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REVIEW

Systematic Review and Meta-Analysis of Elective Open Conversion *versus* Fenestrated and Branched Endovascular Repair for Previous Non-Infected Failed Endovascular Aneurysm Repair

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WHAT THIS PAPER ADDS

This is the first meta-analysis on the outcomes of failed elective non-infected EVAR undergoing either open conversion or F/B-EVAR. Early results seem promising when the analysis is not biased by procedures carried out in an urgent setting or involving the complexity of an infected graft, and it is manifested by a pooled 30 day mortality rate of 2.3% after open conversion and 2.4% after F/B-EVAR ($p = .36$). Late results instead appear in favour of open conversions, which at quantitative analysis showed lower re-intervention rates (4.5% *vs.* 26%, $p < .001$) and better overall survival (92.5% *vs.* 81.6%; $p = .005$) at 18 months.

Objective: To evaluate outcomes of patients electively undergoing fenestrated and branched endovascular repair (F/B-EVAR) or open conversion for failed previous non-infected endovascular aneurysm repair (EVAR).

Data sources: Embase, MEDLINE, Cochrane Library.

Review method: The protocol was prospectively registered on PROSPERO (CRD42023404091). The review followed the PRISMA guidelines; certainty was assessed through the GRADE and quality through MINORS tools. Outcomes data were pooled separately for F/B-EVAR and open conversion. A random effects meta-analysis of proportions was conducted; heterogeneity was assessed with the I^2 statistic.

Results: Thirty eight studies were included, for a total of 1 645 patients of whom 1 001 (60.9%) underwent an open conversion and 644 (39.1%) a F/B-EVAR. The quality of evidence was generally limited. GRADE certainty was judged low for 30 day death (in both groups) and F/B-EVAR technical success, and very low for the other outcomes. Pooled 30 day death was 2.3% (I^2 33%) in the open conversion group and 2.4% (I^2 0%) in the F/B-EVAR conversion group ($p = .36$). Technical success for F/B-EVAR was 94.1% (I^2 23%). The pooled 30 day major systemic complications rate was higher in the open conversion (21.3%; I^2 74%) than in the F/B-EVAR (15.7%; I^2 78%) group ($p = .52$). At 18 months follow up, the pooled re-intervention rate was 4.5% (I^2 58%) in the open conversion and 26% (I^2 0%) in the F/B-EVAR group ($p < .001$), and overall survival was 92.5% (I^2 59%) and 81.6% (I^2 68%), respectively ($p = .005$).

Conclusion: In the elective setting, and excluding infections, the early results of both open conversion and F/B-EVAR after failed EVAR appear satisfactory. Although open conversion presented with higher complication rates in the first 30 days after surgery, at follow up it seemed to be associated with fewer re-interventions and better survival compared with F/B-EVAR.

Keywords: Abdominal aortic aneurysm, Endovascular procedures, Failed endovascular aneurysm repair, Meta-analysis, Open conversion, Systematic review

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INTRODUCTION

The number of failing endovascular aneurysm repairs (EVAR) is rising, with an incidence of open conversion of approximately 2% among 16 000 patients from the Vascular Quality Initiative (VQI) EVAR registry.[1] The new era vascular surgeons will have to deal more and more frequently with failed EVAR, meaning that they will have to be skilled enough to face further complex endovascular corrections such as fenestrated and branched endovascular repairs (F/B-EVAR) extensions or open surgical endoprosthesis explant with aortic reconstruction. However, results in the recent literature have failed to clarify which could be the better solution to offer to patients not needing an emergency or urgent treatment, and currently there is no guideline answering this question.[2–5] The aim of this systematic review and meta-analysis was to evaluate and compare the early and long term outcomes of the elective treatment of failed non-infected EVAR procedures through either open conversion or F/B-EVAR.

Methods

The Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA)[6] guidance was followed and a checklist of items was completed while conducting the review (Supplementary Table S1). The study protocol was preregistered on PROSPERO (CRD42023404091). Ethical approval was not required due to the nature of the study.

Search strategy

The Cochrane Library, Embase, and MEDLINE databases were accessed up to February 2023, with no restrictions regarding date of publication. Restrictions were applied for language (English only) and study design. Unpublished literature was screened by searching for trials on ClinicalTrials.gov, European Union Clinical Trials, and the International Standard Randomised Controlled Trial Number. References from meta-analyses, systematic reviews, and narrative reviews relevant for the topic of interest were screened for further article selection. Appropriate Medical Subject Heading (MeSH) terms and free word searches were used; the full search strategy is available in Supplementary Table S2. References and PubMed Similar articles of the included studies were screened for further eligible articles.

Screening was conducted using the Covidence platform (Veritas Health Innovation, Melbourne, Australia). Titles and abstracts were screened independently by two review authors (D.E. and M.R.) against the inclusion criteria. The full texts of eligible studies were retrieved and assessed independently for eligibility by two reviewers (D.E. and M.R.). Any disagreement was resolved through discussion by a third reviewer (S.O.).

Eligibility criteria

Randomised controlled trials, cohort studies, and $\geq$ 10 patients case series were considered for eligibility. Included articles had at least one of the following characteristics:

1. Studies reporting on outcomes of open surgical conversion for previous failed EVAR.
2. Studies reporting on outcomes of endovascular treatment with F/B-EVAR for previous failed EVAR.
3. Studies comparing the outcomes of F/B-EVAR and open conversion for previous failed EVAR.

Excluded articles had one of the following characteristics:

1. Systematic reviews, meta-analysis, $<$ 10 patients case series and case reports on open conversion and or F/B-EVAR for previous failed EVAR.
2. Studies exclusively reporting on the outcomes of urgent and emergency treatment of failed EVAR.
3. Studies exclusively reporting on the outcomes of open and endovascular treatment of infected EVAR.
4. Studies exclusively reporting on the outcomes of immediate (within primary EVAR procedure) open conversions.

Definitions

Failed EVAR was defined as any EVAR procedure that required open conversion or F/B-EVAR for one or more of the following main reasons: type I-V endoleak, aortic neck dilatation, graft thrombosis, graft migration, graft infection, or aneurysm rupture.

Open conversion consisted of one of the following procedures:

- Complete explant (complete explantation of the endoprosthesis, followed by suturing the new graft onto the native vessel).
- Partial explant (the endoprosthesis is cut and partially removed, leaving either the proximal, distal portion, or both. The new graft is then sutured onto the remaining portion of the endoprosthesis or the native vessel).
- Semi-conversion (the endoprosthesis is preserved and one or more of the following manoeuvres are adopted: sacotomy, feeding vessel ligation or suture, proximal and or distal aortic neck banding, graft direct suturing, aortic wall wrapping).

Conversions for graft infection and aneurysm rupture were not the objective of this study. The research was built on a PICO question (Do patients with abdominal aortic aneurysm and previous non-infected failed EVAR who undergo elective open conversion have better outcomes compared with those who undergo elective F/B-EVAR?).

