A Systematic Review and Meta-Analysis on 30-Day Readmission Rates After Endovascular Abdominal Aortic Aneurysm Repair and Open Repair

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AIM: Endovascular aneurysm repair (EVAR) and open aneurysm repair (OAR) are established treatments for abdominal aortic aneurysm (AAA). This meta-analysis evaluated 30-day readmission, patient characteristics, postoperative complications, and length of stay after EVAR and OAR, and explored whether 30-day readmission may serve as a surrogate marker of healthcare quality.
METHODS: Following Preferred Reporting Items for Systematic reviews and Meta-Analysis (PRISMA) guidelines, a systematic literature search of Embase, PubMed, Web of Science, and Cochrane databases was conducted from 1 January 2010 through 31 December 2024. Observational studies reporting 30-day readmission after elective EVAR and OAR were included. Methodological quality was assessed using the Newcastle-Ottawa Scale (NOS). Pooled proportions and comparative effect estimates were calculated using random-effect models. Heterogeneity was assessed using the I^2 statistic. Meta-analyses and meta-regression models evaluated associations between patient comorbidities, length of stay (LOS), postoperative complications, and 30-day readmission.
RESULTS: Forty-nine studies reported outcomes after EVAR (578,744 patients) and OAR (228,683 patients). In procedure-specific pooled analyses, 30-day readmission rates were 8% after EVAR and 13% after OAR. LOS was shorter after EVAR than after OAR (mean 4.2 vs. 7.4 days; $p < 0.001$). No significant association was observed between length of stay and 30-day readmission for either OAR (effect estimate 0.0004, 95% CI [–0.0256–0.0265]; p = 0.973) or EVAR (effect estimate 0.0113, 95% CI [–0.0036–0.0262]; p = 0.136). Comorbidities including arterial hypertension, congestive heart failure, chronic kidney disease, and chronic obstructive pulmonary disease were significant predictors of readmission after both procedures. Study-level meta-regression suggested that postoperative stroke (EVAR), graft-related and cardiac complications, including myocardial infarction (EVAR and OAR), were significantly associated with higher 30-day readmission rates. Sensitivity analyses confirmed the stability of the pooled estimates, and no significant publication bias was detected. Data on 90-day readmission were too heterogeneous for pooled analysis. In direct comparative studies, random-effects meta-analysis showed no significant difference in 30-day readmission between EVAR and OAR (Odds Ratio [OR] 0.91, 95% CI [0.82–1.01]; I^2 = 93.8%).
CONCLUSIONS: EVAR was associated with lower pooled 30-day readmission rates and shorter hospital stays than OAR. However, direct comparative meta-analysis indicated no significant difference in 30-day readmission rates between procedures. At the study level, readmission was linked to patient comorbidity and postoperative complications, whereas no significant association was observed between length of stay and readmission. Given the observational design, substantial heterogeneity, and potential residual confounding, these findings should be interpreted with caution. Long-term outcomes were not assessed.

Keywords: endovascular abdominal aortic aneurysm repair; open abdominal aortic aneurysm repair; readmission rate; postoperative complication; length of stay; systematic review; meta-analysis

Introduction

Endovascular aneurysm repair (EVAR) and open aneurysm repair (OAR) represent established therapeutic options for abdominal aortic aneurysm (AAA) once the recommended threshold for interventional treatment has been reached [1]. This systematic review aims to evaluate readmission rates after EVAR and OAR. Thirty-day hospital readmission has increasingly been adopted as a surrogate marker of healthcare quality. Previous analyses, including the large database study by Tsai et al. [2], demonstrated that readmission rates are associated with established indicators of hospital performance such as surgical volume and mortality. However, readmissions are influenced not only by perioperative care and procedural complications but also by patient-related factors such as comorbidity burden, socioeconomic status and discharge practices. Particularly in vascular surgery, where patient populations are elderly and multimorbid, the extent to which 30-day readmission re-

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flects surgical quality versus baseline risk remains debated. While the 2024 clinical practice guidelines of the European Society for Vascular Surgery (ESVS) [1] emphasize the short length of stay following EVAR, they do not address readmission rates. Therefore, a systematic evaluation of readmission patterns after EVAR and OAR is necessary to better contextualize its suitability as a contemporary quality metric.

In this context, it should be examined whether a shorter hospital stay leads to more frequent hospital readmissions. The question addressed in the present study is to what extent the length of stay (LOS) influences the 30-day readmission rates, both after EVAR and OAR, and whether patients who receive a very short postoperative hospital stay were possibly discharged too early and therefore must be readmitted within 30 days. Dua et al. [3] identified 120,646 patients who underwent EVAR from 2012 to 2014 in the United States. The overall unplanned readmission rate within 30 days after the index EVAR was 11.6% during this period. Patients who had a longer initial LOS also had a higher incidence of readmission. Mean index LOS was 5.77 days for patients who were readmitted within 30 days vs. 3.64 days for those who were not ($p < 0.001$). They did not provide a comparison between EVAR and OAR. Dakour Aridi et al. [4] found in the Premier Healthcare Database 27,483 (82.5%) EVARs and 5849 (17.5%) OARs. The overall rate of 30-day readmission was 8.1% and was higher after OAR (12.9%) compared with EVAR (7.1%; $p < 0.001$). In this study, LOS was significantly shorter ($p < 0.001$) with EVAR (2 [1–3] days) compared with OAR (8 [6–11] days). Given the limited number of retrospective comparative studies, this systematic review aimed to analyse the readmission rate after elective EVAR and OAR, considering patient comorbidity, perioperative complications, and length of hospital stay for the index procedure. The aim was to investigate whether the 30-day readmission rate could serve as a quality indicator after AAA treatment.

Methods

Search Strategy

This systematic review is reported according to PRISMA 2020 guidelines (**Supplementary Material**).

A systematic literature search was performed in PubMed, Embase, Web of Science and the Cochrane Library to identify studies reporting 30-day readmission after elective repair of intact abdominal aortic aneurysm (iAAA). Studies published between 1 January 2010 and 31 December 2024 were considered. Only studies published in English or German were included.

The search strategy combined controlled vocabulary (e.g., MeSH terms) and free-text terms related to abdominal aortic aneurysm, including endovascular aneurysm repair, open aneurysm repair as well as readmission. The applied search strategy included combinations of the following terms: "endovascular aneurysm repair" AND "readmission", "open abdominal aneurysm repair" AND "readmission", "abdominal aortic aneurysm repair" AND "readmission" AND "intact abdominal aortic aneurysm repair" AND "readmission", using Boolean operators (AND, OR).

Eligibility Criteria

Studies were eligible if they included adult patients undergoing elective repair of intact AAA and reported 30-day readmission rates after EVAR, OAR or both. Studies were excluded if they focused exclusively on ruptured aneurysms or emergency procedures, did not report 30-day readmission outcomes, including overlapping patient cohorts without additional relevant data, or were case reports, reviews, editorials, or conference abstracts without full-text availability.

Study Selection

All identified records were imported into a reference management software and duplicate records were removed. Titles and abstracts were screened independently by two reviewers. Full texts of potentially eligible studies were assessed independently by both reviewers. Discrepancies were resolved by discussion and consensus; if necessary, a third reviewer was consulted.

Studies were excluded if they did not report 30-day readmission outcomes, included non-elective or ruptured aneurysms, lacked sufficient data for extraction or represented duplicate cohorts.

Study Design and Reporting

This systematic review and meta-analysis were conducted with the primary aim of recording the 30-day readmission rate following EVAR and OAR. It follows the Preferred Reporting Items for Systematic reviews and Meta-Analysis (PRISMA) 2020 guidelines, see Fig. 1.

Data Extraction

Data extraction was performed independently by two reviewers using a standardized data collection form. Extracted variables included study characteristics, patient demographics, postoperative complications, readmission rates and length of stay. Discrepancies were resolved by consensus.

Risk of Bias and Methodological Quality Assessment

The methodological quality and risk of bias of the included observational studies were assessed using the Newcastle-Ottawa Scale (NOS) as shown in Table 1 [3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51]. The NOS evaluates studies based on three domains: selection of study groups, comparability of groups and ascertainment of outcomes. Studies scoring 7–9 points were considered high quality, 4–6 points moderate quality and $\leq$3 low quality. Each

