranged between 5% and 35% and between 15% and 63% after OR. The pooled odds ratio for death after EVAR versus OR was 0.44 (0.37–0.53) (Fig. 5). There were no signs of asymmetry in the funnel plot (Appendix 1, Fig. 10). In the sensitivity analysis of observational studies adjusting for age, sex, and haemodynamic stability, the pooled adjusted odds ratio of EVAR versus OR was 0.53 (95% CI 0.29–0.98) with moderate heterogeneity among the studies ( $I^2 = 34%$ ) (Fig. 6).

In the administrative registries, the death rates after EVAR ranged between 15% and 39% and between 33% and 48% after OR. The pooled odds ratio for death after EVAR versus OR was 0.54 (95% CI 0.47–0.62) (Fig. 5). There was moderate heterogeneity in outcomes among the administrative registries ( $I^2 = 67%$ ). No funnel plots were created because of the low number of included administrative registries.

### DISCUSSION

The present systematic review expands upon previous reviews<sup>39–48</sup> considering EVAR versus OR for patients with RAAA in two ways. First, this is the first to include three RCTs. Second, only one previous systematic review also included a thorough study quality assessment. The results of the meta-analyses presented here indicate that EVAR is not

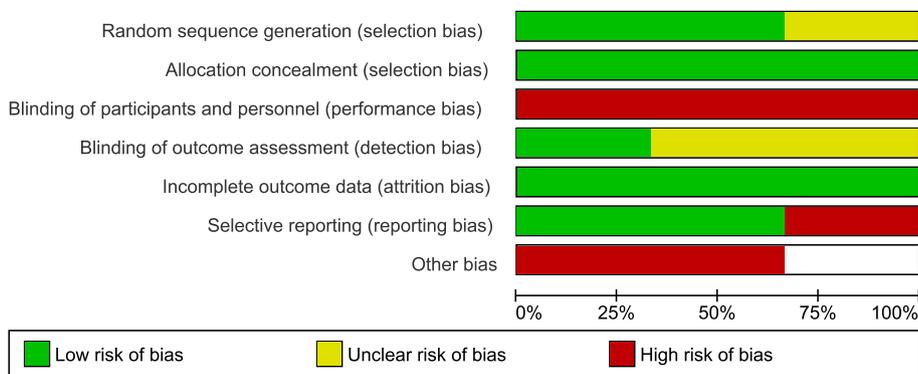


Figure 2. Risk of bias randomised controlled trials.

inferior to OR with regard to short-term survival after RAAA. This supports the use of EVAR in suitable patients and OR as reasonable alternative.

**Study quality**

There was a conspicuous contradiction between the pooled results of the RCTs, the observational cohort studies and the administrative registries. The pooled results of the observational studies and administrative registries show that EVAR improves short-term survival. However, in the pooled results of the RCTs these results were not confirmed. For this reason, we are reluctant to draw the conclusion that short-term survival is lower after EVAR than after OR.

The disparate results are most likely explained by study quality and selection bias. The study quality assessment clearly showed that the RCTs had the least risk of bias for the comparison of EVAR and OR. Treatment allocation by caregivers and thereby selection of patients for either intervention is the most important risk of bias in observational studies. Treatment algorithms and surgeon’s decisions resulted directly in OR in haemodynamically unstable patients and in preoperative computed tomographic angiography and subsequent EVAR in haemodynamically stable patients. By this selection, patients with a low-risk profile for survival were treated with OR and with a high-risk profile for survival with EVAR. In only three<sup>17,3,25</sup> of 21 observational studies was the outcome adjusted for the most important confounders age, sex, and haemodynamic

stability. The improved short-term survival after EVAR persisted in the sensitivity analysis of the observational studies adjusting for these confounders (odds ratio 0.53, 95% CI 0.29–0.98). Contrary to our expectations, these pooled results did not mimic the outcomes of the RCTs. The multivariate analyses may have been affected by residual confounding, which means that statistical methods could not eliminate all differences in observed and unobserved confounders. On the other hand, the RCTs might have been affected by selection bias before enrolment of patients, thereby hampering comparison with daily practice.