Data extraction

Data extraction was performed independently by two authors (D.E. and M.R.). The extracted data were cross checked by the authors; any discrepancies were resolved through discussion. The extracted data included study characteristics (authors, year of publication, study design, study duration, country), general clinical and operative

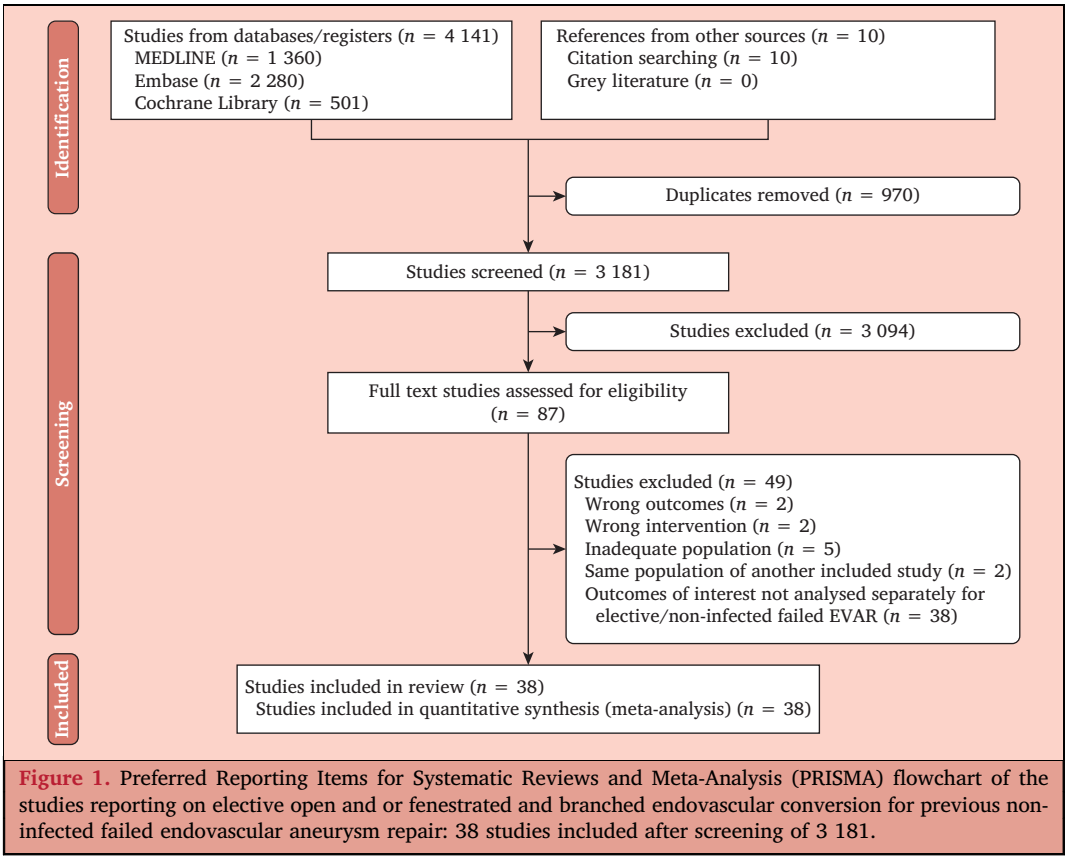


Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) flowchart of the studies reporting on elective open and or fenestrated and branched endovascular conversion for previous non-infected failed endovascular aneurysm repair: 38 studies included after screening of 3 181.

information (baseline demographics and comorbidities, initial aneurysm size and size at conversion, secondary interventions previous to open/F/B-EVAR conversion, time to conversion, indication for conversion, type of explant). Thirty day death, technical success, length of hospital stay, 30 day major systemic complications, re-interventions, overall survival, and follow up times were extracted and recorded when available.

Quality assessment

Quality and certainty assessment were performed independently by two reviewers (D.E. and M.R.) using the Methodological Index for Non-Randomised Studies (MINORS) tool[7] at study level and the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) system[8] at outcome level. The MINORS tool consists of eight items, with four additional items in case of comparative studies; each item is rated 0 to 2 (0 = not reported, 1 = reported but inadequate, 2 = reported and adequate); scores $\leq$ 14, 15 to 22, and $\geq$ 23 were considered poor, fair, and excellent quality, respectively in the case of comparative studies (global ideal score 24); scores $\leq$ 8, 9 to 14, and 15 or 16 were considered poor, fair, and excellent quality, respectively, in the case of non-comparative studies (global ideal score 16). The GRADE system provides explicit criteria for rating the certainty of evidence (high, moderate, low, very low) that include study design, risk of bias, imprecision, inconsistency, indirectness, and magnitude of effect. There were no randomised studies among the included articles. Any discrepancies were mediated by a third reviewer (S.O.).

Outcomes

The primary outcome was 30 day post-operative death. Secondary outcomes were 30 day major systemic complications (cardiac, renal, pulmonary, neurological), technical success (F/B-EVAR group only), re-interventions, and overall survival.

Data synthesis

Study characteristics were synthesised narratively and presented through tables. Statistical analyses were performed using Meta Package for R version 3.3.2 (R Core Team, GNU GPL v2 License) and R Studio version 1.0.44 (RStudio Inc., GNU Affero General Public License v3, Boston, MA, 2016). Data were presented as mean $\pm$ standard deviation (SD) or percentages and compared with the Pearson χ^2 test or the Student t test. Meta-analysis was conducted using a Dersimonian-Laird random effects model. Pooled estimates and 95% confidence intervals (CIs) were calculated separately for F/B-EVAR and open conversion through a meta-analysis of proportions. In the light of high proportions of zero event rates for the primary outcome, the double arcsine Tukey transformation was applied to the data. Heterogeneity was computed with the I^2 statistic,[9] and further subgroup analysis and meta-regression planned in the presence of significant statistical heterogeneity;

Table 1. General characteristics of the studies included after systematic review of the literature on elective open and or fenestrated and branched endovascular conversion for previous non-infected failed endovascular aneurysm repair: 1 001 procedures of open conversion from 28 studies, and 644 procedures of fenestrated and branched endovascular conversions from 12 studies