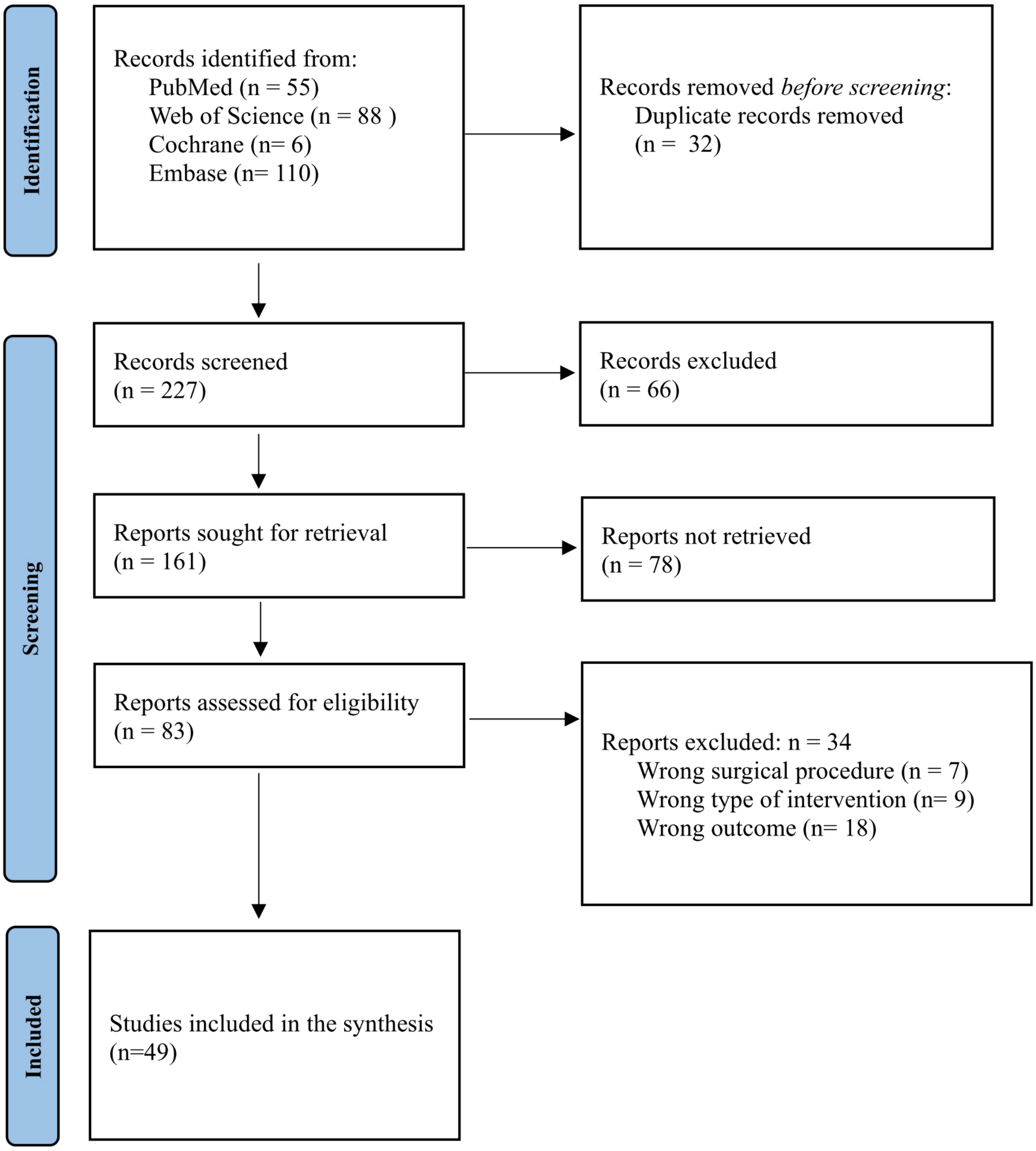

Fig. 1. PRISMA 2020 flow diagram illustrating the study selection process. A total of 49 unique studies were included in the qualitative and quantitative synthesis. Some studies contributed data for both EVAR and OAR analyses when reporting direct within-study comparisons. EVAR, Endovascular aneurysm repair; OAR, open aneurysm repair; PRISMA, Preferred Reporting Items for Systematic reviews and Meta-Analysis.

study was evaluated independently by two reviewers. Any disagreements were resolved by consensus.

Statistical Analysis

Statistical analyses were performed using the R software (version 4.3.3, R Foundation for Statistical Computing, Vienna, Austria). The R packages "meta", "metafor", and "metadat" were used for all analyses. Meta-analyses were conducted using random effects models to account for between-study heterogeneity. Study results were pooled using the inverse-variance method and between-study variance was estimated using the restricted maximum likelihood estimator. Statistical heterogeneity was assessed using the I^2 statistic. Effect estimates were calculated with corresponding 95% CIs and the results were visualized using forest plots displaying study-level and pooled estimates. To account for potential dependencies between overlapping studies using the same data sources, sensitivity analyses were performed using a multilevel meta-analytic model. Additionally, a leave-one-out sensitivity analysis was conducted by sequentially excluding individual studies to evaluate their influence on the pooled effect estimates. As these approaches did not result in substantially different estimates, the primary analyses were conducted using the original model.

Table 1. Quality assessment of included studies using the NOS.

Study	Design	Data source	Selection (0–4)	Comparability (0–2)	Outcome (0–3)	Total (0–9)	Quality
Massarweh et al. 2011 [41]	Retrospective cohort study	Institutional clinical database	2	0	2	4	Moderate
Greenblatt et al. 2012 [9]	Retrospective cohort study	Institutional clinical database	3	1	2	6	Moderate
Casey et al. 2013 [34]	Retrospective cohort study	Institutional clinical database	3	1	2	6	Moderate
de la Motte et al. 2013 [7]	Retrospective cohort study	Institutional clinical database	3	0	2	5	Moderate
Greenblatt et al. 2013 [38]	Retrospective cohort study	Institutional clinical database	3	1	2	6	Moderate
Saunders et al. 2014 [30]	Retrospective cohort study	Institutional clinical database	3	0	2	5	Moderate
Lee et al. 2014 [23]	Prospective cohort study	Institutional clinical database	3	0	2	5	Moderate
Gupta et al. 2014 [46]	Prospective cohort study	ACS-NSQIP	4	1	3	8	High
Faizer et al. 2014 [36]	Retrospective cohort study	Medicare administrative database (USA)	4	2	3	9	High
Chang et al. 2015 [35]	Retrospective cohort study	Institutional clinical database	3	1	2	6	Moderate
Orr et al. 2015 [6]	Prospective cohort study	ACS-NSQIP	4	1	3	8	High
Teivelis et al. 2016 [45]	Retrospective cohort study	Institutional clinical database	4	1	2	7	High
Soden et al. 2016 [31]	Retrospective cohort study	ACS-NSQIP	4	1	3	8	High
Flink et al. 2016 [37]	Retrospective cohort study	ACS-NSQIP	4	1	3	8	High
Feo et al. 2016 [17]	Retrospective cohort study	Institutional clinical database	3	0	2	5	Moderate
Mao et al. 2017 [49]	Retrospective cohort study	Institutional clinical database	3	1	2	6	Moderate
Patel et al. 2018 [50]	Retrospective cohort study	Institutional clinical database	3	0	2	5	Moderate
Rajasinghe et al. 2018 [28]	Prospective cohort study	Prospective multicenter registry study	2	2	1	5	Moderate
Boitano et al. 2019a [14]	Retrospective cohort study	ACS-NSQIP	2	0	2	4	Moderate
Lagergren et al. 2019 [21]	Retrospective cohort study	Institutional clinical database	3	1	2	6	Moderate
Chen et al. 2018 [5]	Retrospective cohort study	ACS-NSQIP	4	1	3	8	High
Aziz et al. 2018 [13]	Retrospective cohort study	ACS-NSQIP	4	1	3	8	High
Martinez et al. 2018 [40]	Retrospective cohort study	Institutional clinical database	2	1	2	5	Moderate
Krajcer et al. 2018 [20]	Prospective cohort study	Prospective multicenter registry study	3	0	1	4	Moderate
Symonides et al. 2018 [44]	Retrospective cohort study	National insurance registry	4	2	2	8	High
Atti et al. 2019 [12]	Retrospective cohort study	NRD (HCUP)	4	0	3	7	High
Dakour Aridi et al. 2018 [4]	Retrospective cohort study	Institutional clinical database	4	1	2	7	High
Bath et al. 2018 [32]	Retrospective cohort study	ACS-NSQIP	4	1	3	8	High
Dua et al. 2019 [3]	Retrospective cohort study	NRD (HCUP)	4	1	3	8	High
Boitano et al. 2019b [47]	Retrospective cohort study	ACS-NSQIP	4	1	3	8	High
Bath et al. 2019 [33]	Retrospective cohort study	ACS-NSQIP	4	1	3	8	High
Janssen et al. 2019 [39]	Retrospective cohort study	Single-center institutional database	2	0	2	4	Moderate
Perlstein et al. 2019 [42]	Retrospective cohort study	Institutional clinical database	3	1	2	6	Moderate
Ash et al. 2020 [11]	Retrospective cohort study	Institutional clinical database	3	0	1	4	Moderate
Lim et al. 2020 [24]	Retrospective cohort study	Institutional clinical database	3	1	2	6	Moderate
Preece et al. 2020 [27]	Retrospective cohort study	Institutional clinical database	2	0	2	4	Moderate
Rozental et al. 2020 [43]	Retrospective cohort study	Institutional clinical database	3	1	2	6	Moderate
Hugar et al. 2020 [18]	Retrospective cohort study	ACS-NSQIP	3	0	3	6	Moderate
Lo et al. 2021 [25]	Retrospective cohort study	Single-center institutional database	3	0	2	5	Moderate
Farzaneh et al. 2020 [10]	Retrospective cohort study	ACS-NSQIP	4	1	2	7	High
Fairman et al. 2020 [48]	Retrospective cohort study	Single-center institutional database	3	1	2	6	Moderate
Dua et al. 2020 [15]	Retrospective cohort study	NRD	3	2	2	7	High
Gray et al. 2020 [8]	Retrospective cohort study	UK Hospital Episode statistics (HES) database	4	2	3	9	High
Ribieras et al. 2023 [29]	Prospective cohort study	ACS-NSQIP	4	1	3	8	High

Table 1. Continued.

Study	Design	Data source	Selection (0–4)	Comparability (0–2)	Outcome (0–3)	Total (0–9)	Quality
Jacobs et al. 2022 [19]	Prospective cohort study	Single-center institutional database	4	1	2	7	High
Suckow et al. 2022 [51]	Retrospective cohort study	VQI	4	1	3	8	High
Corsi et al. 2022 [16]	Retrospective cohort study	Institutional electronic medical record database	2	1	2	5	Moderate
Le et al. 2022 [22]	Multicenter retrospective cohort	Multicenter clinical registry	3	1	3	7	Moderate
Polovneff et al. 2024 [26]	Retrospective cohort study	Single-center institutional database	3	1	2	6	Moderate

The methodological quality of non-randomized studies was assessed using the NOS. The scale evaluates three domains: Selection (0–4 points), Comparability (0–2 points), and Outcome (0–3 points), with a maximum score of 9 points. Studies scoring 7–9 points were considered high quality, 4–6 points moderate quality and less than or equal to three low quality.

