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ORIGINAL ARTICLE

Burns

Free Flap Failure and Complications in Acute Burns: A Systematic Review and Meta-analysis

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Background: Severe acute burn injuries represent a challenge to the reconstructive surgeon. Free flap reconstruction might be required in cases of significant critical structure exposure and soft tissue deficits, when local options are unavailable. This study aimed to determine the free flap complication rate in acute burn patients.

Methods: A systematic review and meta-analysis were conducted and reported according to Preferred Reporting Items for Systematic Reviews and Meta-Analysis guidelines and registered on the International Prospective Register of Systematic Reviews database (CRD42023404478). The following databases were accessed: Embase, PubMed, Web of Science, and Cochrane Library. The primary outcome was the free flap failure rate.

Results: The study identified 31 articles for inclusion. A total of 427 patients (83.3% men, 16.7% women) accounting for 454 free flaps were included. The mean patient age was 36.21 [95% confidence interval (CI), 31.25–41.16]. Total free flap loss rate was 9.91% [95% CI, 7.48%–13.02%], and partial flap loss was 4.76% [95% CI, 2.66%–8.39%]. The rate of venous thrombosis was 6.41% [95% CI, 3.90%–10.36%] and arterial thrombosis was 5.08% [95% CI, 3.09%–8.26%]. Acute return to the operating room occurred in 20.63% [16.33%–25.71%] of cases. Stratified by body region, free flaps in the lower extremity had a failure rate of 8.33% [95% CI, 4.39%–15.24%], whereas in the upper extremity, the failure rate was 6.74% [95% CI, 3.95%–11.25%].

Conclusion: This study highlights the high risk of free flap complications and failure in acute burn patients. *(Plast Reconstr Surg Glob Open 2023; 11:e5311; doi: 10.1097/GOX.0000000000005311; Published online 9 October 2023.)*

INTRODUCTION

Burn injuries are a global health issue, with over 8 million cases reported globally in 2019, resulting in more than 110,000 fatalities that same year.[1] Skin grafting is generally an effective strategy for reconstructing partial and full-thickness burns, as it restores skin functionality and increases survival rates, especially in burn patients with a high total body surface area affected.[2,3]

In instances where wounds are not suitable for skin grafting, the temporary application of interim treatments such as skin substitutes or negative pressure dressings can be beneficial. These solutions promote neovascularization of the wound bed, often enabling subsequent skin grafting in a two-stage process.[4–6]

However, in cases of extensive exposure of critical structures (such as the bone, cartilage, tendons, or neurovascular bundles), flap reconstruction proves to be a more appropriate choice.[7,8] It allows for a single-stage reconstruction, thus reducing healing time and hospital period.[8,9] Thus, flap reconstruction may decrease the complications associated with delayed wound healing, which include dehydration of exposed structures and infection.[10]

In circumstances where local flaps are either unavailable or deemed unsuitable, free flaps are utilized. Free flaps allow for the transfer of healthy and well-vascularized tissue from donor areas located far from the injury zone, thereby covering deep and large defects. Although flap application in acute burns is typically limited to cases of exceptionally severe soft tissue loss or

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limb-preservation scenarios, there is a paucity of data on the implications of free flap reconstruction in acute burns.[8] This study aimed to determine the failure rate and complication rate of free flaps used in the reconstruction of acute burns.

MATERIALS AND METHODS

This systematic review was reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analysis guidelines.[11] Institutional review board approval and informed consent were not required for this study because all the reported data were obtained from the published literature. The review protocol was registered on International Prospective Register of Systematic Reviews database (CRD42023404478).

Inclusion and Exclusion Criteria

The PICOS framework was used in developing the literature search strategy: population (P), acute burn patients; intervention (I), free flap reconstruction; comparator (C), none; outcome (O), total free flap loss; study type (S), randomized controlled trials, prospective and retrospective cohort studies, and case series.[12] Studies were excluded if (a) they were not in English, (b) they were not available in full-text form, (c) data on free flap loss were not extractable, (d) the study reported fewer than five patients, (e) the article type was a conference abstract, review, case report, book chapter, or letter to the editor,

Takeaways

Question: This study is the first meta-analysis investigating the prevalence of free flap failure in acute burn reconstruction, which has been estimated to be around 9.91%.

Findings: This study investigates the prevalence of complications related to free flap reconstruction in acute burns, including vascular thrombosis of the microanastomosis, infection, acute return to the operating room, and subanalysis of free flap failure based on body area and burn etiology.

Meaning: This study highlights the high risk of free flap complications and failure in acute burn patients.