Author (year)	Study type		Country	Study period	Open conversions − *n*	F/B-EVAR conversions − *n*
Tiesenhausen (2006)[10]	Single centre	Retrospective	Austria	1996–2003	19	
Verzini (2006)[11]	Single centre	Retrospective	Italy	1997–2005	25	
Jimenez (2007)[12]	Single centre	Retrospective	United States	1993–2006	11	
Kelso (2009)[13]	Single centre	Retrospective	United States	1999–2007	30	
Nabi (2009)[14]	Single centre	Retrospective	United States	2000–2008	12	
Brinster (2011)[15]	Single centre	Retrospective	United States	2002–2009	16	
Arya (2013)[16]	Single centre	Retrospective	United States	2002–2012	23	
Katsargyris (2013)[17]	Multicentre	Retrospective	Netherlands, Germany	2002–2012		26
Marone (2013)[18]	Single centre	Retrospective	Italy	2005–2011	45	
Klonaris (2014)[19]	Single centre	Retrospective	Greece	2004–2013	15	
Martin (2014)[20]	Single centre	Prospective	United States	2001–2013		52
Scali (2014)[21]	Single centre	Retrospective	United States	2000–2012	25	
Mangialardi (2015)[22]	Multicentre	Retrospective	Italy	2001–2014	24	
Wu (2015)[23]	Single centre	Retrospective	China	1994–2011	69	
Steenberge (2016)[24]	Single centre	Retrospective	United States	1999–2012	19	
Ben Abdallah (2017)[25]	Single centre	Retrospective	France	2008–2016	19	
Falkensammer (2017)[26]	Single centre	Retrospective	Austria	2013–2016		12
Dias (2018)[27]	Single centre	Retrospective	United States	1999–2016	115	85
Kansal (2018)[28]	Single centre	Retrospective	Canada	1999–2015	10	
Boyle (2019)[29]	Single centre	Retrospective	Ireland	1997–2018	10	
Manunga (2019)[30]	Single centre	Retrospective	United States	2013–2019		16
Marques de Marino (2019)[31]	Single centre	Retrospective	Germany	2010–2018		45
Mohapatra (2019)[32]	Single centre	Retrospective	United States	2002–2017	65	
Sveinsson (2019)[33]	Multicentre	Retrospective	Sweden	2002–2015		28
Davidovic (2020)[34]	Multicentre	Retrospective	Serbia, Italy, Czech Republic, Germany	2010–2017	22	
Marone (2020)[35]	Single centre	Retrospective	Italy	2016–2019	22	
Perini (2020)[36]	Multicentre	Retrospective	Italy	1996–2017	145	
Stilo (2020)[37]	Single centre	Retrospective	Italy	2014–2018	10	
Doumenc (2021)[38]	Single centre	Retrospective	France	2009–2018	26	33
Dubois (2021)[39]	Multicentre	Retrospective	Canada	2003–2018	66	
Haidar (2022)[40]	Single centre	Retrospective	Germany	2016–2021	28	
Hostalrich (2021)[41]	Multicentre	Prospective	France	2010–2019		85
Makaloski (2021)[42]	Single centre	Retrospective	Germany	2015–2017		16
Zerwes (2021)[43]	Single centre	Retrospective	Germany	2013–2020	24	
Budtz-Lilly (2022)[44]	Multicentre	Retrospective	Sweden, Denmark, Italy, Germany, Switzerland, Netherlands	2006–2021		236
Jacobs (2022)[45]	Single centre	Retrospective	United States	2002–2020	85	
Kiernan (2022)[46]	Single centre	Retrospective	Ireland	2009–2019		10
Ohmori (2023)[47]	Single centre	Retrospective	Japan	2007–2020	21	
					Total 1 001	Total 644

F/B-EVAR = fenestrated/branched endovascular aneurysm repair.

adjectives of low, moderate, and high were assigned to I^2 values of 25%, 50%, and 75%.[9] Forest plots were used to present results; a funnel plot and Egger's test were used to assess for publication bias in the primary outcome.

RESULTS

A total of 4 141 studies were retrieved applying the research strategy, of which 970 were duplicates. After titles and abstracts screening of 3 181 studies, 87 studies were fully examined for inclusion in data extraction. Forty nine studies were excluded due to either wrong outcome or intervention, inadequate population (sample size < 10 patients or elective previous non-infected failed EVAR population not extractable from a more comprehensive cohort), unextractable data for elective and non-infected failed EVAR, or same population of another included study (Supplementary Table S3). One additional study was included after included studies' references and similar articles screening. The final number of included studies was 38.[10–47] The PRISMA flow diagram of study selection is depicted in Figure 1.

Study characteristics

All but two included studies[20,41] were retrospective, eight were multicentre experiences[17,22,33,34,36,39,41,44]; the primary EVAR procedures were performed between 1993 and

2021. Twenty six of 38 (68.4%) studies dealt with open conversions, while 10 (26.3%) dealt with F/B-EVAR conversions; two (5.3%) studies compared the results of open *vs.* F/B-EVAR conversions.[27,38] As a whole, 1 645 patients were treated electively for a non-infected failed EVAR, of whom 1 001 (60.9%) underwent an open conversion and 644 (39.1%) a F/B-EVAR procedure (Table 1).

Quality of the evidence

According to MINORS criteria, most studies were judged of poor quality (27, 71.1%); no study was considered of excellent quality, 11 (28.9%) were judged of fair quality. Fair quality studies were more represented in papers dealing with F/B-EVAR conversion (50% *vs.* 25%). GRADE certainty for 30 day death (in both groups) and F/B-EVAR technical success was low; certainty was judged very low for the other outcomes. No evidence of publication bias was detected on visual examination for symmetry of the primary outcome funnel plots, and in Egger's test in both the open conversion (intercept 0.207, standard error 0.022, 95% CI 0.164 — 0.249, $p = .053$) and F/B-EVAR (intercept 0.202, standard error 0.020, 95% CI 0.163 — 0.240, $p = .94$) groups. The comprehensive summary of findings, along with all pertinent details, can be found in Table 2, Supplementary Table S4, and Supplementary Figure S1.

Demographics, comorbidities, pre-, peri- and post-operative characteristics

Data of interest were not always available or extractable for elective non-infected failed EVAR. It was possible to extract data on demographics and comorbidities from 15 (39.5%) studies: weighted average of mean ages at conversion was 71.7 ± 9.4 years, 86.1% (95% CI 82.8 — 90.1) were male, 77.9% (95% CI 70.4 — 85.4) had hypertension, 52.3% (95% CI 45.3 — 59.3) coronary artery disease, 20.3% (95% CI 13.6 — 27) chronic obstructive pulmonary disease, 25.3% (95% CI 17.8 — 32.8) chronic kidney disease, 20.9% (95% CI 16.6 — 25.2) diabetes, and 57.7% (95% CI 46 — 69.4) had smoking history.

Pre-operative data were extractable from 20 (52.6%) studies: mean time to conversion was 45.1 months (95% CI 39.2 — 51.1), mean aneurysm size at conversion was 76.9 mm (95% CI 71.9 — 81.8), and 50.6% (95% CI 39.4 — 61.8) had secondary endovascular re-intervention prior to conversion.

Length of hospital stay was available for 10 (35.7%) open conversion studies and for three (25%) F/B-EVAR studies; overall, the pooled length of stay was 8.7 days (95% CI 6.9 — 10.4). Data are shown in Supplementary Tables S5 and S6.