The suffixes "a" and "b" identify two distinct studies published by the same first author in 2019 and are used to ensure consistent identification across the manuscript and figures, "a" indicates [14], "b" indicates [47].

NOS, Newcastle–Ottawa Scale; ACS, American College of Surgeons; NSQIP, National Surgical Quality Improvement Program; NRD, Nationwide Readmissions Database; HCUP, Healthcare Cost and Utilization Project; VQI, Vascular Quality Initiative.

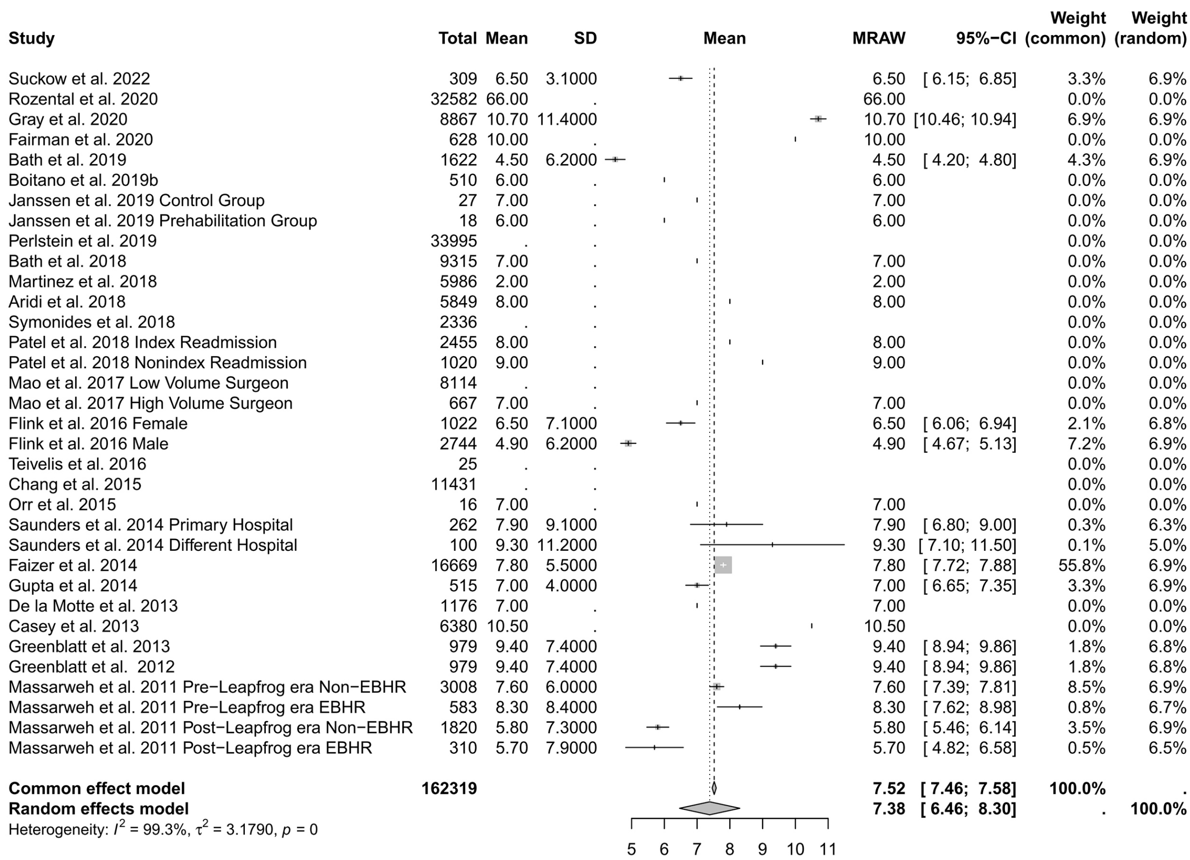

Fig. 2. Forest plot of the pooled length of stay after OAR.

Publication bias was assessed visually using funnel plots and statistically using Egger's test for funnel plot asymmetry. If Egger's test indicated potential publication bias, the trim-and-fill method was applied to estimate bias-corrected effect sizes. Funnel plot symmetry was subsequently reassessed and corrected estimates were compared with the original results. In all cases, the 95% confidence intervals of corrected and original estimates overlapped. Where applicable, the use of the trim-and-fill method is indicated in the Results section.

At the study level, two-sample t-tests were performed to compare pooled procedure-specific characteristics and outcomes between EVAR and OAR. These analyses were exploratory and intended to describe differences between sep-

Table 2. Heterogeneity of study-level variables (I^2 and τ^2) in EVAR and OAR analyses, based on pooled data from all studies included in the quantitative synthesis (n = 49).

Surgical procedure	OAR		EVAR	
Heterogeneity variables	I^2	τ^2	I^2	τ^2
30-day readmission	99%	0.4865	99%	0.3162
Patient characteristics				
Male sex	98%	0.0912	99%	0.3333
Female sex	98%	0.0905	99%	0.2259
Age (years)	100%	5.4223	100%	16.7636
Arterial hypertension	100%	0.9451	100%	0.7279
Congestive heart failure	99%	1.9244	99%	2.3490
Chronic kidney disease (stages 3–5)[1]	99%	1.1251	99%	2.8348
COPD[2]	98%	0.2275	99%	0.2013
Postoperative complications and length of stay				
Length of stay (days)	99%	3.1790	100%	4.1623
Stroke	0%	0	99%	2.9733
Graft/transplant-related complication[3]	98%	0.6828	99%	0.6790
Adverse cardiac complications[4]	98%	1.2423	99%	2.8776
Myocardial infarction	98%	0.7119	99%	1.8511
Bleeding, shock	100%	0.8543	96%	4.9240
Renal complication[5]	97%	0.9890	100%	2.7584
Wound infection	99%	1.2679	98%	2.6105
Respiratory complication[6]	97%	0.4515	100%	2.1836
Diagnosis leading to readmission 30 days after OAR and EVAR				
Wound infection	99%	1.0177	99%	1.9457
Cardiovascular complication (AMI/ACS)[7]	89%	0.1272	99%	0.3534
Chronic kidney disease	97%	0.5367	99%	2.0189
Gastrointestinal complication/Gastrointestinal obstruction	98%	0.8569	99%	0.6449
Stroke	83%	0.1339	88%	1.4634
Pneumonia	96%	0.2897	98%	4.0703
Sepsis	94%	0.2025	93%	0.1454
Device/graft complication	98%	0.2708	99%	0.6519
30 d-mortality	98%	1.1458	99%	1.6787

Study heterogeneity for pooled variables included in the meta-analysis is presented using the I^2 statistic and τ^2 (between-study variance) for both EVAR and OAR datasets. Across most variables, substantial heterogeneity was observed ($I^2 > 90\%$), reflecting considerable variability in patient populations, comorbidity profiles, perioperative management and healthcare system characteristics across the included studies. These findings support the use of random-effect models for pooled analyses and highlight the need for cautious interpretation of aggregated effect estimates; chronic kidney disease (stages 3–5)[1], glomerular filtration rate under 60 mL/min/1.73 m^2; COPD[2], chronic obstructive pulmonary disease; graft/transplant-related complication[3] including endoleaks type I and II for EVAR and for OAR including wound/graft complication or urinary tract infection (UTI); adverse cardiac complication[4] including congestive heart failure and ventricular arrhythmia; renal complication[5] including temporary or permanent renal replacement therapy and/or a documented doubling of the baseline creatinine level or acute kidney injury; Respiratory complication[6] including prolonged intubation (>48 h), reintubation, and/or pneumonia; cardiovascular complications[7] including acute myocardial infarction (AMI)/acute coronary syndrome (ACS) and arrhythmia.

arately pooled groups rather than to provide comparative effect estimates between procedures.

Meta-regression analyses were performed to evaluate whether patient comorbidities, length of stay and postoperative complications were associated with 30-day readmission rate. Effect estimates are reported with the 95% confidence intervals. These coefficients can be interpreted analogously to those from a linear regression model: positive coefficients indicate an increase in readmission rates with increasing values of the respective parameter, whereas negative coefficients indicate a decrease. The significance level was set at 0.05 and p-values $\leq$ 5% were considered significant.