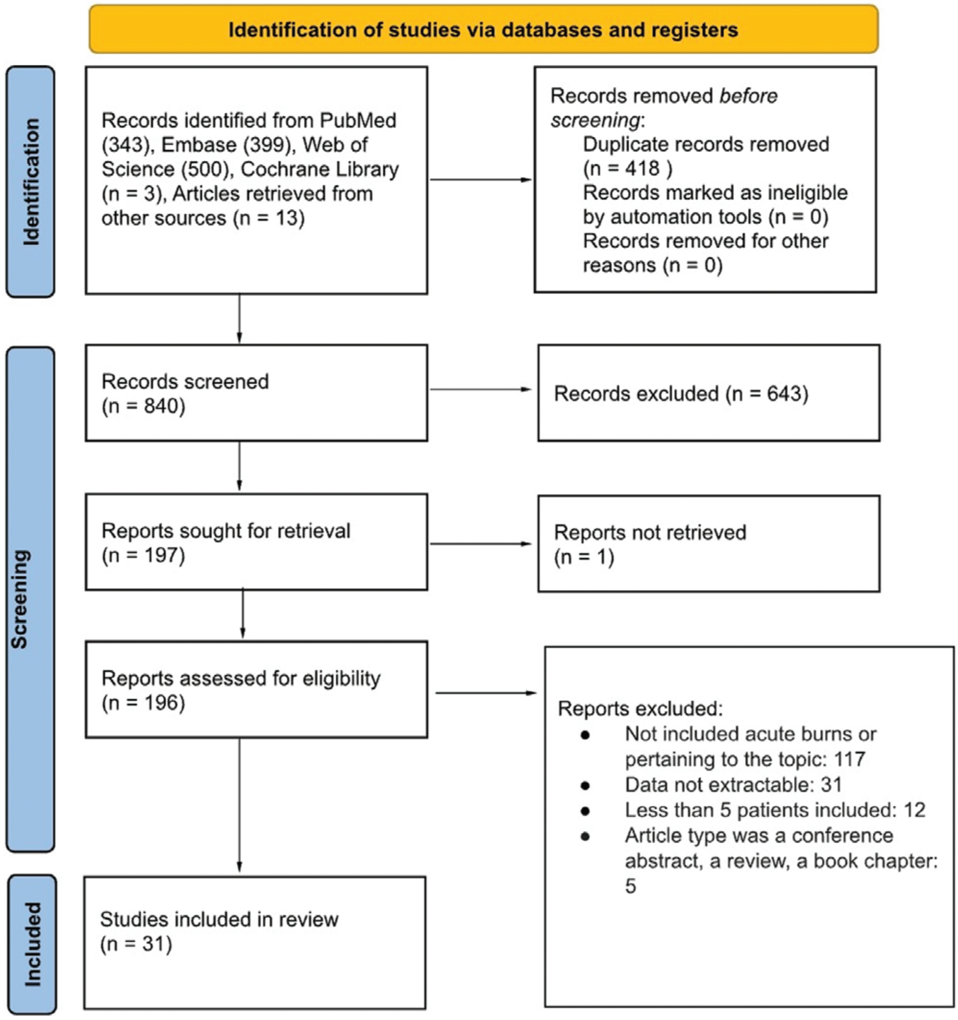

Fig. 1. Prisma flow diagram.

or (f) data presented were not specific to acute burn injuries. No restriction on publication date was applied, but articles had to be published in a peer-reviewed journal. Only free flaps performed within 6 weeks from the day of injury were included. Flap failure was defined as complete flap necrosis.

Outcome Measures

This systematic review aimed to measure the overall risk of free flap loss in acute burns as the primary outcome. Secondary outcomes included rates of partial flap loss, infection, arterial thrombosis, venous thrombosis, and rate of comeback to the operating room. The risk of flap loss in different anatomical areas as well as for different burn etiologies was also assessed.

Among the different anatomical locations, subgroup analysis was performed only for total and partial free flap loss rates in upper extremity and lower extremity acute burns, due to insufficient data on other body parts. Etiologies were divided into electrical and nonelectrical

Study	Events	Total	Events per 100 observations GLMM, Fixed, 95% CI
Al-Qattan et al.	0	8	0.00 [0.00; 36.94]
Barisoni et al.	1	10	10.00 [0.25; 44.50]
Baumeister et al.	10	43	23.26 [11.76; 38.63]
Brewin et al.	0	7	0.00 [0.00; 40.96]
Castro et al.	0	5	0.00 [0.00; 52.18]
Cerkes et al.	0	6	0.00 [0.00; 45.93]
Chick et al.	0	7	0.00 [0.00; 40.96]
Di et al.	0	8	0.00 [0.00; 36.94]
Handschin et al.	4	9	44.44 [13.70; 78.80]
Hsiao et al.	1	5	20.00 [0.51; 71.64]
Jabir et al.	0	23	0.00 [0.00; 14.82]
Koul et al.	1	16	6.25 [0.16; 30.23]
Liu et al.	0	7	0.00 [0.00; 40.96]
Monga et al.	3	20	15.00 [3.21; 37.89]
Pan et al.	0	38	0.00 [0.00; 9.25]
Parrett et al.	1	7	14.29 [0.36; 57.87]
Pedrazzi et al.	2	12	16.67 [2.09; 48.41]
Pessoa Vaz et al.	2	15	13.33 [1.66; 40.46]
Saint-Cyr et al.	3	15	20.00 [4.33; 48.09]
Sauerbier et al.	5	21	23.81 [8.22; 47.17]
Shen et al.	9	54	16.67 [7.92; 29.29]
Silverberg et al.	1	6	16.67 [0.42; 64.12]
Stefanacci et al.	1	12	8.33 [0.21; 38.48]
Uslu	0	11	0.00 [0.00; 28.49]
Yang et al.	0	11	0.00 [0.00; 28.49]
Yang et al.	0	15	0.00 [0.00; 21.80]
Yu et al.	0	11	0.00 [0.00; 28.49]
Zhang et al.	0	14	0.00 [0.00; 23.16]
Zhao et al.	0	12	0.00 [0.00; 26.46]
Zhou et al.	0	12	0.00 [0.00; 26.46]
Ziegler et al.	1	14	7.14 [0.18; 33.87]
Total (95% CI)		**454**	**9.91 [7.48; 13.02]**
Prediction interval			**[0.64; 38.29]**

Heterogeneity: $Tau^2 = 1.1185$; $Chi^2 = 8.97$, df = 30 ($P = 1.00$); $I^2 = 0\%$