General indications for conversion were mentioned in all studies, but granularity (such as: type of endoleak, neck dilatation, graft thrombosis, stent migration, others) was extractable from nine (75%) studies in the F/B-EVAR group and 17 (60.7%) in the open conversion group (Supplementary Table S7). Specification on the type of open conversion was extractable from 15 (53.6%) studies (Supplementary Table S8).

The most reported indication for conversion was type I endoleak (Supplementary Fig. S2); open conversion consisted of complete explants in 151 (43%) patients, partial explants in 113 (33%), and semi-conversions (open conversions with graft preservation) in 84 (24%).

Meta-analysis

Primary outcome. The 30 day mortality rate was extractable for all but one[27] of the studied cohorts. Specifically, in the open conversion cohort the pooled 30 day mortality rate was 2.3% (95% CI 0.89 — 4.18; I^2 33%), and in the F/B-EVAR conversion group it was 2.4% (95% CI 1.10 — 4.04; I^2 0%), with no statistical difference between the groups ($p = .36$). Forest plots and funnel plots are illustrated in Figures 2 and 3.

Secondary outcomes. The technical success of F/B-EVAR was 94.1% (95% CI 90.56 — 96.97; I^2 23%). The pooled 30 day major systemic complication rate was 21.3% (95% CI 11.83 — 32.38; I^2 74%) in the open conversion group and 15.7% (95% CI 5.57 — 29.22; I^2 78%) in the F/B-EVAR group ($p = .52$).

The weighted average of mean follow ups was 21.2 ± 3.9 months in the open conversion group and 17.1 ± 1.6 months in the F/B-EVAR one. At 18 months, re-intervention rate and overall survival were 4.5% (95% CI 1.17 — 9.19; I^2 58%) and 92.5% (95% CI 85.25 — 97.82; I^2 59%), respectively, in the open conversion group and 26% (95% CI 20.01 — 32.36; I^2 0%) and 81.6% (95% CI 71.52 — 90.02; I^2 68%) in the F/B-EVAR group, with a statistically significant difference in favour of the open conversion group for both outcomes ($p < .001$ and $p = .005$, respectively).

Forest plots of the additional outcomes are available in Figures 4 and 5. Details on outcomes are presented in Supplementary Table S9.

DISCUSSION

Based on the findings of the current systematic review, it is important to recognise that the literature on open and fenestrated and branched endovascular conversions for failed EVAR still lacks robust methodological strength. Nevertheless, it was found that the weighted 30 day mortality rates after both open and F/B-EVAR conversion for elective non-infected failed EVAR were comparable and within acceptable ranges, even though the 30 day major systemic complications rates were slightly higher in the open conversion group. Despite this disadvantage, at follow up open conversions seemed to exhibit better performance in terms of freedom from re-interventions and overall mortality rate compared with the F/B-EVAR group.

Recently, studies with rigorous methodological standards have been published regarding the concept of failed EVAR,[48–51] which have tried to sum up the outcomes after either open or F/B-EVAR conversions; anyway, the previously mentioned papers did not conduct distinct analyses specifically for elective non-infected EVAR conversions, and this limitation could have potentially obscured the

Table 2. Summary of findings for the primary (30 day mortality) and secondary (30 day major systemic complications, technical success after fenestrated/branched endovascular conversion, re-interventions, overall survival) outcomes after elective open and or fenestrated and branched endovascular conversion for previous non-infected failed endovascular aneurysm repair

Outcome	Number and design of studies	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	GRADE certainty	MINORS study quality	Proportion (95% CI) − %	Heterogeneity
Open conversion										
30 day mortality	27 observational non-RCTs (26 non-comparative, 1 comparative)	Not serious	Not serious	Not serious	Not serious	None	⊕⊕○○ Low	6 fair, 21 poor	2.3 (0.89 − 4.18)	Low (I^2 33%)
30 day major systemic complications	11 observational non-RCTs (10 non-comparative, 1 comparative)	Serious	Serious	Not serious	Not serious	Wide variation in the effects across studies; publication bias suspected	⊕○○○ Very Low	5 fair, 6 poor	21.3 (11.83 − 32.38)	Moderate (I^2 74%)
Re-interventions	13 observational non-RCTs (12 non-comparative, 1 comparative)	Serious	Not serious	Not serious	Not serious	Publication bias suspected	⊕○○○ Very Low	6 fair, 7 poor	4.5 (1.17 − 9.19)	Moderate (I^2 58%)
Overall survival	11 observational non-RCTs (10 non-comparative, 1 comparative)	Serious	Not serious	Not serious	Serious	Small sample size; publication bias suspected	⊕○○○ Very Low	4 fair, 7 poor	92.5 (85.25 − 97.82)	Moderate (I^2 59%)
F/B-EVAR										
30 day mortality	12 observational non-RCTs (10 non-comparative, 2 comparative)	Not serious	Not serious	Not serious	Not serious	None	⊕⊕○○ Low	6 fair, 6 poor	2.4 (1.10 − 4.04)	No (I^2 0%)
Technical success	9 observational non-RCTs (7 non-comparative, 2 comparative)	Not serious	Not serious	Not serious	Not serious	None	⊕⊕○○ Low	6 fair, 3 poor	94.1 (90.56 − 96.97)	No (I^2 23%)
30 day major systemic complications	5 observational non-RCTs (4 non-comparative, 1 comparative)	Serious	Serious	Not serious	Serious	Wide variation in the effects across studies; small sample size; publication bias suspected	⊕○○○ Very Low	4 fair, 1 poor	15.7 (5.57 − 29.22)	High (I^2 78%)
Re-interventions	5 observational non-RCTs (4 non-comparative, 1 comparative)	Not serious	Not serious	Not serious	Serious	Small sample size	⊕○○○ Very Low	4 fair, 1 poor	26 (20.01 − 32.36)	No (I^2 0%)
Overall survival	6 observational non-RCTs (5 non-comparative, 1 comparative)	Serious	Not serious	Not serious	Serious	Small sample size; publication bias suspected	⊕○○○ Very Low	5 fair, 1 poor	81.6 (71.52 − 90.02)	Moderate (I^2 68%)

GRADE = Grading of Recommendations Assessment, Development, and Evaluation; MINORS = Methodological Index for Non-Randomised Studies; F/B-EVAR = fenestrated and branched endovascular aneurysm repair; CI = confidence interval; RCT = randomised controlled trial.

improved outcomes reported in the current meta-analysis (Table 3).

Clearly, interventions performed for ruptured EVAR exhibit a disproportionately increased risk of all adverse outcomes, especially in the case of open conversions. In a systematic review and meta-analysis conducted by Goudeketting *et al.*,[48] a pooled 30 day mortality rate of 28.3% was reported for open conversions performed urgently, with a rate of 2.8% in the elective setting. A more recent systematic review by de Boer *et al.*[50] presented even worse 30 day mortality outcomes (urgent setting 43.3%; elective setting 3.3%). It is worth noting that both studies included open conversions for infected endoprostheses in their analysis, which could have importantly influenced the results. It was possible to extract the 30 day mortality outcomes from 27 studies, including a total of 1 001 patients who underwent open conversions in an elective setting and were free from infective conditions, not surprisingly obtaining a more favourable 30 day mortality rate of 2.3% (95% CI 0.9 − 4.2; I^2 33%).