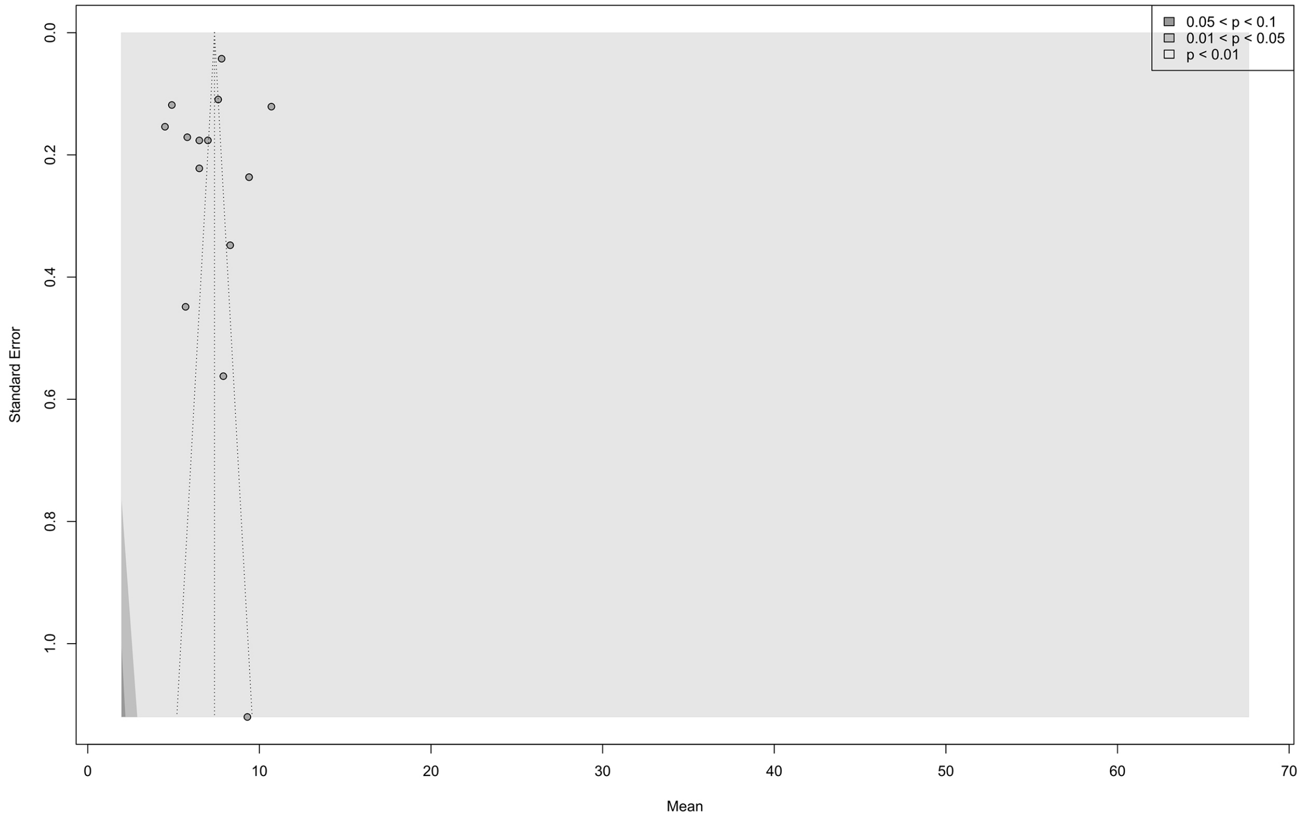

Fig. 3. Funnel plot of pooled length of stay after OAR.

Study Population

Most publications originate from the USA (n = 43/49). Other publications originate from the Netherlands, Brazil, Denmark, England, Italy, and Taiwan.

A total of 49 studies were included in the qualitative and quantitative synthesis (references listed in Table 1). Some studies contributed data to both the EVAR and OAR analyses when reporting direct within-study comparisons. In addition, several studies reported subgroup analyses (e.g., sex or age groups), which were treated as independent cohorts in the quantitative analysis but were assessed once in the methodological quality. Among the 49 included studies, 20 studies directly compared EVAR and OAR, 23 reported EVAR-only outcomes and 6 reported OAR-only outcomes. Consequently, 43 datasets contributed to the EVAR analysis and 26 datasets to the OAR analysis (Fig. 1).

The methodological quality assessment using the Newcastle-Ottawa Scale demonstrated a median score of 6 (range 4–9), with 21 studies classified as high quality, 28 as moderate quality. No study was classified as low quality (Table 1).

Results

Results of Explorative Analysis

Patients

The following procedure-specific comparisons are presented as exploratory analyses to describe differences between separately pooled EVAR and OAR cohorts. The primary objective of the study was to evaluate factors associated with 30-day readmission, which are reported in the subsequent meta-regression analyses.

The heterogeneity of the variables at the study level in the EVAR and OAR analyses is shown in Table 2. The baseline characteristics of the patients and comorbidities are listed in Table 3.

Patients undergoing EVAR were significantly older than those undergoing OAR (74.5 [73.2–75.7] years vs. 72.4 [71.4–73.4] years; p = 0.012). In addition, the proportion of patients with diabetes was higher in EVAR than in OAR (18% [15–20] vs. 13% [10–17]; p = 0.043). Furthermore, the proportion of male patients was significantly higher in EVAR than in OAR (79% [76–81] vs. 75% [72–77]; p = 0.001).

The minimum aneurysm diameter in the EVAR studies was 3.6 cm (3.2–3.9) and the maximum was 8.2 cm (± 2). Due to a lack of data, no information could be provided for OAR.

Postoperative Complications of Index Surgery

The length of stay was significantly longer for patients treated with OAR than for patients treated with EVAR (7.4 [6.5–8.3] days vs. 4.2 days [3.4–4.9]; p < 0.001) (Figs. 2,3,4,5 [3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51]).

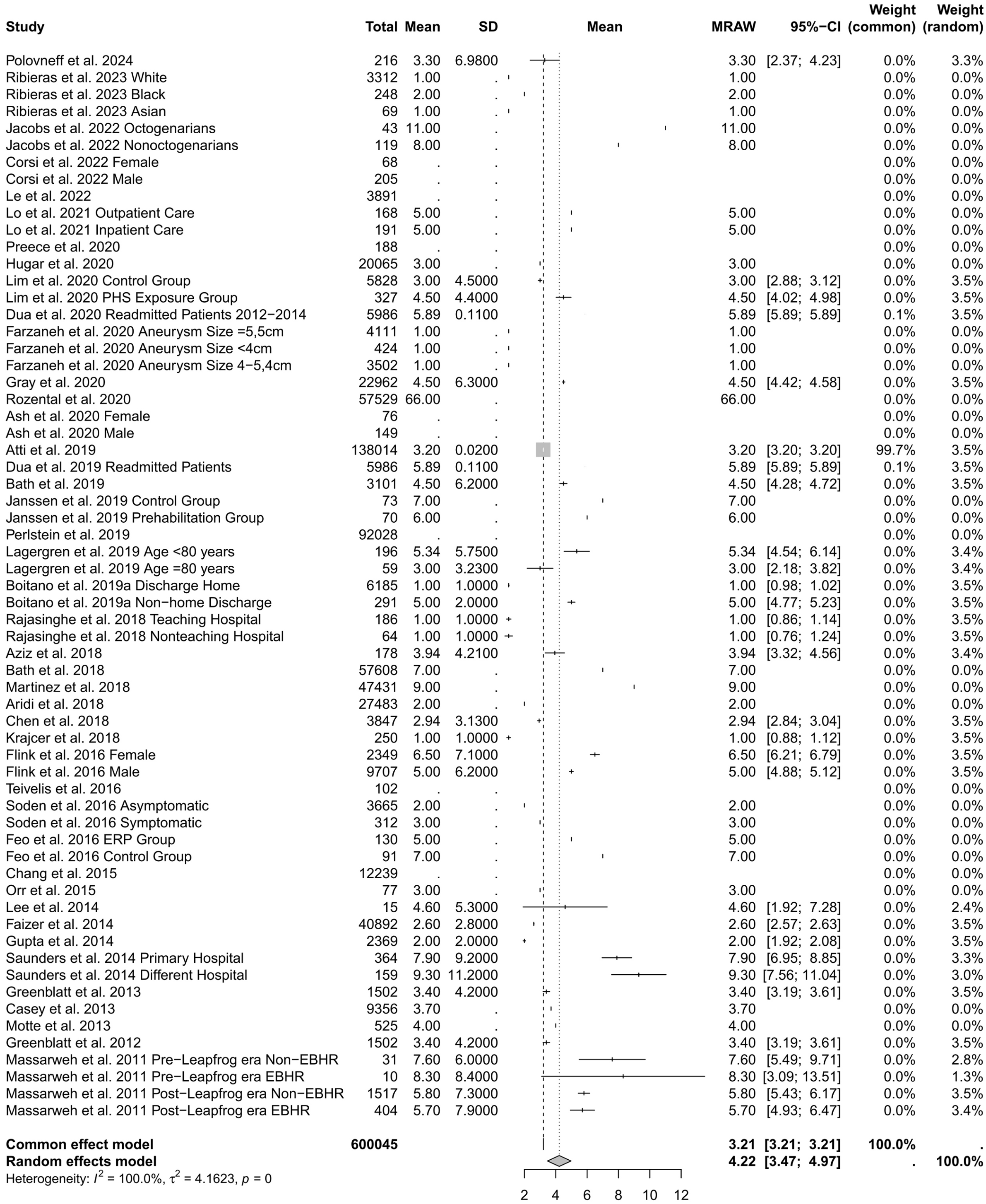

Fig. 4. Forest plot of pooled length of stay after EVAR.

Postoperative complications of the index procedure in EVAR and OAR patients are listed in Table 4.

Patients with OAR had significantly more adverse cardiac complications after the index procedure compared to EVAR (11% [6–19] vs. 3% [1–6]; p = 0.001), wound infections (5% [2–9] vs. 1% [0–2]; p = 0.014), and respiratory complications (20% [15–28] vs. 5% [3–11]; p = 0.001).

Readmission Rate

The 30-day readmission rate was significantly higher for OAR than for EVAR (13% [10–16] vs. 8% [7–9]; p = 0.003). Forest plots illustrating the pooled effect estimates and funnel plots assessing publication bias are listed in Figs. 6,7,8,9 [3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51].