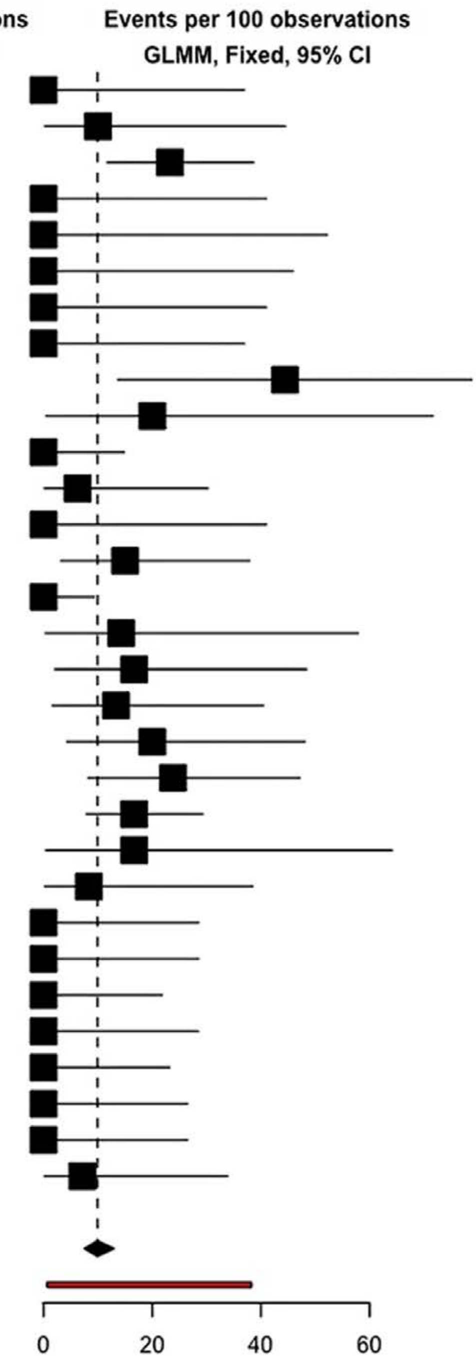

Fig. 2. Forest plot showing the prevalence of total free flap loss in acute burns.

burns. Nonelectrical burns could not be further stratified based on a more specific etiology due to unreported data.

Data Source and Study Search

An electronic search was performed on PubMed, Embase, Web of Science, and Cochrane Library using relevant keywords, phrases, and medical subject headings (MeSH) terms. The search strategy applied for PubMed was as follows: ("Burns"[MeSH Terms] OR "burn"[All Fields]) AND ("Free Tissue Flaps"[MeSH Terms] OR "free tissue"[All Fields] OR "free flaps"[All Fields]) AND ("fail*"[All Fields] OR "issue*"[All Fields] OR "complic*"[All Fields]). The reference lists of review articles and included articles were checked to screen for potentially relevant studies (ie, snowballing method). The search was carried out on February 8, 2023.

Selection of Studies and Data Extraction

Two reviewers independently conducted the electronic literature search (J. A. K. and H. Y. L.). The reference lists from four databases (ie, PubMed, Embase, Web of Science, and Cochrane Library) were merged, and the duplicates were removed using the reference management software EndNoteX9 (version X9.3.3). Titles and abstracts were screened for relevance. Whenever appropriate, full texts of relevant articles underwent subsequent evaluation for eligibility. Discrepancies were resolved by the senior author (F.M.E.). Data extracted from selected articles were archived in an Excel (Microsoft Corp, Seattle, Wash.) spreadsheet. Collected variables included the number of free flaps and free flap complications (total and partial flap loss, arterial and venous thrombosis, infection), need for acute return to the operating room, patient demographics (gender, age, percentage of total body surface area, follow-up), burn etiology, and area of the body requiring a free flap reconstruction.

Reasons for acute return to the operating room included revision of the anastomosis, hematoma evacuation, debridement due to flap necrosis or infection, and need for further skin grafting. Burns were separated into electrical and nonelectrical etiology. Nonelectrical burns could not be divided into further subgroups due to unreported data.