Nana *et al.*[51] instead, analysing the literature concerning re-intervention with F/B-EVAR after failed previous EVAR, reported an overall 30 day mortality rate of 2.2% which was not distant from the 2.4% (95% CI 1.10 − 4.04; I^2 0%) retrieved from 12 papers in the present study, but it must be mentioned that they investigated on a smaller number of patients (total of 423 patients *vs.* 644 in the present study) and did not perform a weighted analysis of the results.

Concerning early major systemic complications, the systematic reviews on open conversions as mentioned earlier reported overall 30 day major systemic complication rates of 36.7%[48] and 37.1%,[50] which according to the present findings tend to decrease substantially to 21.3% when excluding urgencies and infected EVARs; the overall survival rates showed a similar trend, with the rate changing from

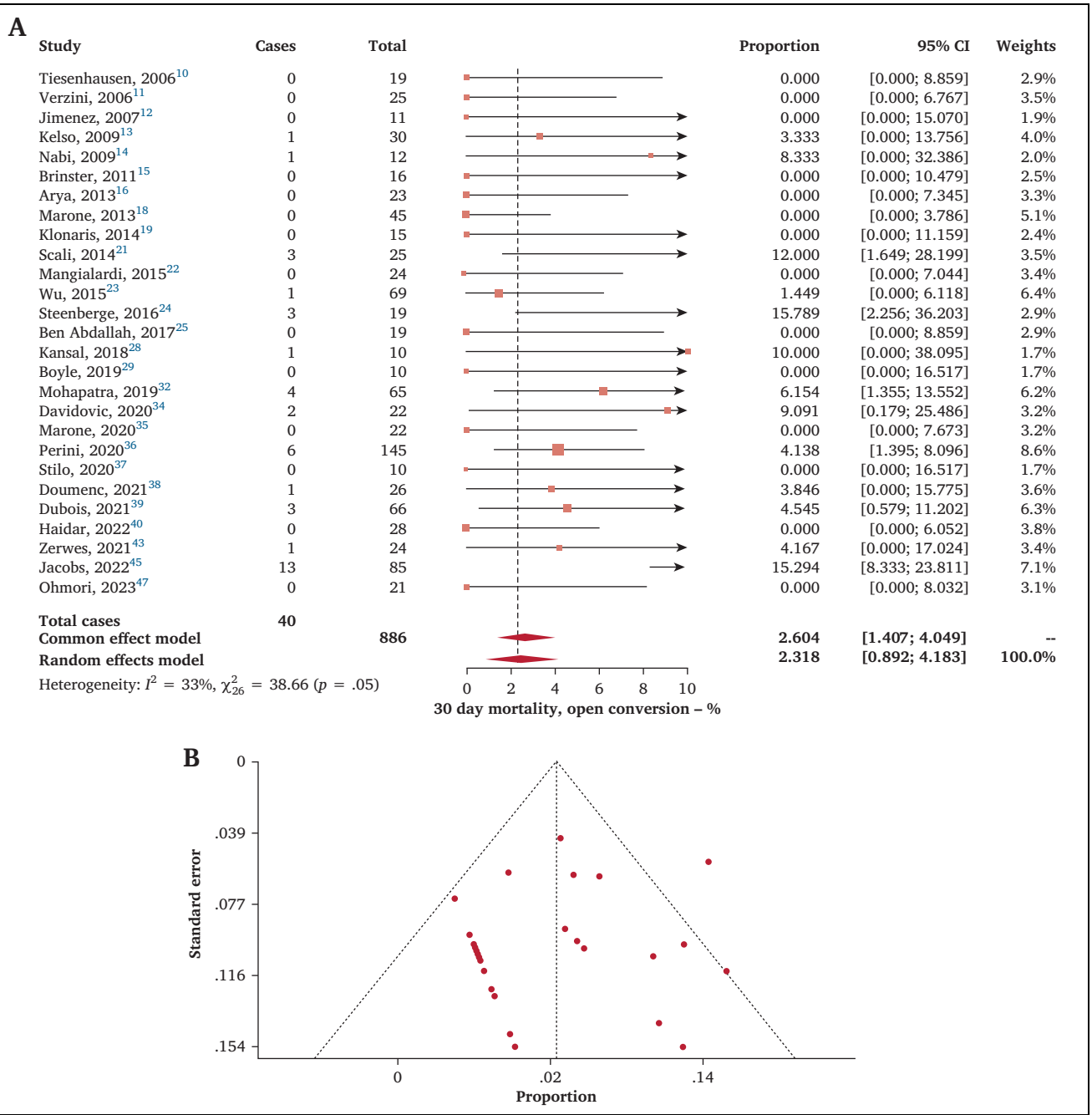


Figure 2. (A) Forest and (B) funnel plots of the primary outcome (30 day mortality rate) after open conversion for previous elective non-infected failed endovascular aneurysm repair: outcome extractable from 27 studies reporting on open conversions.

83.2%, as reported by the same authors,[48] to a higher 92.5% overall survival rate after the present analysis of open elective non-infected failed EVAR conversions.

Apart from early mortality, the immediate and early results available for extraction and combination for the F/B-EVAR conversion group appeared promising in terms of technical success and major systemic complications (94.1% and 15.7%, respectively); on the other hand, when observing follow up results concerning re-interventions and survival (26% and 81.6%, respectively), it appears that the open conversion option would be preferable.

In general, the selected evidence was judged uncertain due to the majority of studies being non-randomised and limited in numbers. However, it was observed that studies reporting on F/B-EVAR conversions were more frequently of fair quality. This observation might be attributed to the impact of points assigned by the MINORS tool to the adequacy of follow up, which is understandably expected to be more stringent after an endovascular exclusion of the aneurysm.