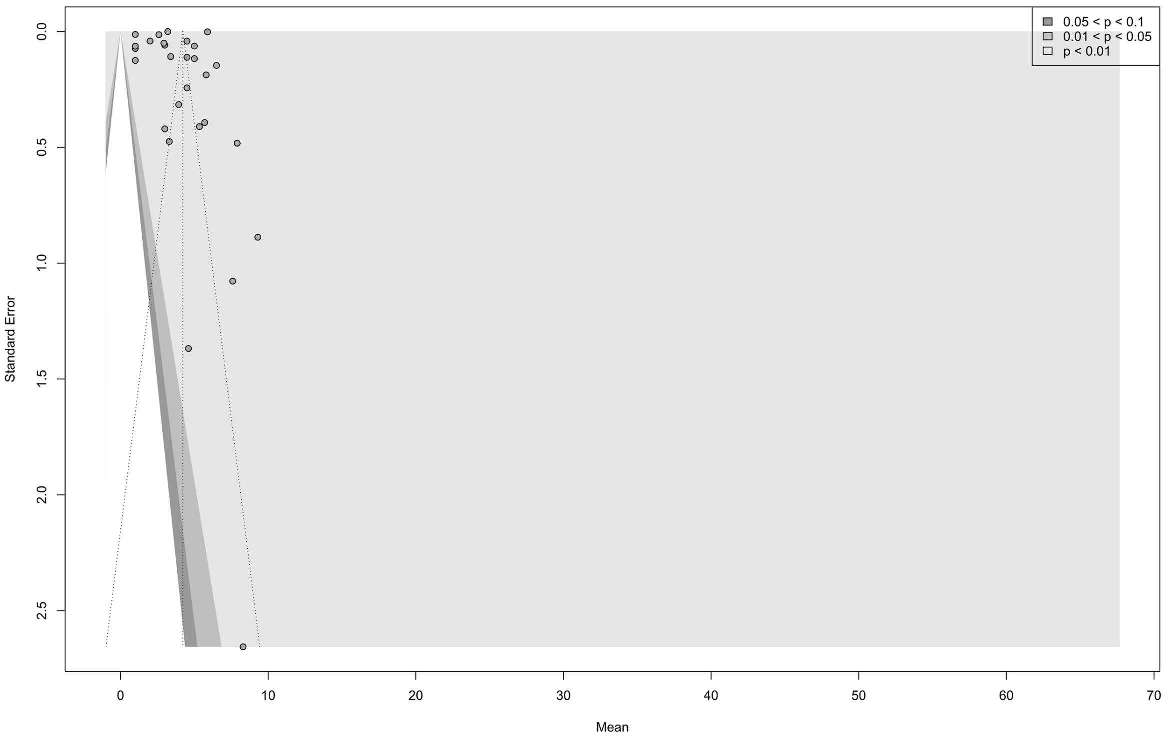

Fig. 5. Funnel plot of pooled length of stay after EVAR.

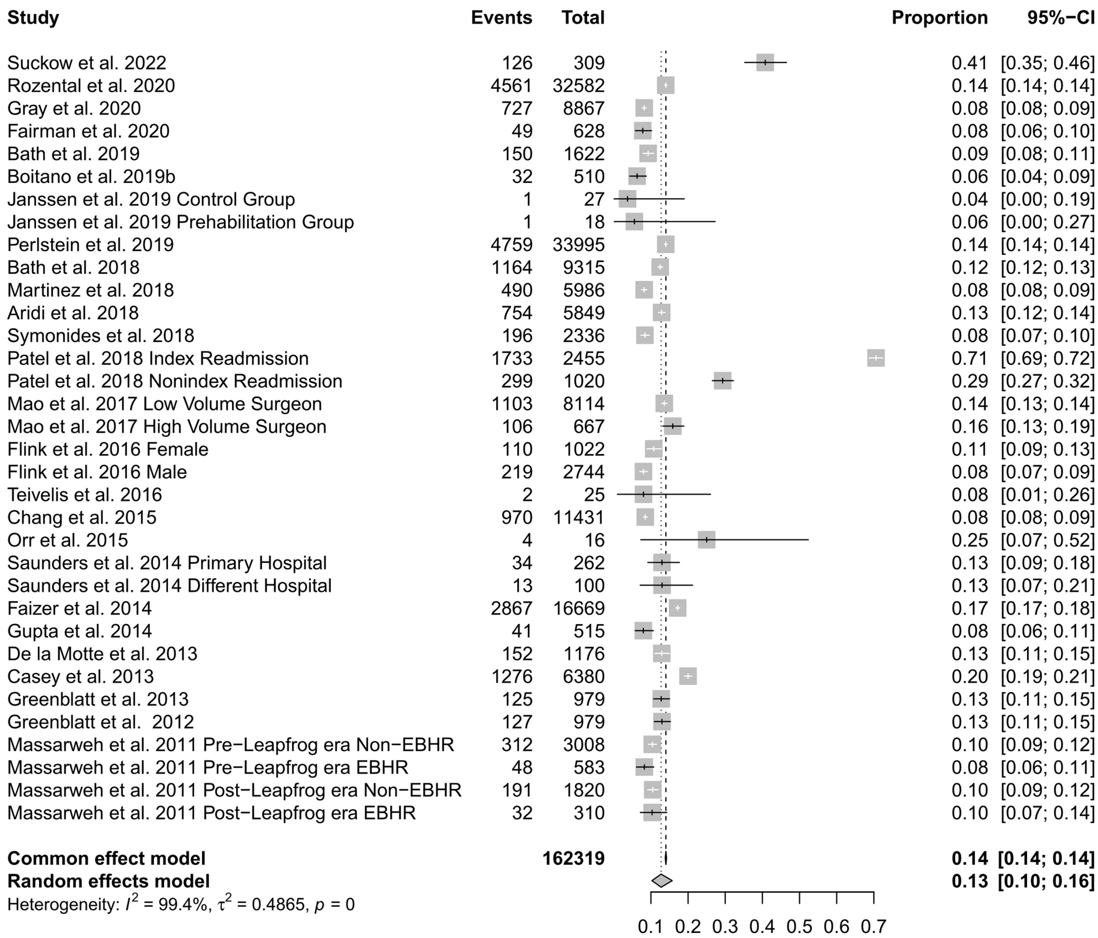

Fig. 6. Forest plot of pooled 30-day readmission rates after OAR. "b" indicates [47].

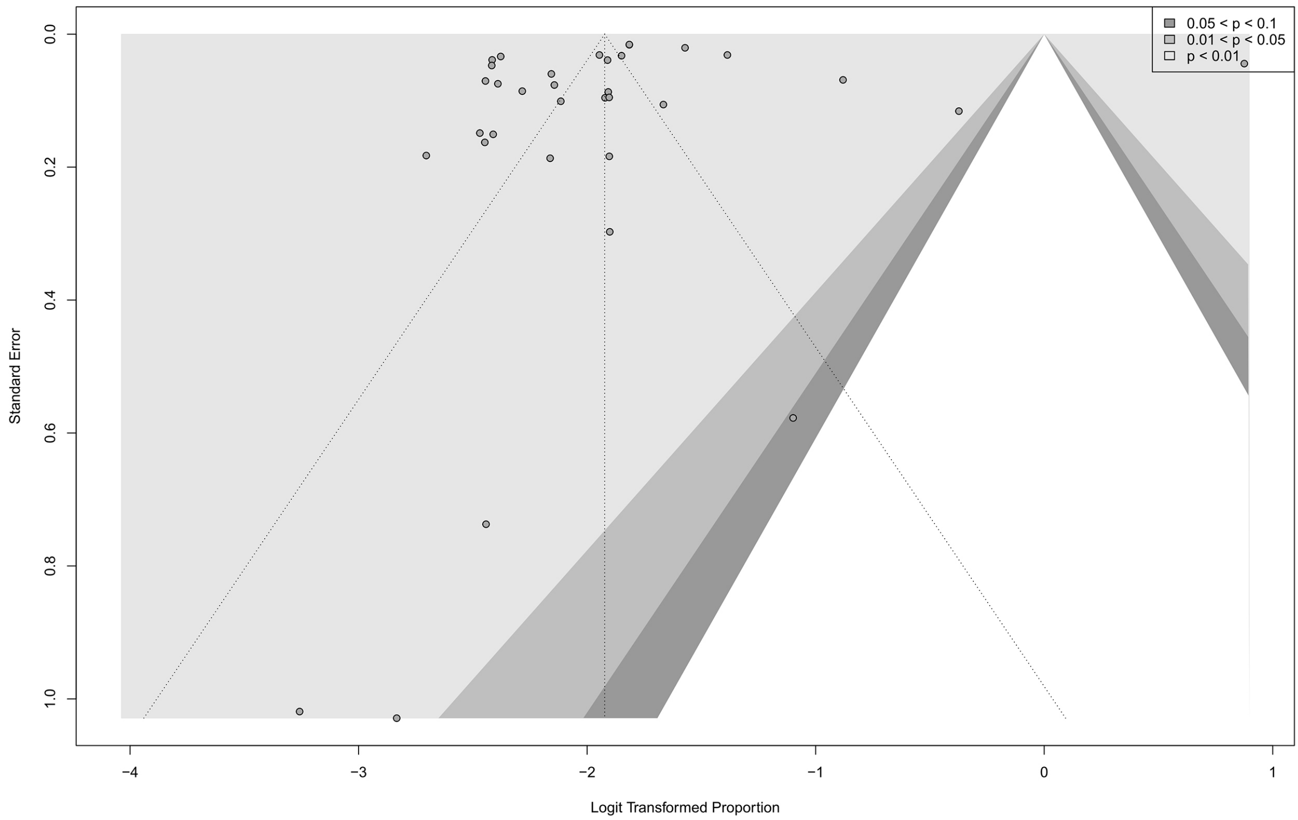

Fig. 7. Funnel plot of pooled 30-day readmission rates after OAR.