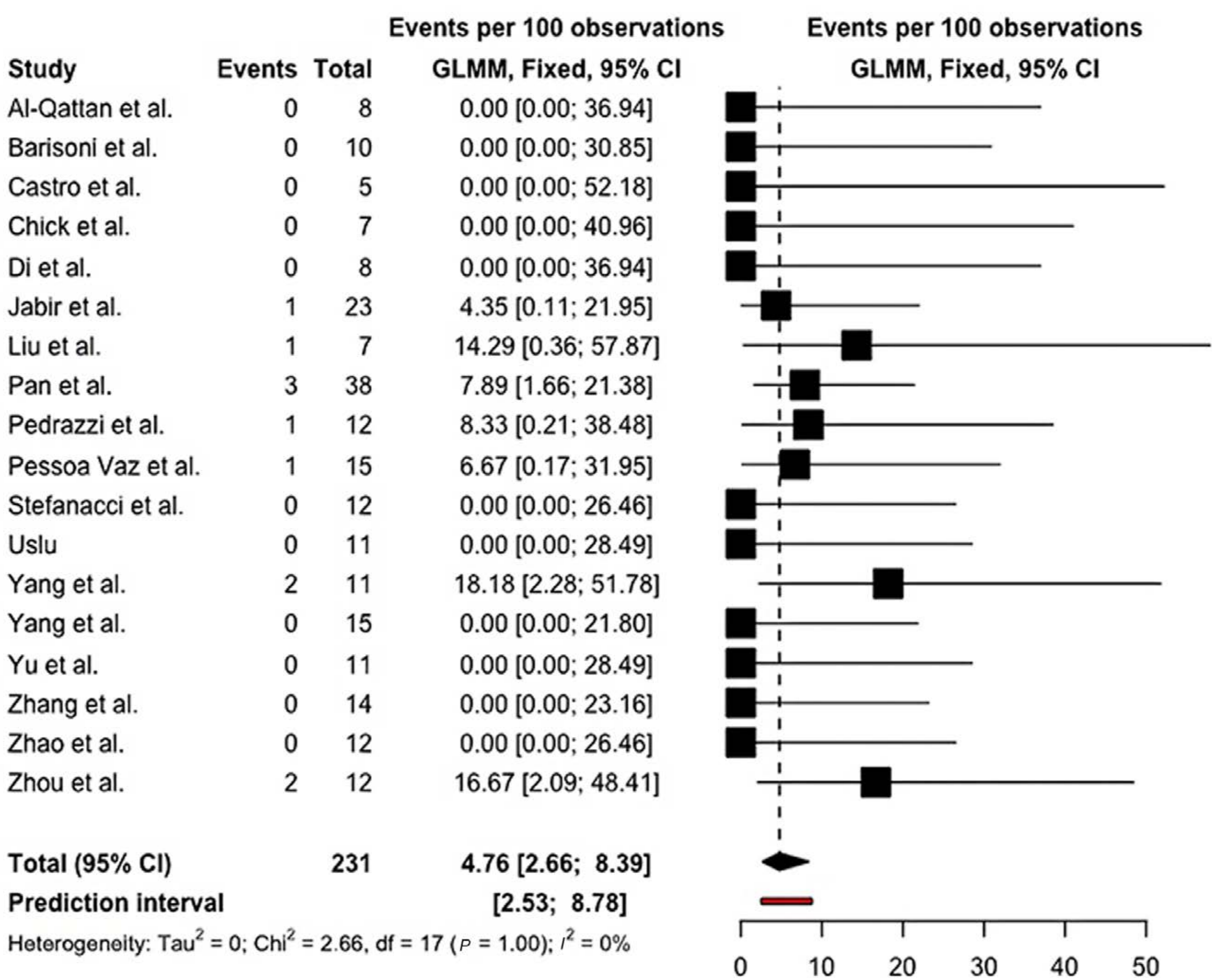

Fig. 3. Forest plot showing the prevalence of partial free flap loss in acute burns.

Risk of Bias and Study Quality Assessment

The methodological quality of included studies was assessed independently by two separate authors (J.A.K. and H.Y.L.). Because no RCTs were included, the Methodological Index for Nonrandomized Studies (MINORS) criteria were used to measure study quality.[13] The MINORS maximum score for noncomparative studies is 16.[13] (**See table, Supplemental Digital Content 1,** which displays MINORS scores of the included studies. **http://links.lww.com/PRSGO/C792**.)

Data Synthesis and Statistical Analysis

Data from the included studies were summarized using descriptive statistics. Dichotomous variables were reported as frequencies and percentages, whereas continuous variables were reported as a mean, with a 95% confidence interval (CI) calculated using the method described by McGrath et al.[14]

A single-arm meta-analysis of proportions was performed for all outcomes on the entire cohort using a logistic regression model. The maximum-likelihood estimator was used to estimate the between-study variance (τ^2). Results are presented as pooled estimates with a 95% CI. A forest-plot graph was created for each outcome. Cochran Q method was used to assess heterogeneity between studies.[15] I^2 was calculated as a measure of heterogeneity.[16] An I^2 value represents the percentage of total variation across studies caused by heterogeneity rather than by chance. If the heterogeneity test produced a low probability value (Q-statistic, $P < 0.05$), a more conservative random effects model was used. If not, a fixed effects model was used. All the analyses were performed using the R software for statistical computing (R version 4.0.1; "meta" package).

Analysis of publication bias was performed by inspection of the funnel plot and calculating the Peter linear

Study	Events	Total	Events per 100 observations GLMM, Fixed, 95% CI
Barisoni et al.	0	10	0.00 [0.00; 30.85]
Baumeister et al.	6	43	13.95 [5.30; 27.93]
Castro et al.	0	5	0.00 [0.00; 52.18]
Cerkes et al.	1	6	16.67 [0.42; 64.12]
Chick et al.	0	7	0.00 [0.00; 40.96]
Handschin et al.	3	9	33.33 [7.49; 70.07]
Hsiao et al.	0	5	0.00 [0.00; 52.18]
Jabir et al.	1	23	4.35 [0.11; 21.95]
Pan et al.	1	38	2.63 [0.07; 13.81]
Pedrazzi et al.	3	12	25.00 [5.49; 57.19]
Pessoa Vaz et al.	1	15	6.67 [0.17; 31.95]
Saint-Cyr et al.	2	15	13.33 [1.66; 40.46]
Sauerbier et al.	4	21	19.05 [5.45; 41.91]
Shen et al.	7	54	12.96 [5.37; 24.90]
Silverberg et al.	0	6	0.00 [0.00; 45.93]
Stefanacci et al.	0	12	0.00 [0.00; 26.46]
Uslu	0	11	0.00 [0.00; 28.49]
Yang et al.	0	11	0.00 [0.00; 28.49]
Yu et al.	1	11	9.09 [0.23; 41.28]
Zhao et al.	0	12	0.00 [0.00; 26.46]
Zhou et al.	0	12	0.00 [0.00; 26.46]
Ziegler et al.	1	14	7.14 [0.18; 33.87]
Total (95% CI)		**352**	**8.81 [6.26; 12.25]**
Prediction interval			**[2.16; 23.12]**

Heterogeneity: $Tau^2 = 0.2943$; $Chi^2 = 10.27$, df = 21 ($P = 0.98$); $I^2 = 0\%$

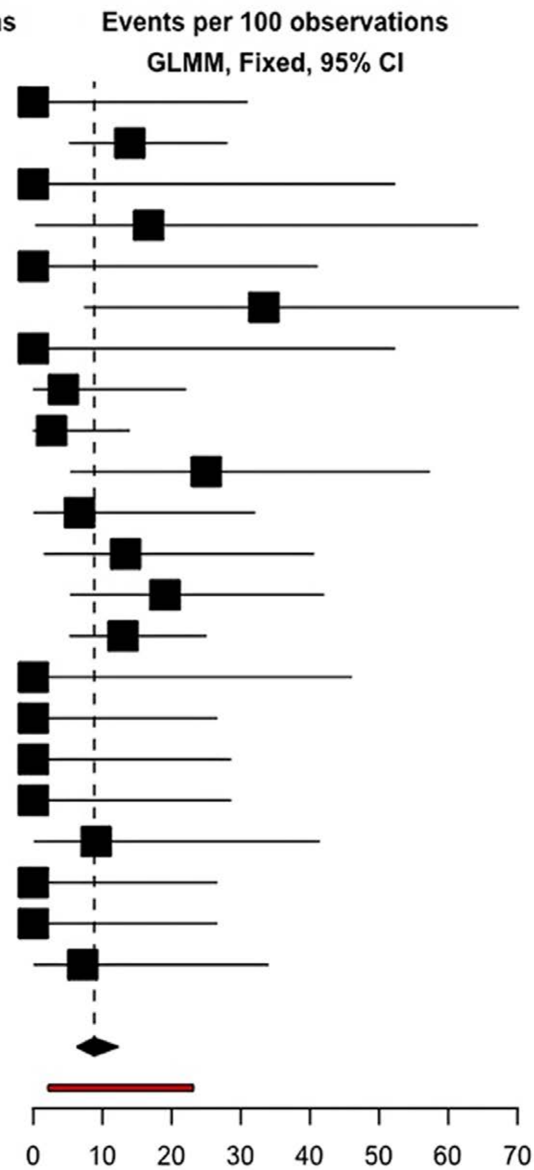

Fig. 4. Forest plot showing the prevalence of arterial thrombosis of the free flap in acute burns.