The administrative registries with a low risk of bias described their data quality checks and represented both secondary and tertiary hospitals. These registries reflect the daily practice of EVAR and OR over a longer time period and are state-, nation-, or continent-wide. An advantage is that referral patterns are automatically incorporated in the results. However, rejection rates and detailed patient characteristics are scarcely available which are essential elements of the direct comparison between EVAR and OR. Moreover, accuracy of patient identification with use of ICD coding can be questioned.

**Preferred intervention**

The present review considers short-term survival. Although this is the most important outcome for patients with RAAA, other arguments might support either EVAR or OR. In general, it might be argued that non-inferiority suffices for a

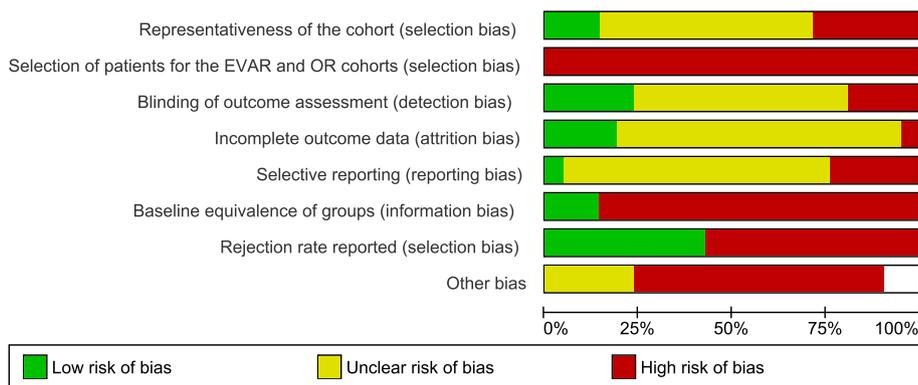


Figure 3. Risk of bias observational studies.

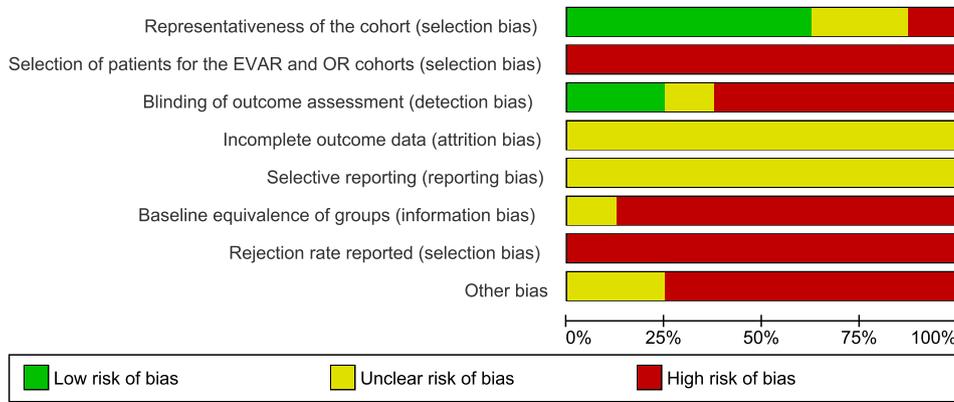


Figure 4. Risk of bias administrative registries.

minimally invasive surgical technique compared with the open equivalent. In the RCTs there appears to be a benefit for EVAR with regard to secondary outcomes like reduction of intensive care unit and hospital stay, need for mechanical ventilation, and blood loss.<sup>2,3</sup> The number of in-hospital

reinterventions appears to be comparable.<sup>2,3</sup> In the direct comparison of costs after 30 days between EVAR and OR in the AJAX trial, EVAR was €5,306 more expensive (95% CI 1,854–12,659).<sup>49</sup> In the comparison of costs after 30 days between the endovascular and open strategy in the