Twenty of the included studies reported data for both endovascular aneurysm repair (EVAR) and open aneurysm repair (OAR) within the same study population and were therefore eligible for direct comparison. The pooled random-effects meta-analysis showed no statistically significant difference in 30-day readmission between EVAR and OAR (Odds Ratio [OR] 0.91, 95% CI [0.82–1.01]). However, substantial heterogeneity across studies was observed ($I^2 = 93.8\%$). In fixed-effect analysis, EVAR was associated with slightly lower readmission (OR 0.93, 95% CI [0.91–0.95]), although this estimate should be interpreted cautiously given the substantial between-study heterogeneity.

The main diagnoses recorded at readmission after 30 days are listed in Table 5. The most common diagnoses leading to readmission after 30 days are wound infections (OAR 8% [4–14] vs. EVAR 13% [6–24]; $p = 0.226$) and cardiovascular complications (OAR 5% [4–7] vs. EVAR 9% [6–12]; $p = 0.028$). Patients with EVAR had significantly more cardiovascular complications than patients with OAR (9% [6–12] vs. 5% [4–7]; $p = 0.028$). Patients with OAR, on the other hand, were significantly more likely to be diagnosed with chronic kidney disease than patients with EVAR (3% [2–4] vs. 2% [1–4]; $p = 0.050$). The 30-day mortality rate did not differ between EVAR and OAR (EVAR 2% [1–5], OAR 2% [1–3]; $p = 0.703$).

Results of the Meta-Regression Analysis

30-Day Readmission Depending on Patient Characteristics and Comorbidities.

The impact of patient characteristics and comorbidities on 30-day readmission is shown in Table 6. In OAR, patient age had a significant impact on readmission after 30 days. The older the patients, the higher the readmission rate after 30 days (OAR: effect estimate 0.0817, 95% CI [0.0111–0.1522]; $p = 0.023$). In OAR and EVAR, a higher proportion of patients with arterial hypertension, congestive heart failure, chronic kidney disease, and COPD led to a higher 30-day readmission rate (arterial hypertension [OAR: effect estimate 0.0496, 95% CI [0.0484–0.0509], $p < 0.001$; EVAR: effect estimate 0.0512, 95% CI [0.0499–0.0524], $p < 0.001$]; congestive heart failure [OAR: effect estimate 0.1850, 95% CI [0.1410–0.2289], $p < 0.001$; EVAR: effect estimate 0.0263, 95% CI [0.0043–0.0483], $p = 0.019$]; chronic kidney disease [OAR: effect estimate 0.1160, 95% CI [0.0910–0.1410], $p < 0.001$; EVAR: effect estimate 0.1336, 95% CI [0.1135–0.1538], $p < 0.001$]; chronic obstructive pulmonary disease [OAR: effect estimate 0.0372, 95% CI [0.0172–0.0573], $p < 0.001$; EVAR: effect estimate 0.0187, 95% CI [0.0000–0.0373]; $p = 0.050$]). Gender showed no correlation with the readmission rate in either procedure (Table 6).

Study	Events	Total	Proportion	95%−CI
Polovneff et al. 2024	20	216	0.09	[0.06; 0.14]
Ribieras et al. 2023 White	241	3312	0.07	[0.06; 0.08]
Ribieras et al. 2023 Black	29	248	0.12	[0.08; 0.16]
Ribieras et al. 2023 Asian	6	69	0.09	[0.03; 0.18]
Jacobs et al. 2022 Octogenarians	4	43	0.09	[0.03; 0.22]
Jacobs et al. 2022 Nonoctogenarians	3	119	0.03	[0.01; 0.07]
Corsi et al. 2022 Female	12	68	0.18	[0.09; 0.29]
Corsi et al. 2022 Male	16	205	0.08	[0.05; 0.12]
Le et al. 2022	287	3891	0.07	[0.07; 0.08]
Lo et al. 2021 Outpatient Care	4	168	0.02	[0.01; 0.06]
Lo et al. 2021 Inpatient Care	4	191	0.02	[0.01; 0.05]
Preece et al. 2020	3	188	0.02	[0.00; 0.05]
Hugar et al. 2020	501	20065	0.02	[0.02; 0.03]
Lim et al. 2020 Control Group	553	5828	0.09	[0.09; 0.10]
Lim et al. 2020 PHS Exposure Group	60	327	0.18	[0.14; 0.23]
Dua et al. 2020 Readmitted Patients 2012−2014	694	5986	0.12	[0.11; 0.12]
Farzaneh et al. 2020 Aneurysm Size =5,5cm	250	4111	0.06	[0.05; 0.07]
Farzaneh et al. 2020 Aneurysm Size <4cm	30	424	0.07	[0.05; 0.10]
Farzaneh et al. 2020 Aneurysm Size 4−5,4cm	210	3502	0.06	[0.05; 0.07]
Gray et al. 2020	2388	22962	0.10	[0.10; 0.11]
Rozental et al. 2020	8054	57529	0.14	[0.14; 0.14]
Ash et al. 2020 Female	4	76	0.05	[0.01; 0.13]
Ash et al. 2020 Male	9	149	0.06	[0.03; 0.11]
Atti et al. 2019	14077	138014	0.10	[0.10; 0.10]
Dua et al. 2019 Readmitted Patients	694	5986	0.12	[0.11; 0.12]
Bath et al. 2019	201	3101	0.06	[0.06; 0.07]
Janssen et al. 2019 Control Group	4	73	0.05	[0.02; 0.13]
Janssen et al. 2019 Prehabilitation Group	5	70	0.07	[0.02; 0.16]
Perlstein et al. 2019	12883	92028	0.14	[0.14; 0.14]
Lagergren et al. 2019 Age <80 years	13	196	0.07	[0.04; 0.11]
Lagergren et al. 2019 Age =80 years	3	59	0.05	[0.01; 0.14]
Boitano et al. 2019a Discharge Home	408	6185	0.07	[0.06; 0.07]
Boitano et al. 2019a Non−home Discharge	27	291	0.09	[0.06; 0.13]
Rajasinghe et al. 2018 Teaching Hospital	1	186	0.01	[0.00; 0.03]
Rajasinghe et al. 2018 Nonteaching Hospital	1	64	0.02	[0.00; 0.08]
Aziz et al. 2018	13	178	0.07	[0.04; 0.12]
Bath et al. 2018	5876	57608	0.10	[0.10; 0.10]
Martinez et al. 2018	3225	47431	0.07	[0.07; 0.07]
Aridi et al. 2018	1923	27483	0.07	[0.07; 0.07]
Chen et al. 2018	315	3847	0.08	[0.07; 0.09]
Krajcer et al. 2018	4	250	0.02	[0.00; 0.04]
Flink et al. 2016 Female	253	2349	0.11	[0.10; 0.12]
Flink et al. 2016 Male	776	9707	0.08	[0.07; 0.09]
Teivelis et al. 2016	11	102	0.11	[0.06; 0.18]
Soden et al. 2016 Asymptomatic	282	3665	0.08	[0.07; 0.09]
Soden et al. 2016 Symptomatic	34	312	0.11	[0.08; 0.15]
Feo et al. 2016 ERP Group	0	130	0.00	[0.00; 0.03]
Feo et al. 2016 Control Group	3	91	0.03	[0.01; 0.09]
Chang et al. 2015	998	12239	0.08	[0.08; 0.09]
Orr et al. 2015	14	77	0.18	[0.10; 0.29]
Lee et al. 2014	3	15	0.20	[0.04; 0.48]
Faizer et al. 2014	6460	40892	0.16	[0.15; 0.16]
Gupta et al. 2014	180	2369	0.08	[0.07; 0.09]
Saunders et al. 2014 Primary Hospital	47	364	0.13	[0.10; 0.17]
Saunders et al. 2014 Different Hospital	20	159	0.13	[0.08; 0.19]
Greenblatt et al. 2013	199	1502	0.13	[0.12; 0.15]
Casey et al. 2013	1627	9356	0.17	[0.17; 0.18]
Motte et al. 2013	68	525	0.13	[0.10; 0.16]
Greenblatt et al. 2012	199	1502	0.13	[0.12; 0.15]
Massarweh et al. 2011 Pre−Leapfrog era Non−EBHR	3	31	0.10	[0.02; 0.26]
Massarweh et al. 2011 Pre−Leapfrog era EBHR	0	10	0.00	[0.00; 0.31]
Massarweh et al. 2011 Post−Leapfrog era Non−EBHR	159	1517	0.10	[0.09; 0.12]
Massarweh et al. 2011 Post−Leapfrog era EBHR	42	404	0.10	[0.08; 0.14]
Common effect model		**600045**	**0.11**	**[0.11; 0.11]**
Random effects model			**0.08**	**[0.07; 0.09]**

Heterogeneity: $I^2 = 99.0\%$, $\tau^2 = 0.3162$, $p = 0$

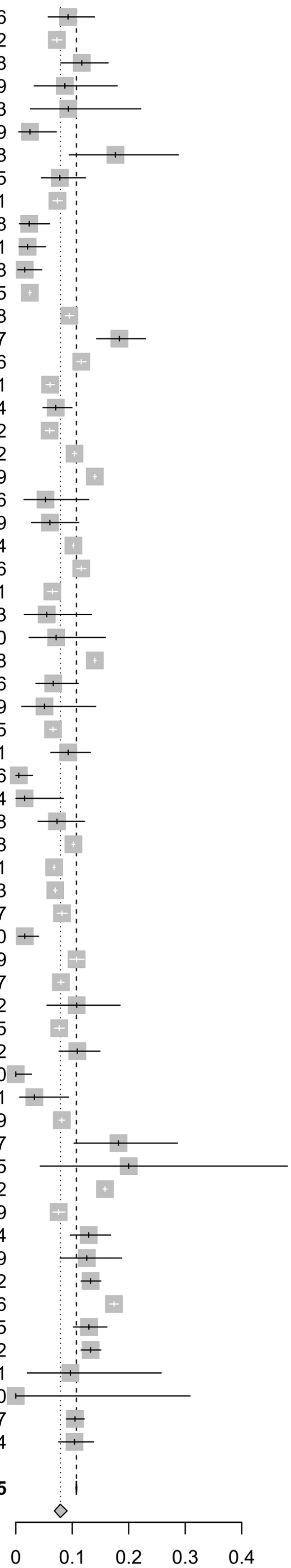

Fig. 8. Forest plot of pooled 30-day readmission rates after EVAR.