regression test, which statistically examines the asymmetry of the funnel plot.[17]

RESULTS

Electronic Database Search Results and General Features of the Studies Included

A total of 1258 eligible articles were retrieved from the preliminary search. After the removal of duplicates and screening for both titles and abstracts, 197 full-text articles were assessed for eligibility. After applying inclusion and exclusion criteria, 31 articles were included in the qualitative and quantitative synthesis.[8–10,18–46] A flow chart of the study inclusion process and the reasons justifying the exclusion of the 166 studies are shown in Figure 1.

The included studies comprised a total of 454 free flaps performed for the reconstruction of complex acute burn wounds in 427 patients (83% men, 17% women). The patient mean age was 36.21 [95% CI, 31.25–41.16]. The mean follow-up period was 12.59 months [95% CI, 7.54–17.65]. Burn etiology was electrical in 60% of the cases and nonelectrical in 40%. Among the 454 free flaps included, the body area involved was extractable for 326 flaps. Of them, 59% of free flaps were performed to the upper extremity, 33% to the lower extremity, and only 8% to the head and neck region. (**See table, Supplemental Digital Content 2,** which displays the studies' general characteristics. **http://links.lww.com/PRSGO/C793.**)

Risk of Bias Assessment

In the 31 included studies, scores ranged from 9 to 14, with a median of 10. The major deficiencies were a lack of calculation of study size and a lack of prospective collection of data. All studies showed a clearly stated aim, appropriate endpoints, and scarce loss to follow-up. Most of the studies included consecutive patients.

Complications of Free Flaps in Acute Burns

Total Free Flap Loss

The meta-analysis showed a pooled total free flap loss in acute burns of 9.91% (95% CI, 7.48%–13.02%), as shown in the forest plot in Figure 2. Small between-study heterogeneity ($Q^2 = 897$, $P = 0.99$) was measured [$I^2 = 0\%$

Study	Events	Total	Events per 100 observations GLMM, Fixed, 95% CI
Barisoni et al.	1	10	10.00 [0.25; 44.50]
Baumeister et al.	1	43	2.33 [0.06; 12.29]
Castro et al.	1	5	20.00 [0.51; 71.64]
Chick et al.	1	7	14.29 [0.36; 57.87]
Handschin et al.	1	9	11.11 [0.28; 48.25]
Hsiao et al.	1	5	20.00 [0.51; 71.64]
Jabir et al.	1	23	4.35 [0.11; 21.95]
Pan et al.	0	38	0.00 [0.00; 9.25]
Pedrazzi et al.	2	12	16.67 [2.09; 48.41]
Shen et al.	2	54	3.70 [0.45; 12.75]
Silverberg et al.	1	6	16.67 [0.42; 64.12]
Stefanacci et al.	0	12	0.00 [0.00; 26.46]
Uslu	0	11	0.00 [0.00; 28.49]
Yang et al.	1	11	9.09 [0.23; 41.28]
Yu et al.	0	11	0.00 [0.00; 28.49]
Zhao et al.	0	12	0.00 [0.00; 26.46]
Zhou et al.	0	12	0.00 [0.00; 26.46]
Ziegler et al.	2	14	14.29 [1.78; 42.81]
Total (95% CI)		**295**	**5.08 [3.09; 8.26]**
Prediction interval			**[2.96; 8.59]**

Heterogeneity: $Tau^2 = 0$; $Chi^2 = 7.58$, df = 17 ($P = 0.97$); $I^2 = 0\%$

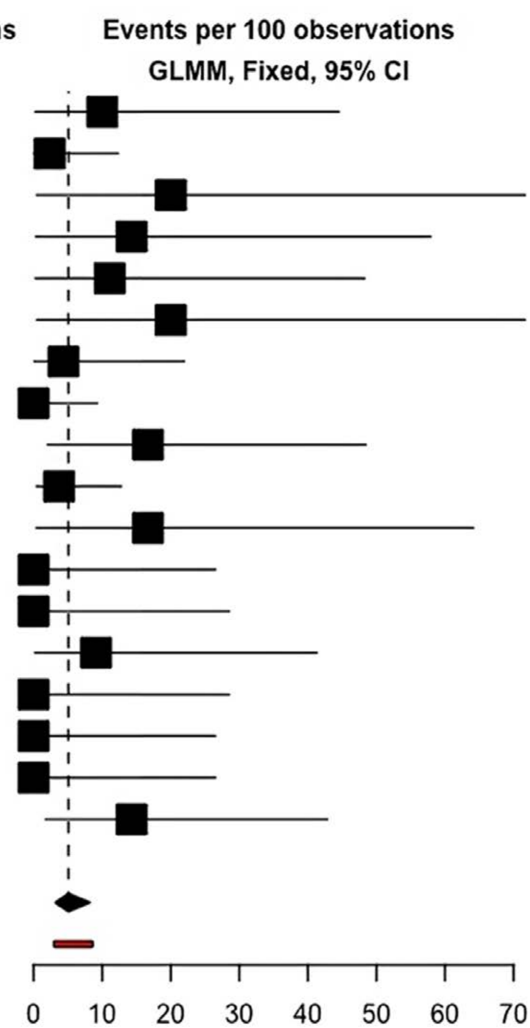

Fig. 5. Forest plot showing the prevalence of venous thrombosis of the free flap in acute burns.