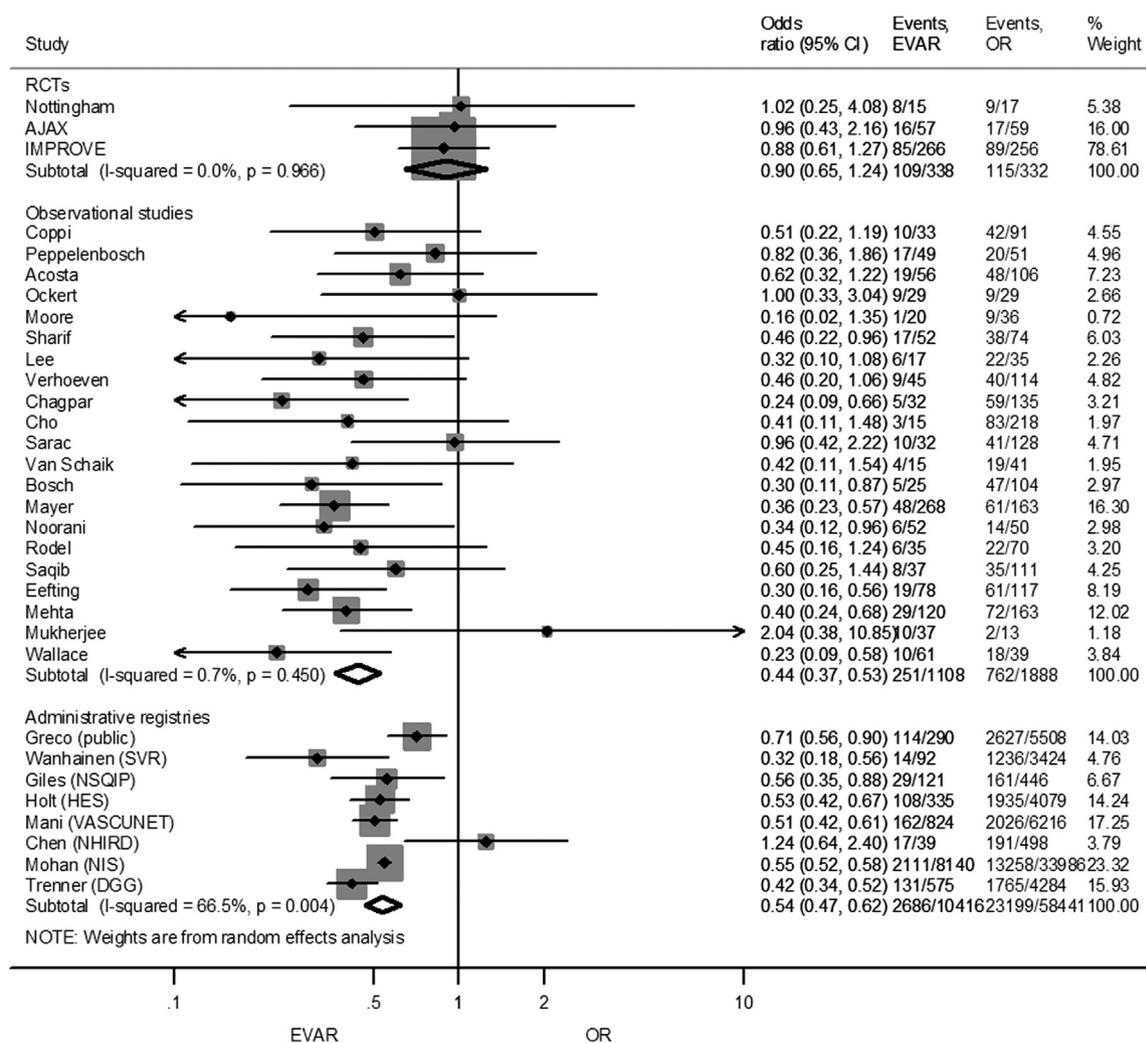
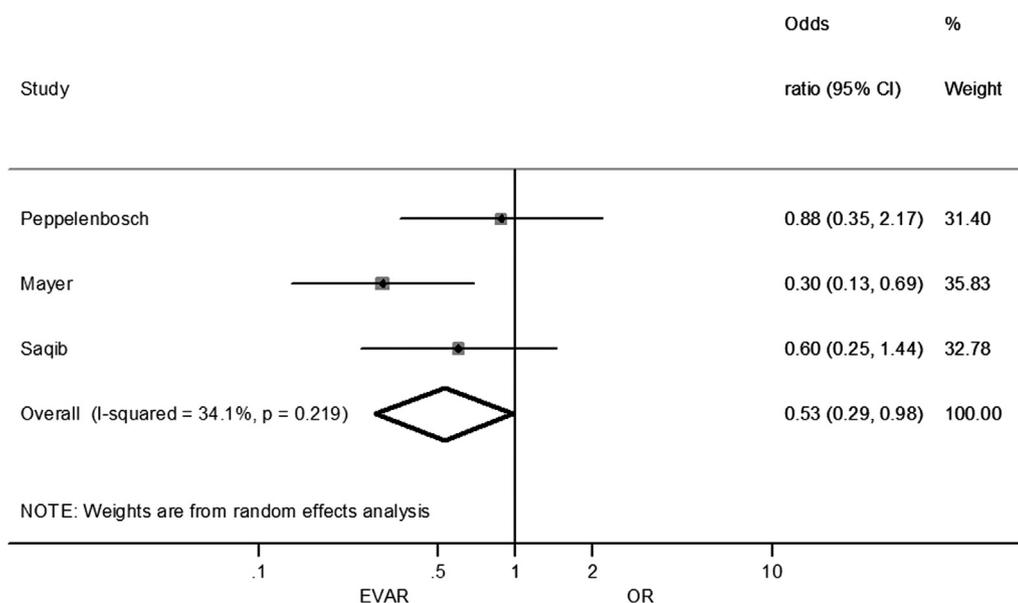