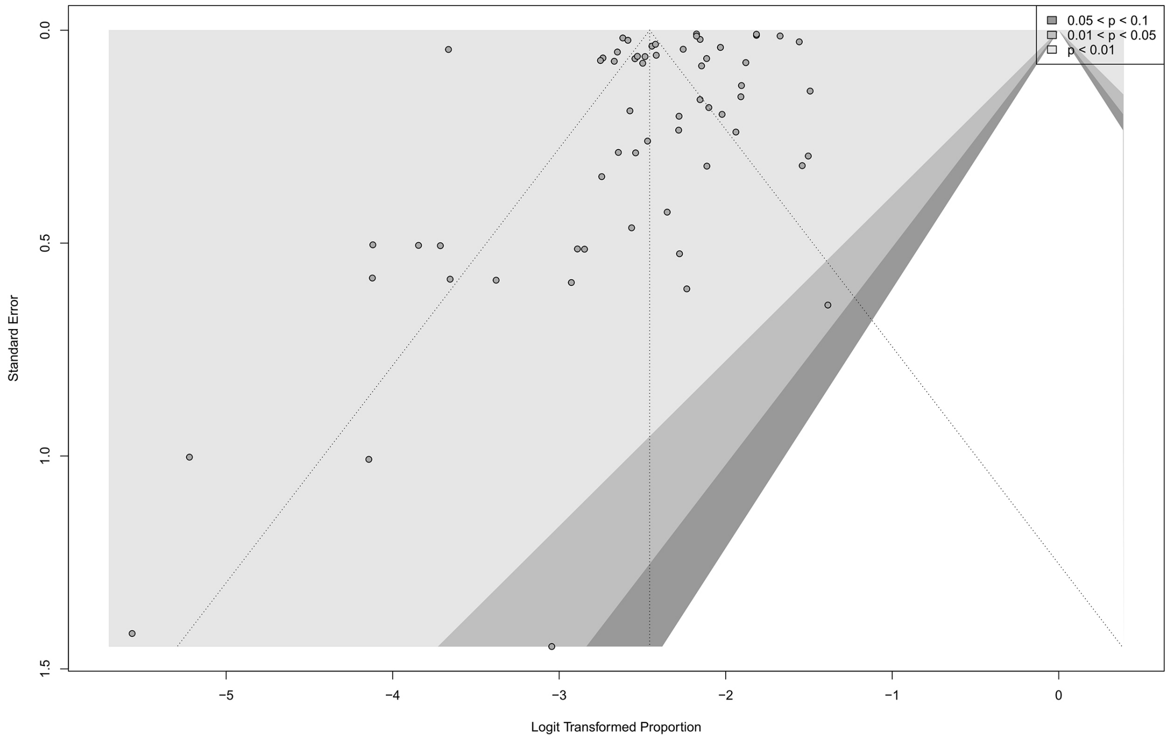

Fig. 9. Funnel plot of pooled 30-day readmission rates after EVAR.

Association Between Postoperative Complications and LOS of the Index Procedure and 30-Day Readmission

The relationship between postoperative complications of the index procedure, LOS and 30-day readmission is shown in Table 6. The primary inpatient length of stay for the index procedure showed no significant relationship with the readmission rate for either procedure. In EVAR, the occurrence of strokes had a significant influence on readmission after 30 days (EVAR: effect estimate 0.2206, 95% CI [0.1219–0.3193]; $p < 0.001$). For both OAR and EVAR, the proportion of patients with graft/transplant-related complications, adverse cardiac complications, and myocardial infarction correlated with the readmission rate after 30 days (graft/transplant-related complication [OAR: effect estimate 0.1447, 95% CI [0.0872–0.2002]; $p < 0.001$, EVAR: effect estimate 0.2870, 95% CI [0.2706–0.3034]; $p < 0.001$], adverse cardiac complication [OAR: effect estimate 0.0835, 95% CI [0.0641–0.1030]; $p < 0.001$, EVAR: effect estimate 0.1291, 95% CI [0.0879–0.1703]; $p < 0.001$], myocardial infarction [OAR: effect estimate 0.1427, 95% CI [0.1029–0.1761]; $p < 0.001$, EVAR: effect estimate 0.1122, 95% CI [0.0665–0.1579]; $p < 0.001$]). In both EVAR and OAR, bleeding/shock, renal complications, wound infections, and respiratory complications showed no correlation with the level of readmission.

Discussion

In this meta-analysis, EVAR was associated with a lower 30-day readmission rate (8%) compared with OAR (13%; $p = 0.003$). Dakour Aridi et al. [4] reported similar values (7.1% vs. 12.9%; $p < 0.001$), while Chen et al. [5] found a 30-day readmission rate of 8.2% after EVAR in the ACS-NSQIP database. Orr et al. [6] observed slightly higher readmissions after EVAR (14%) than OAR (13%; $p = 1.0$). The lower readmission rates after EVAR may reflect its less invasive nature, avoidance of laparotomy and aortic cross-clamping, reduced physiological stress, and faster recovery. In contrast, OAR involves greater surgical trauma and cardiopulmonary strain, increasing the risk of early postoperative complications. Differences in patient selection and postoperative management may also contribute to variations in readmission patterns.

In the direct comparative meta-analysis, no statistically significant difference in 30-day readmission was observed between EVAR and OAR. High statistical heterogeneity likely reflects variations in study design, patient populations, comorbidities, healthcare systems, and temporal changes in endovascular technology, perioperative management, and discharge pathways. The consistently high heterogeneity underscores that pooled estimates should be interpreted as average effects across highly diverse study populations rather than precise effect measures. The discrepancy between pooled procedure-specific readmission rates and the directly comparable meta-analysis likely reflects structural differences between study sets. Procedure-specific pooling includes non-comparative datasets, whereas the comparative analysis relies exclusively on studies reporting both procedures within the same population, thereby reducing confounding by study-level differences.

Table 3. Characteristics and comorbidities of patients undergoing OAR and EVAR, based on pooled data from all studies included in the quantitative synthesis (n = 49).

	OAR (n)	OAR, Mean (95% CI)	EVAR (n)	EVAR, Mean (95% CI)	*p* value
Total cohort	228,683		578,744		
Male sex	171,512	75% (72–77)	457,208	79% (76–81)*	0.001*
Female sex	57,171	25% (23–27)	121,536	21% (19–24)*	0.021*
Age (years)		72.4 (71.4 –73.4)		74.5 (73.2–75.7)	0.012
Arterial hypertension	111,433	64% (54–73)	314,792	77% (72–81)	0.371
Diabetes mellitus	30,659	13% (10–17)	82,151	18% (15–20)	0.043
Congestive heart failure	7920	6% (3–11)	24,714	4% (2–6)	0.398
COPD	60,952	26% (22–30)	135,885	22% (20– 24)*	0.494*
Chronic kidney disease[1] (stages 3–5)	24,843	8% (5–12)	54,957	5% (3–8)*	0.901*

Chronic kidney disease[1] (stages 3–5) glomerular filtration rate under 60 mL/min/1.73 m^2; * values determined using the "trim and fill" method.

Table 4. Postoperative complications and length of stay following index OAR and EVAR, based on pooled data from all studies included in the quantitative synthesis (n = 49).

	OAR (n)	OAR, Mean (95% CI)	EVAR (n)	EVAR, Mean (95% CI)	*p* value
Total cohort	228,683		578,744		
Length of stay (days)		7.4 (6.5–8.3)		4.2 (3.4–4.9)	<0.001
Stroke	2287	1% (0–1)	5787	1% (0–3)	0.759
Graft/transplant-related complication[1]	16,008	7% (4–14)	28,937	5% (2–8)	0.263
Adverse cardiac complication[2]	25,155	11% (6–19)	17,362	3% (1–6)	0.001
Myocardial infarction	9147	4% (2–7)	11,575	2% (1–6)	0.500
Bleeding, shock	22,868	10% (5–17)	5787	1% (0–7)	0.441
Acute kidney injury[3]	29,729	13% (8–22)*	11,575	2% (1–5)	0.170*
Wound infection	11,434	5% (2–9)	5787	1% (0–2)	0.014
Respiratory complication[4]	45,737	20% (15–28)	28,937	5% (3–11)	0.001

* values determined using the "Trim and Fill" method; graft/transplant-related complication[1] including endoleaks type I and II for EVAR and for OAR including wound/graft complication or UTI (urinary tract infection); adverse cardiac complication[2] including congestive heart failure and ventricular arrhythmia; acute kidney injury[3] including temporary or permanent renal replacement therapy and/or a documented doubling of the baseline creatinine level; respiratory complication[4] including prolonged intubation (>48 h), reintubation, and/or pneumonia.

Table 5. Diagnoses leading to readmission 30 days after OAR and EVAR, based on pooled data from all studies included in the quantitative synthesis (n = 49).