Patients are presenting later after the index EVAR procedure; Jacobs *et al.*[52] described an increase of open conversions at their institution, rising from 9% to 27% over the decade before and after 2010 (from 5% to 15% for graft

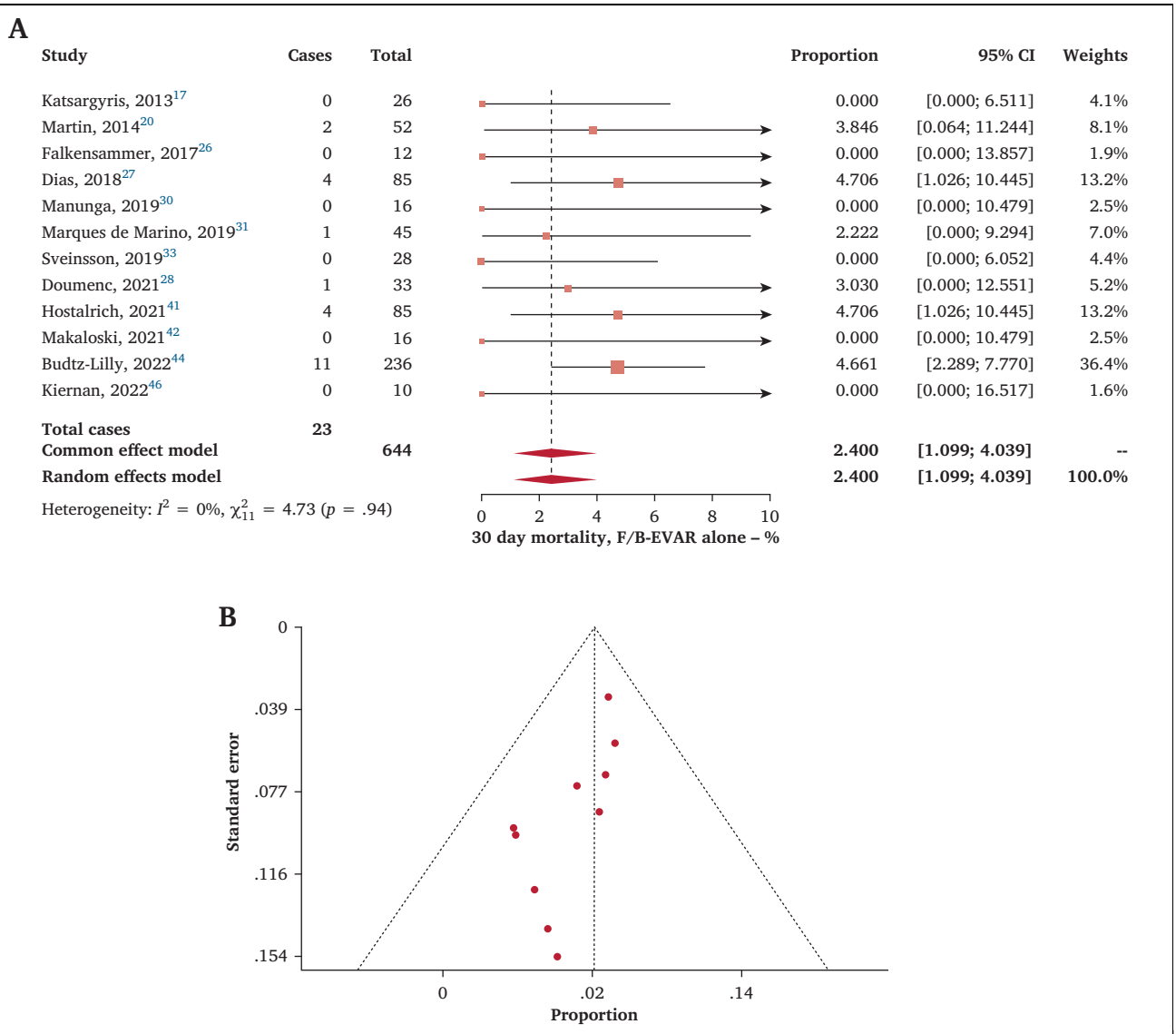


Figure 3. (A) Forest and (B) funnel plots of the primary outcome (30 day mortality rate) after fenestrated and branched endovascular conversion for previous elective non-infected failed endovascular aneurysm repair: outcome extractable from 12 studies reporting on fenestrated and branched endovascular conversions. F/B-EVAR = fenestrated and branched endovascular aneurysm repair.

infections), reporting a prolongation in the time to EVAR conversion, increasing from 16 to 48 months. This trend was confirmed by the present analysis, revealing a mean time to conversion of 45.1 months, with patients presenting at a considerably advanced age, which might raise concerns about the appropriateness of giving the indication for major surgery such as open explant in this context.

It was decided to exclude *a priori* failed EVAR conversions for graft infections from the present review; these cases have been associated with a 3.74 times higher risk of 30 day death compared with non-infected cases.[53] This increased risk is probably attributable to the higher technical complexity of the procedure and the necessity of performing additional digestive tract procedures in cases involving aorto-enteric fistulas.

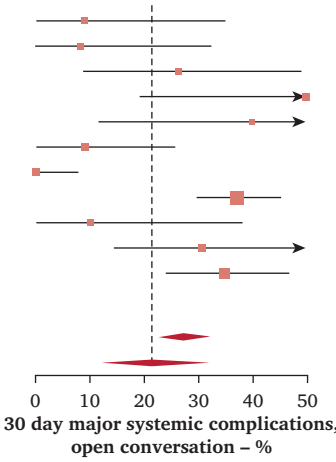
A less invasive open option, such as semi-conversion with graft preservation, could be considered for more compromised patients presenting with a failed EVAR, even though this approach requires further validation as it seems to have poor midterm outcomes.[54] In the present cohort, 24% of patients undergoing an open conversion were subjected to a semi-conversion, but it was not feasible to extract specific data for this population for subgroup analysis. In this scenario F/B-EVAR conversions could be a viable alternative, in light of the acceptable early mortality and morbidity rates demonstrated in the present study and supported by recent literature, provided that these procedures are carried out in highly experienced centres equipped with hybrid rooms featuring fusion imaging and the most advanced materials.[55]

Patients with a failing EVAR may not be suitable candidates for both open conversion and F/B-EVAR. Therefore, a careful case by case evaluation is imperative to determine the most appropriate indication. New era aortic centres should possess the capability to offer both techniques and

A

Study	Cases	Total	Proportion	95% CI	Weights
Jimenez, 2007[12]	1	11	9.091	[0.000; 35.011]	7.5%
Nabi, 2009[14]	1	12	8.333	[0.000; 32.386]	7.7%
Ben Abdallah, 2017[25]	5	19	26.316	[8.541; 48.754]	9.2%
Kansal, 2018[28]	5	10	50.000	[18.916; 81.084]	7.2%
Boyle, 2019[29]	4	10	40.000	[11.315; 72.377]	7.2%
Davidovic, 2020[34]	2	22	9.091	[0.179; 25.486]	9.6%
Marone, 2020[35]	0	22	0.000	[0.000; 7.673]	9.6%
Perini, 2020[36]	54	145	37.241	[29.531; 45.288]	12.9%
Stilo, 2020[37]	1	10	10.000	[0.000; 38.095]	7.2%
Doumenc, 2021[38]	8	26	30.769	[14.258; 50.053]	10.1%
Dubois, 2021[39]	23	66	34.848	[23.755; 46.814]	12.0%
Total cases	**104**				
Common effect model		**353**	**27.261**	**[22.445; 32.323]**	--
Random effects model			**21.305**	**[11.825; 32.380]**	**100.0%**