(95% CI, 0.0%–40.2%) and τ^2 = 1.12]; hence, a fixed-effect model was used. Peter linear regression test showed no obvious publication bias (t = 0.01, P = 0.99). Inspection of the funnel plot shows a symmetric distribution of the points. (**See table, Supplemental Digital Content 3,** which displays a series of funnel plots related to the study. **http://links.lww.com/PRSGO/C794**.)

Partial Free Flap Loss

The pooled prevalence of partial free flap loss was 4.76% (95% CI, 2.66%–8.39%), as shown in the forest plot in Figure 3. Small between-study heterogeneity (Q^2 = 2.66, P = 1.00) was measured [I^2 = 0% (95% CI, 0.0%–50.0%) and τ^2 = 0]; hence, a fixed-effect model was used. Peter linear regression test showed no obvious publication bias (t = 1.94, P = 0.07). Inspection of the funnel plot shows a symmetric distribution of the points (**Supplemental Digital Content 3B, http://links.lww.com/PRSGO/C794**).

Arterial Thrombosis of the Flap

The pooled prevalence of arterial thrombosis of free flaps was 8.81% (95% CI, 6.26%–12.25%), as shown in the forest plot in Figure 4. Small between-study heterogeneity (Q^2 = 10.27, P = 0.98) was measured [I^2 = 0% (95% CI, 0.0%–46.2%) and τ^2 = 0.29]; hence, a fixed-effect model was used. Peter linear regression test showed no obvious publication bias (t = 1.32, P = 0.20). Inspection of the funnel plot shows a symmetric distribution of the points (**Supplemental Digital Content 3C, http://links.lww.com/PRSGO/C794**).

Venous Thrombosis of the Flap

The pooled prevalence of venous thrombosis of free flaps was 5.08% (95%CI, 3.09%–8.26%), as shown in the forest plot in Figure 5. Small between-study heterogeneity (Q^2 = 7.58, P = 0.97) was measured [I^2 = 0% (95% CI, 0.0%–50%) and τ^2 = 0]; hence, a fixed-effect model was used. Peter linear regression test showed potential publication bias (t = 4.38, P = 0.0005). Inspection of the funnel plot shows a moderate asymmetry of the points (**Supplemental Digital Content 3D, http://links.lww.com/PRSGO/C794**).

Flap Infection

The pooled prevalence of postoperative infection of free flaps was 7.18% (95% CI, 4.22%–11.98%), as shown in the forest plot in Figure 6. Small between-study heterogeneity (Q^2 = 2.42, P = 0.99) was measured [I^2 = 0% (95% CI: 0.0%-55%) and τ^2 = 0]; hence, a fixed-effect model was used. Peter linear regression test showed no obvious publication bias (t = 2.14, P = 0.054). Inspection of the funnel plot shows a symmetric distribution of the points (**Supplemental Digital Content 3E, http://links.lww.com/PRSGO/C794**).

Study	Events	Total	Events per 100 observations GLMM, Fixed, 95% CI
Al-Qattan et al.	0	8	0.00 [0.00; 36.94]
Brewin et al.	1	7	14.29 [0.36; 57.87]
Di et al.	1	8	12.50 [0.32; 52.65]
Hsiao et al.	0	5	0.00 [0.00; 52.18]
Jabir et al.	1	23	4.35 [0.11; 21.95]
Koul et al.	1	16	6.25 [0.16; 30.23]
Pan et al.	3	38	7.89 [1.66; 21.38]
Parrett et al.	1	7	14.29 [0.36; 57.87]
Silverberg et al.	0	6	0.00 [0.00; 45.93]
Stefanacci et al.	2	12	16.67 [2.09; 48.41]
Yang et al.	0	11	0.00 [0.00; 28.49]
Yang et al.	2	15	13.33 [1.66; 40.46]
Yu et al.	0	11	0.00 [0.00; 28.49]
Ziegler et al.	1	14	7.14 [0.18; 33.87]
Total (95% CI)		**181**	**7.18 [4.22; 11.98]**
Prediction interval			**[3.97; 12.66]**

Heterogeneity: $Tau^2 = 0$; $Chi^2 = 2.42$, df = 13 (P = 1.00); $I^2 = 0\%$

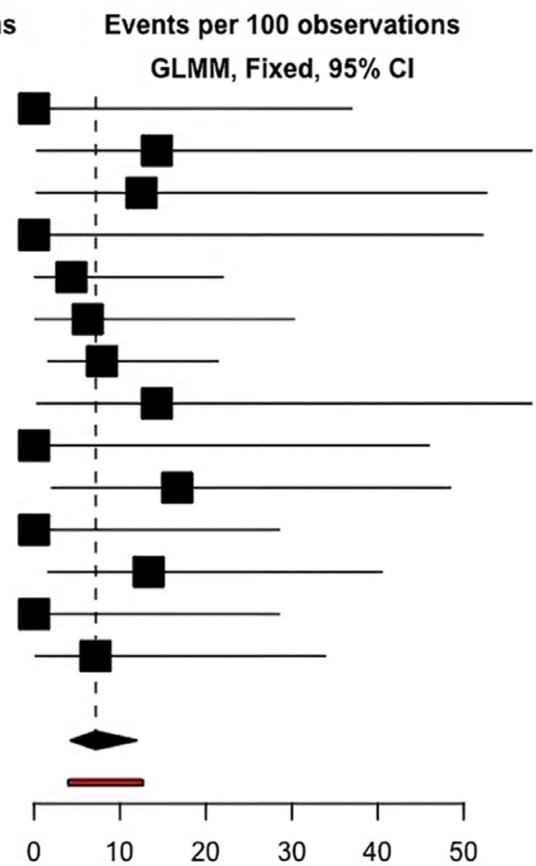

Fig. 6. Forest plot showing the prevalence of postoperative infection of the free flap in acute burns.