	OAR (n)	OAR, Mean (95% CI)	EVAR (n)	EVAR, Mean (95% CI)	*p* value
Total cohort	228,683		578,744		
Wound infection	18,295	8% (4–14)	75,237	13% (6–24)*	0.226*
Cardiovascular complication (AMI/ACS)[1]	11,434	5% (4–7)	52,087	9% (6–12)	0.028
Chronic kidney disease	6860	3% (2–4)	11,575	2% (1–4)	0.050
Gastrointestinal complication/obstruction	13,721	6% (3–10)	3472	6% (4–8)	0.916
Stroke	4574	2% (1–2)	11,575	2% (1–4)*	0.216*
Pneumonia	13,723	6% (4–8)	40,512	7% (3–15)*	0.878*
Sepsis	13,721	6% (4–8)	46,270	8% (7–10)*	0.246
Device/graft complication	9147	4% (3–6)	34,725	6% (4–10)	0.260
30 d-mortality	4574	2% (1–3)	11,575	2% (1–5)	0.703

* values determined using the "Trim and Fill" method; cardiovascular complications[1] including acute myocardial infarction (AMI)/acute coronary syndrome (ACS).

EVAR was consistently associated with shorter postoperative hospital stay (4.2 vs. 7.4 days; $p < 0.001$), consistent with reports from de la Motte et al. [7], Gray et al. [8], and Behrendt et al. [52]. No significant association was found between length of stay and 30-day readmission for either procedure, suggesting that shorter hospitalization does not inherently increase rehospitalization risk. Reduced LOS may reflect improved perioperative care

Table 6. Meta-regression analysis evaluating the association between study-level variables and 30-day readmission following OAR and EVAR, based on pooled data from all studies included in the quantitative synthesis (n = 49).

	OAR			EVAR		
	Effect estimate	95% CI	*p* value	Effect estimate	95% CI	*p* value
Patient characteristics						
Male sex	–0.0248	–0.0312–0.0014	0.062	–0.0149	–0.0314–0.0016	0.076
Female sex	0.0248	–0.0013–0.0312	0.061	0.0149	–0.0016–0.0314	0.076
Age (years)	0.0817	0.0111–0.1522	0.023	0.0183	–0.0331–0.0697	0.486
Arterial hypertension	0.0496	0.0484–0.0509	<0.001	0.0512	0.0499–0.0524	<0.001
Congestive heart failure	0.1850	0.1410–0.2289	<0.001	0.0263	0.0043–0.0483	0.019
Chronic kidney disease (stages 3–5)[1]	0.1160	0.0910–0.1410	<0.001	0.1336	0.1135–0.1538	<0.001
COPD	0.0372	0.0172–0.0573	<0.001	0.0187	0.0000–0.0373	0.050
Postoperative complications and length of stay						
Length of stay (days)	0.0004	–0.0256–0.0265	0.973	0.0113	–0.0036–0.0262	0.136
Stroke	0.5605	–0.6304 –1.7514	0.356	0.2206	0.1219–0.3193	<0.001
Graft/transplant-related complication	0.1447	0.0872–0.2002	<0.001	0.2870	0.2706–0.3034	<0.001
Adverse cardiac complications	0.0835	0.0641–0.1030	<0.001	0.1291	0.0879–0.1703	<0.001
Myocardial infarction	0.1427	0.1029–0.1761	<0.001	0.1122	0.0665–0.1579	<0.001
Bleeding, shock	0.0085	–0.0114–0.0284	0.401	0.0161	–0.0244–0.0566	0.436
Renal complication	0.0329	–0.0052–0.0710	0.091	0.0074	–0.0145–0.0292	0.510
Wound infection	0.0090	–0.0181–0.0362	0.515	0.0373	–0.0071–0.0817	0.410
Respiratory complication	0.0104	–0.0281–0.0490	0.596	0.0072	–0.0069–0.0214	0.316

Chronic kidney disease (stages 3–5)[1] glomerular filtration rate under 60 mL/min/1.73 m^2.

pathways, whereas prolonged hospitalization may indicate complications or higher baseline comorbidity. These findings align with enhanced recovery after surgery programs, where shortened LOS is not associated with increased readmission or complication rates [53,54], whereas longer stays in complex surgeries can reflect higher readmission risk [55].

The broader question of whether 30-day readmission is a reliable hospital quality indicator was addressed by Tsai et al. [2]. High-volume hospitals and those with lower surgical mortality had significantly lower readmission rates, suggesting that readmission reflects both procedural and institutional factors. In our meta-analysis, no association was found between postoperative mortality and 30-day readmission, as patients who die within 30 days cannot be readmitted, representing a competing risk that may influence the interpretation of readmission rates. Patient comorbidities strongly influence readmission risk. Table 6 shows that arterial hypertension, congestive heart failure, chronic kidney disease, and COPD were significant risk factors in both EVAR and OAR, while age affected OAR readmissions. Not all readmissions reflect perioperative deficiencies; some, such as wound infections, may be prevented through careful management, meticulous surgical technique, and standardized postoperative pathways. In EVAR, device-related complications such as endoleaks may be influenced by anatomical and patient-specific factors. Adherence to anatomical suitability criteria remains critical, and off-label EVAR is associated with higher complication risk, indicating that careful patient selection can reduce some device-related readmissions.

Meta-regression showed that postoperative cardiac and graft-related complications were associated with higher 30-day readmission for both EVAR and OAR, with stroke additionally increasing EVAR readmissions (Table 6). Gastrointestinal complications, such as ileus, were more frequent after OAR, whereas graft-related complications occurred more often after EVAR [4,9]. These complications—including wound, renal/urological, cardiac issues, and reoperations—substantially influence readmission risk.

Procedure-specific differences in post-30-day readmission diagnoses were observed (Table 5): renal failure was more frequent after OAR (3% vs. 2%; $p = 0.050$), and cardiovascular complications were more common after EVAR (9% vs. 5%; $p = 0.028$).

Data on 90-day readmission were heterogeneous and insufficient for meta-analysis. Frailty, comorbidity burden, and post-discharge care appear to drive longer-term readmissions. Sparse and inconsistent data highlight the need for standardized outcome definitions and harmonized reporting to enable reliable long-term comparisons.

Limitations

Most studies were of moderate-to-high quality (Newcastle-Ottawa Scale). Meta-regression analyses were based on study-level aggregated data and may not reflect individual patient relationships (ecological bias). Most publications originated from the USA, with data from large administrative databases such as the Nationwide Readmissions Database (NRD) and National Surgical Quality Improvement Program (NSQIP). Healthcare systems, reimbursement policies, discharge practices, and post-acute care utilization differ across countries, so generalizability is limited.

Many datasets lacked detailed information on social determinants of health, hospital case volumes, and surgeon experience, which may confound associations between procedure type and readmission outcomes. Most studies were retrospective and observational, inherently susceptible to residual confounding, selection bias, and coding inaccuracies. The primary comparison between EVAR and OAR relied on procedure-specific pooled proportions rather than exclusively comparative effect estimates, which may introduce structural differences.

Studies spanned extended periods during which endovascular technology, perioperative management, and discharge pathways evolved, contributing to temporal heterogeneity in complications and readmission patterns. Variations in follow-up care, access to outpatient services, and structured home nursing or rehabilitation may further influence readmission independently of procedural characteristics. Data on 90-day readmission were insufficient and too heterogeneous for meta-analysis, limiting conclusions regarding longer-term rehospitalization. The limited number of directly comparative studies relative to total datasets may affect the stability of pooled comparative estimates.

Conclusions

Pooled data suggest lower 30-day readmission rates after EVAR compared with OAR. However, given the substantial heterogeneity and the predominance of observational study designs, these findings should be interpreted cautiously and regarded as hypothesis-generating rather than prescriptive. Readmissions were frequently associated with patient comorbidities and procedure-related complications, such as cardiac events, in both OAR and EVAR. Furthermore, stroke was also associated with an increased readmission rate in EVAR. These observations underscore the importance of careful patient selection and individualized procedural planning, particularly in high-risk patients, where minimally invasive approaches may offer advantages. No significant relationship was observed between postoperative length of stay and readmission rate, suggesting that shorter hospitalization does not necessarily increase rehospitalization risk.

Future quality assessment frameworks should incorporate risk-adjusted readmission metrics that account for patient comorbidity burden and baseline risk profiles. Extended follow-up intervals, such as 90-day readmission, and structured evaluation of potentially avoidable readmissions may allow a more nuanced and equitable assessment of healthcare quality in abdominal aortic aneurysm repair.

Future research should prioritize prospective, multicenter studies with detailed patient-level data, including social determinants of health, to distinguish modifiable from non-modifiable drivers of readmission. The establishment of standardized and harmonized datasets would enable cross-national comparisons of extended follow-up metrics. Finally, developing abdominal aortic aneurysm-specific readmission risk prediction models could improve risk adjustment and provide a more clinically meaningful interpretation of quality indicators.

Availability of Data and Materials

The data used and analyzed during the current study are available from the corresponding author on reasonable request.

Author Contributions

CB, JE, RG, AH, SD and RTG were involved in the conception and design of the study. CB was responsible for data collection and preparing the data for statistical analysis. The analysis was then carried out by RG, CB and JE. The first draft of the manuscript was written by RTG and CB. All authors contributed to the critical revision of the manuscript for important intellectual content. All authors read and approved the final manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

Not applicable.

Acknowledgment

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Conflict of Interest

The authors declare no conflict of interest.

Supplementary Material

Supplementary material associated with this article can be found, in the online version, at https://doi.org/10.62713/aic.4536.

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