Figure 5. Forest plot showing the pooled odds ratios of the randomised controlled trials, observational studies, and administrative registries comparing endovascular versus open repair in patients with a ruptured abdominal aortic aneurysm. SVR = Swedish Vascular Registry; NSQIP = American College of Surgeons National Surgical Quality Improvement Program; HES = Hospital Episode Statistics; NHIRD = National Health Insurance Research Database; NIS = Nationwide Inpatient Sample; DGG = German Vascular Society.



**Figure 6.** Sensitivity analysis of observational studies comparing endovascular vs. open repair after adjustment for at least age, sex, and hemodynamic stability.

IMPROVE trial, the endovascular strategy was €1,435 cheaper (95% CI 3,626–756).<sup>2</sup> These seemingly contradictory outcomes can be explained in the IMPROVE trial by the 112/275 patients treated by open surgery in the endovascular strategy group, by shorter stay in the intensive care unit and hospital, and by a cheaper endograft. Yet, the results are not contradictory if it is argued that EVAR is more expensive than OR but that a treatment strategy offering both EVAR and OR is not more expensive than a treatment strategy including only OR. Although it is of importance in decision-making, few data are available on surgeons and patient preferences. Finally, in elective aortic surgery, the long-term risk of reinterventions and aneurysm rupture is higher after EVAR than after OR.<sup>50</sup> A recent observational study in patients with RAAA reported a higher late reintervention rate after EVAR (16/62, median follow-up 42 months with an interquartile range 4–76) than after OR (4/85, median follow-up 39 months with an interquartile range 2–75) ( $p = .008$ ).<sup>51</sup> More data are needed before definite conclusions can be drawn with regard to long-term outcomes. However, one might question whether long-term risks should impact decision-making in the acute clinical setting and EVAR for RAAAs could be considered a damage control intervention.

### Future directions

What are the future directions after the present review? Currently, there is still one RCT underway aiming to compare EVAR versus OR,<sup>9</sup> which might change the pooled results. Based on the results from the currently available RCTs that show small differences in short-term survival, it seems unlikely that a new RCT will show marked differences. To our current knowledge the clinical equipoise on short-term survival will remain and the differences between EVAR and OR should be found in the secondary and long-

term outcomes. The aggregated results from the RCTs, the observational studies and administrative registries guide us to the conclusion that EVAR is a good choice in patients that are anatomically and clinically fit for endovascular repair. In other patients OR is a reasonable alternative.