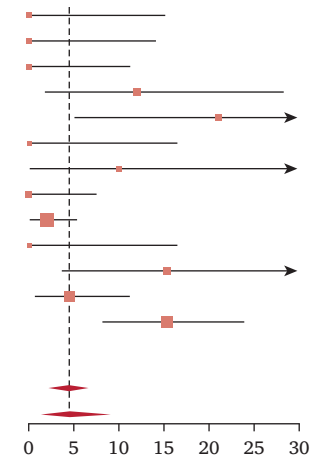
Heterogeneity: $I^2 = 74\%$, $\chi^2_{10} = 38.91$ ($p < .01$)



B

Study	Cases	Total	Proportion	95% CI	Weights
Jimenez, 2007[12]	0	11	0.000	[0.000; 15.070]	5.2%
Nabi, 2009[14]	0	12	0.000	[0.000; 13.857]	5.4%
Klonaris, 2014[19]	0	15	0.000	[0.000; 11.159]	6.2%
Scali, 2014[21]	3	25	12.000	[1.649; 28.199]	8.2%
Ben Abdallah, 2017[25]	4	19	21.053	[5.161; 42.680]	7.1%
Kansal, 2018[28]	0	10	0.000	[0.000; 16.517]	4.8%
Boyle, 2019[29]	1	10	10.000	[0.000; 38.095]	4.8%
Marone, 2020[35]	0	22	0.000	[0.000; 7.673]	7.7%
Perini, 2020[36]	3	145	2.069	[0.257; 5.179]	13.5%
Stilo, 2020[37]	0	10	0.000	[0.000; 16.517]	4.8%
Doumenc, 2021[38]	4	26	15.385	[3.619; 32.205]	8.3%
Dubois, 2021[39]	3	66	4.545	[0.579; 11.202]	11.6%
Jacobs, 2022[45]	13	85	15.294	[8.333; 23.811]	12.3%
Total cases	**31**				
Common effect model		**456**	**4.126**	**[2.117; 6.581]**	--
Random effects model			**4.497**	**[1.168; 9.190]**	**100.0%**

Heterogeneity: $I^2 = 58\%$, $\chi^2_{12} = 28.41$ ($p < .01$)



C

Study	Cases	Total	Proportion	95% CI	Weights
Jimenez, 2007[12]	8	11	72.727	[42.080; 95.612]	7.2%
Nabi, 2009[14]	11	12	91.667	[67.614; 100.000]	7.6%
Brinster, 2011[15]	16	16	100.000	[89.521; 100.000]	8.7%
Klonaris, 2014[19]	15	15	100.000	[88.841; 100.000]	8.4%
Scali, 2014[21]	23	25	92.000	[77.375; 99.847]	10.4%
Ben Abdallah, 2017[25]	19	19	100.000	[91.141; 100.000]	9.4%
Kansal, 2018[28]	8	10	80.000	[48.683; 99.456]	6.8%
Marone, 2020[35]	22	22	100.000	[92.327; 100.000]	10.0%
Stilo, 2020[37]	8	10	80.000	[48.683; 99.456]	6.8%
Doumenc, 2021[38]	22	26	84.615	[67.795; 96.381]	10.6%
Jacobs, 2022[45]	69	85	81.176	[72.099; 88.857]	14.1%
Total cases	**221**				
Common effect model		**251**	**91.026**	**[86.679; 94.717]**	--
Random effects model			**92.543**	**[85.250; 97.835]**	**100.0%**

Heterogeneity: $I^2 = 59\%$, $\chi^2_{10} = 24.53$ ($p < .01$)

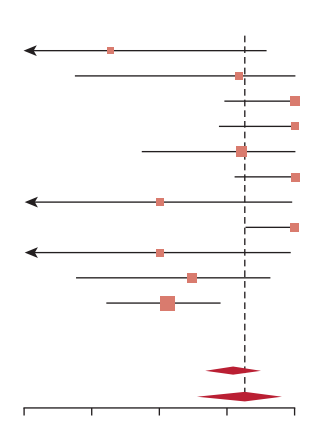


Figure 4. Forest plots of the secondary outcomes after open conversion for previous elective non-infected failed endovascular aneurysm repair: (A) 30 day major systemic complications (extractable from 11 studies), (B) re-intervention rate (extractable from 13 studies), and (C) overall survival (extractable from 11 studies).