Need for Acute Return to the Operating Room after Free Flap Reconstruction in Acute Burns

The need for acute comeback to the operating room had a pooled prevalence of 20.63% (95% CI, 16.33%–25.71%), as shown in the forest plot in Figure 7. Small between-study heterogeneity (Q^2 = 20.20, P = 0.38) was measured [I^2 = 5.9% (95% CI, 0.0%–39.4%) and τ^2 = 0.14]; hence, a fixed-effect model was used. Peter linear regression test showed potential publication bias (t = 2.60, P = 0.018). Inspection of the funnel plot shows a moderate asymmetry of the points (**Supplemental Digital Content 3F, http://links.lww.com/PRSGO/C794**).

Free Flap Loss in Upper Extremities

The pooled prevalence of free flap loss in the upper extremity was 6.74% (95% CI, 3.95%–11.25%) as shown in the forest plot in Figure 8. Small between-study heterogeneity (Q^2 = 3.49, P = 1) was measured [I^2 = 0% (95% CI, 0.0%–48%) and τ^2 = 0.68]; hence, a fixed-effect model was used. Peter linear regression test showed no obvious publication bias (t = 0.72, P = 0.48). Inspection of the funnel plot shows a symmetric distribution of the points (**Supplemental Digital Content 3G, http://links.lww.com/PRSGO/C794**).

Free Flap Loss in Lower Extremities

The pooled prevalence of free flap loss in the lower extremity was 8.33% (95% CI, 4.39%–15.24%) as shown in the forest plot in Figure 9. Small between-study heterogeneity (Q^2 = 2.61, P = 1) was measured [I^2 = 0% (95% CI, 0.0%–50%) and τ^2 = 2.2]; hence, a fixed-effect model was used. Peter linear regression test showed no obvious publication bias (t = 0.27, P = 0.79). However, inspection of the funnel plot shows a moderate asymmetry of the points (**Supplemental Digital Content 3H, http://links.lww.com/PRSGO/C794**).

Free Flap Loss in Electrical Burns

The pooled prevalence of free flap loss in acute electrical burns was 9.13% (95% CI, 5.98%–13.73%), as shown

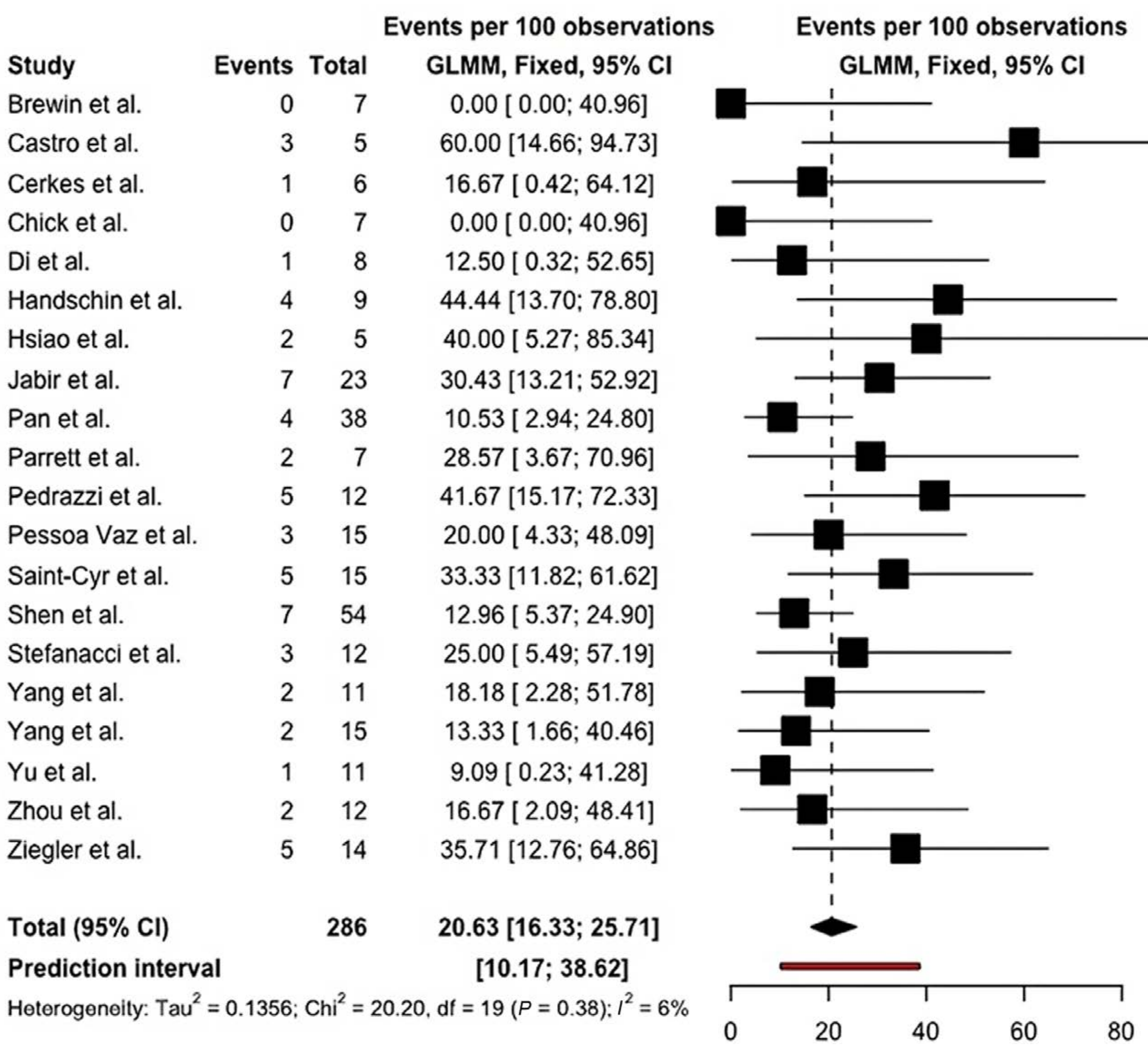

Fig. 7. Forest plot showing the prevalence of need for acute return to the operating room.

in the forest plot in Figure 10. Small between-study heterogeneity ($Q^2 = 4.65$, $P = 1$) was measured [$I^2 = 0\%$ (95% CI, 0.0%–43.9%) and $\tau^2 = 1.12$]; hence, a fixed-effect model was used. Peter linear regression test showed no obvious publication bias ($t = 1.46$, $P = 0.16$). Inspection of the funnel plot shows a symmetric distribution of the points (**Supplemental Digital Content 3I, http://links.lww.com/PRSGO/C794**).