Specific patient groups could be studied: EVAR might be more beneficial in women<sup>2</sup> and OR might be more beneficial in patients with hostile aortic anatomy. Although a detailed description runs beyond the scope of the present review, several studies gave other future directions of care for patients with RAAA. Centralisation of care in high-volume hospitals was suggested in four of 30 studies.<sup>3,19,33,34</sup> Two studies proposed ‘EVAR-first’ or hybrid repair comprising rapid proximal aortic balloon occlusion in all patients and subsequently EVAR or OR.<sup>20,30</sup> Another study suggested an ‘EVAR-only’ approach and treated 70 of 73 consecutive RAAA patients with EVAR.<sup>17</sup> These suggestions are promising, but much research needs to be done before definite conclusions can be drawn.

Finally, the most important benefit of EVAR might be that patients who were considered unfit for open surgical repair earlier might be considered eligible for endovascular intervention nowadays. This leads to an increase in the number of treated patients, which might explain the improved population-based survival that was found in a recent systematic review.<sup>1</sup> Another indication of a reduction of rejection rates is a trend towards older patients being treated for RAAAs in administrative registries<sup>35,37</sup> However, meta-regression of the study midpoint dates and rejection rates showed no significant trend over time (data not shown). Therefore, more high-quality data are needed before definite conclusions can be drawn and the present systematic review cannot answer the question of a reduction in rejection rates. Moreover, a reduction in rejection rates might be caused by EVAR but also by permissive hypotension during transport, massive transfusion protocols,

specialised cardiovascular anaesthetic care, and improvements in the intensive care unit.

### Limitations

An important limitation of this systematic review is that it might have been affected by publication bias. No funnel plots of the RCTs or administrative registries could be created because of the low number of studies. Data might have been missed since one eligible study was excluded because of language restrictions and one because data were missing and could not be provided by the corresponding author. The impact of publication bias on the conclusions is difficult to assess. In general, publication bias leads to an overestimation of treatment effect.

An important limitation of the meta-analysis of the RCTs is that it included only 761 patients. The low number of patients limits the external validity of outcomes for the general RAAA population. It is concluded that EVAR is not inferior to OR. Based on an expected survival rate after EVAR of 68% and after OR of 65% and assuming an  $\alpha$  of 5% and a  $\beta$  of 80%, the sample size needed for a hypothetical non-inferiority trial would be 680 patients for a margin of 6% and 860 patients for a margin of 5%. Assuming a survival rate of 65% after OR, the margin of this non-inferiority conclusion includes a survival after EVAR of at least 59% (65 minus 6%). It could be argued that this margin is too wide and more patients are needed to decrease the margin. However, given the pooled results of EVAR from the RCTs, observational studies, and administrative registries it is considered highly unlikely that the survival of EVAR is worse than 59%. The inclusion of the IMPROVE trial troubled our statistical analysis. From this RCT, only the surgically treated RAAA patients were included, and this violated the intention-to-treat principle to reduce bias from patients with no RAAA and patients without treatment. Inclusion of non-surgically treated RAAA patients ( $n = 36$ ) and patients with other diseases ( $n = 55$ ) was considered inappropriate. Noteworthy, after including all patients from the IMPROVE trial the pooled odds ratio of the RCTs barely differed (0.93, 95% CI 0.69–1.25).

### CONCLUSION

The results of the present systematic review, meta-analyses, and study quality assessment indicate that EVAR is not inferior to OR in patients with a ruptured abdominal aortic aneurysm with regard to short-term survival. This supports the use of EVAR in suitable patients and OR as reasonable alternative.

### ACKNOWLEDGEMENTS

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and interpretation of data; in the writing of the manuscript; or in the decision to submit the manuscript for publication.

### CONFLICT OF INTEREST

None.

### FUNDING

None.

### APPENDIX A. SUPPLEMENTARY DATA

Supplementary data related to this article can be found online at <http://dx.doi.org/10.1016/j.ejvs.2014.03.003>.

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