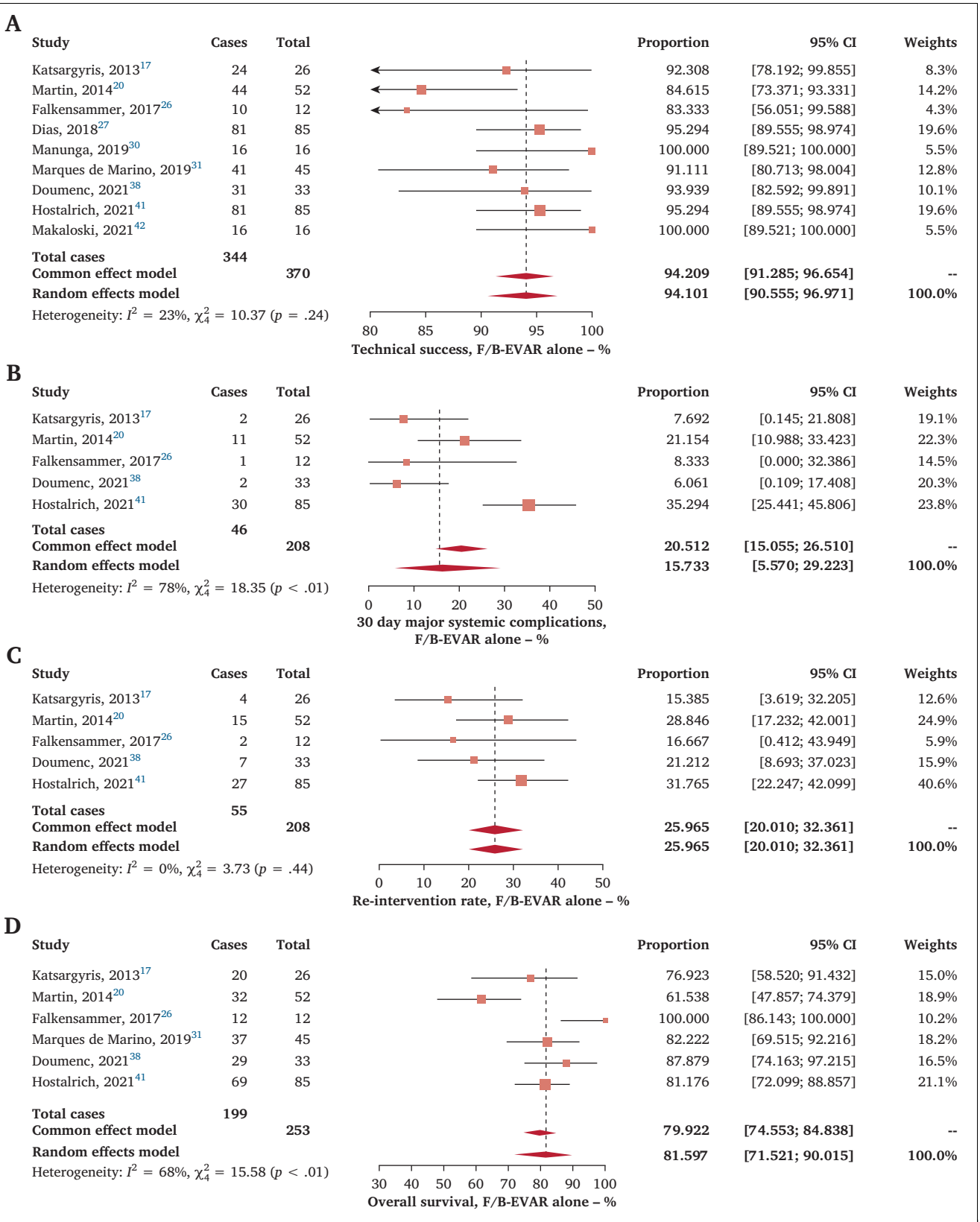


Figure 5. Forest plots of the secondary outcomes after fenestrated and branched endovascular conversion for previous elective non-infected failed endovascular aneurysm repair: (A) technical success (extractable from nine studies), (B) 30 day major systemic complications (extractable from five studies), (C) re-intervention rate (extractable from five studies), and (D) overall survival (extractable from six studies). F/B-EVAR = fenestrated and branched endovascular aneurysm repair.

Table 3. Comparison of present study's outcomes against recent literature on open and fenestrated and branched endovascular conversion for previous failed endovascular aneurysm repair

Author (year)	Study type	Included studies − *n*	Patients − *n*	30 day mortality (95% CI) − %	Technical success (95% CI) − %	30 day major complications (95% CI) − %	Re-interventions (95% CI) − %	Overall survival (95% CI) − %	Notes
Open conversion									
Goudeketting (2019)[48]	Systematic review and meta-analysis	27	791	Elective: 2.8 (1.6 − 4.1) Urgent: 28.3 (20.4 − 36.2)	NR	36.7 (27 − 46.4)	NR	83.2 (80.6 − 85.8)	Includes urgent setting and graft infections
Perini (2019)[49]	Systematic review and meta-analysis	10	89	6.6 (1.7 − 11.5)	NR	NR	NR	NR	Includes urgent setting. Type 1a endoleak was the only indication for conversion
de Boer (2022)[50]	Systematic review	41	1324	Elective: 3.3 Urgent: 43.3	NR	37.10	NR	NR	Includes urgent setting and graft infections
Present study	Systematic review and meta-analysis	27	1001	2.3 (0.9 − 4.2)	NR	21.3 (11.8 − 32.4)	4.5 (1.2 − 9.2)	92.5 (85.3 − 97.8)	Elective non-infected failed EVAR only
F/B-EVAR conversion									
Perini (2019)[49]	Systematic review and meta-analysis	5	97	NR	86.2 (77.3 − 95.1)	NR	NR	NR	Includes urgent setting. Type 1a endoleak was the only indication for conversion
Nana (2023)[51]	Systematic review	10	423	2.20	94.90	NR	16.50%	85.20	Includes urgent setting
Present study	Systematic review and meta-analysis	11	644	2.4 (1.1 − 4)	94.1 (90.6 − 97)	15.7 (5.6 − 29.2)	26 (20 − 32.4)	81.6 (71.5 − 90)	Elective non-infected failed EVAR only

NR = not reported; F/B-EVAR = fenestrated and branched endovascular aneurysm repair; EVAR = endovascular aneurysm repair; CI = confidence interval.

be equipped to make informed decisions based on individual patient characteristics and conditions.

Study limitations

The present study has several limitations. Firstly, there is a selection bias as a substantial number of studies had to be excluded that did not provide or from which it was not possible to extract data exclusively focused on elective non-infected EVAR conversions.

Another important limitation is the possible variation in the indications for either open or F/B-EVAR conversion, as well as patients' general conditions and anatomical characteristics. Unfortunately, the extraction and analysis of these factors from all studies was not feasible for the reasons previously described, resulting in a high number of not available (NA) data in the tables presented. This lack of detailed information, particularly concerning patients' demographics and comorbidities for the elective non-infected previous failed EVAR population, made it challenging to directly compare the two groups. As a result, major differences between the open conversion and F/B-EVAR populations may be suspected, and these potential disparities could have influenced the overall survival, especially in the F/B-EVAR group, which is expected to consist of older and more compromised patients.

It is acknowledged that there were no studies that randomised the treatment strategy to either an open or endovascular solution, either at the time of primary EVAR procedure or at conversion, and for this reason concerns might exist about patients' fitness for an open repair.

There were only two studies in which outcomes of interest were compared between open and F/B-EVAR conversion; consequently, a comparative head to head meta-analysis was not possible, and a meta-analysis of single armed studies had to be conducted instead, making direct comparisons between studies challenging.

However, the generally low to moderate statistical heterogeneity does help mitigate this limitation to some extent. Nonetheless, it is crucial not to underestimate the low and very low GRADE certainty of outcomes; this is particularly evident in the context of the 30 day mortality outcome for open conversions, where the two points (Steenberge *et al.*[24] focusing solely on partial explants, and Jacobs *et al.*[45] concerning the octogenarian population) falling right outside the funnel plot and the borderline results of Egger's test may be attributed to a potential degree of publication bias, clinical heterogeneity, and the influence of small study effects, all of which could have potentially compromised the validity of the results. Included papers were mostly retrospective, and results should be interpreted cautiously, considering the generally poor to fair quality level assigned based on MINORS criteria.

Furthermore, the studies in the present review spanned a wide time period, during which EVAR expertise and the characteristics of endoprostheses to be explanted varied considerably, and separate analyses could not be performed due to limited availability of data.

Conclusions

Early results following failed EVAR conversions show reasonable outcomes for both open and F/B-EVAR conversions when performed in an elective environment and for indications other than graft infection. Although open

conversion may carry a higher risk of major systemic complications after surgery, it appears to be more effective in preventing the need for re-interventions during follow up and seems associated with prolonged patient survival. As a result, in patients with acceptable general health conditions, open conversion may be considered as a preferred option over F/B-EVAR. Ultimately, there is a need for more studies that directly compare open and endovascular conversions for failed EVAR, with a specific focus on conducting separate analyses for elective non-infected conditions. These studies should strive to include comparable cohorts in terms of demographics and comorbidities to provide more robust and reliable evidence. Adopting such an approach would be highly desirable as it would contribute to advancing understanding of the optimal treatment approach for patients with failed EVAR, particularly in elective non-infected cases.

CONFLICT OF INTEREST STATEMENT AND FUNDING

None.

APPENDIX A. SUPPLEMENTARY DATA

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ejvs.2023.09.036.

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