Free Flap Loss in Nonelectrical Burns

The pooled prevalence of free flap loss in acute nonelectrical burns was 7.48% (95% CI, 4.19%–13.00%), as shown in the forest plot in Figure 11. Small between-study heterogeneity ($Q^2 = 1.52$, $P = 1$) was measured [$I^2 = 0\%$ (95% CI, 0.0%–52.3%) and $\tau^2 = 0.99$]; hence, a fixed-effect model was used. Peter linear regression test showed potential publication bias ($t = -2.63$, $P = 0.02$). Inspection of the funnel plot shows an asymmetric distribution of the points (**Supplemental Digital Content 3J, http://links.lww.com/PRSGO/C794**).

DISCUSSION

Burn injuries that require wound coverage are primarily treated with the use of skin grafts, as skin grafting can cover a large surface area, especially if meshed, without the need for a complicated harvesting process. Skin grafts also have minor morbidity at the donor site.[47] Flap reconstruction is rarely required, with the usage of free flaps being even rarer.[10] Free flaps are reserved for severe and extensive wounds involving the exposure of critical structures when local options are inadequate.[48,49]

To date, there is limited evidence regarding the outcomes and complications of free flaps in acute burns. The current literature indicates a free flap loss rate ranging from 0% to 44%. This meta-analysis estimates the risk of total flap loss in acute burns to be nearly 10%, with over 20% of these free flaps requiring acute return to the operating room. Therefore, the rate of free flap loss in acute burns observed in this study is higher than the free flap loss rate (between 2% and 5%) reported in other

Study	Events	Total	Events per 100 observations GLMM, Fixed, 95% CI
Al-Qattan et al.	0	8	0.00 [0.00; 36.94]
Brewin et al.	0	3	0.00 [0.00; 70.76]
Castro et al.	0	1	0.00 [0.00; 97.50]
Cerkes et al.	0	6	0.00 [0.00; 45.93]
Chick et al.	0	6	0.00 [0.00; 45.93]
Handschin et al.	1	3	33.33 [0.84; 90.57]
Hsiao et al.	1	5	20.00 [0.51; 71.64]
Jabir et al.	0	11	0.00 [0.00; 28.49]
Koul et al.	1	14	7.14 [0.18; 33.87]
Pan et al.	0	38	0.00 [0.00; 9.25]
Pedrazzi et al.	1	7	14.29 [0.36; 57.87]
Pessoa Vaz et al.	1	5	20.00 [0.51; 71.64]
Saint-Cyr et al.	1	10	10.00 [0.25; 44.50]
Sauerbier et al.	5	21	23.81 [8.22; 47.17]
Silverberg et al.	0	1	0.00 [0.00; 97.50]
Stefanacc et al.	1	7	14.29 [0.36; 57.87]
Zhang et al.	0	14	0.00 [0.00; 23.16]
Zhao et al.	0	7	0.00 [0.00; 40.96]
Zhou et al.	0	12	0.00 [0.00; 26.46]
Ziegler et al.	1	14	7.14 [0.18; 33.87]
Total (95% CI)		**193**	**6.74 [3.95; 11.25]**
Prediction interval			**[0.80; 28.84]**

Heterogeneity: $Tau^2 = 0.6792$; $Chi^2 = 3.46$, df = 19 ($P = 1.00$); $I^2 = 0\%$

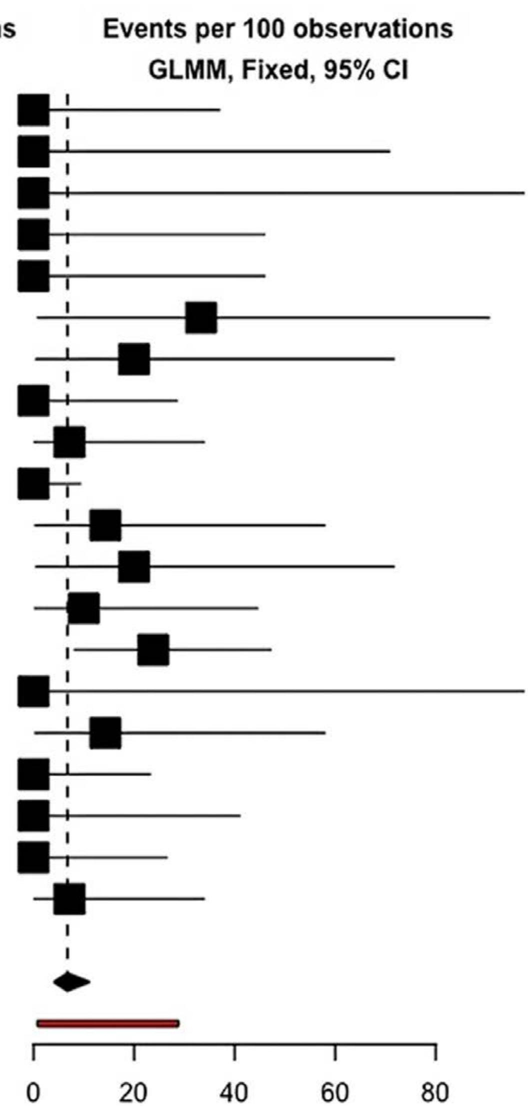

Fig. 8. Forest plot showing the prevalence of total free flap loss in upper extremity acute burns.

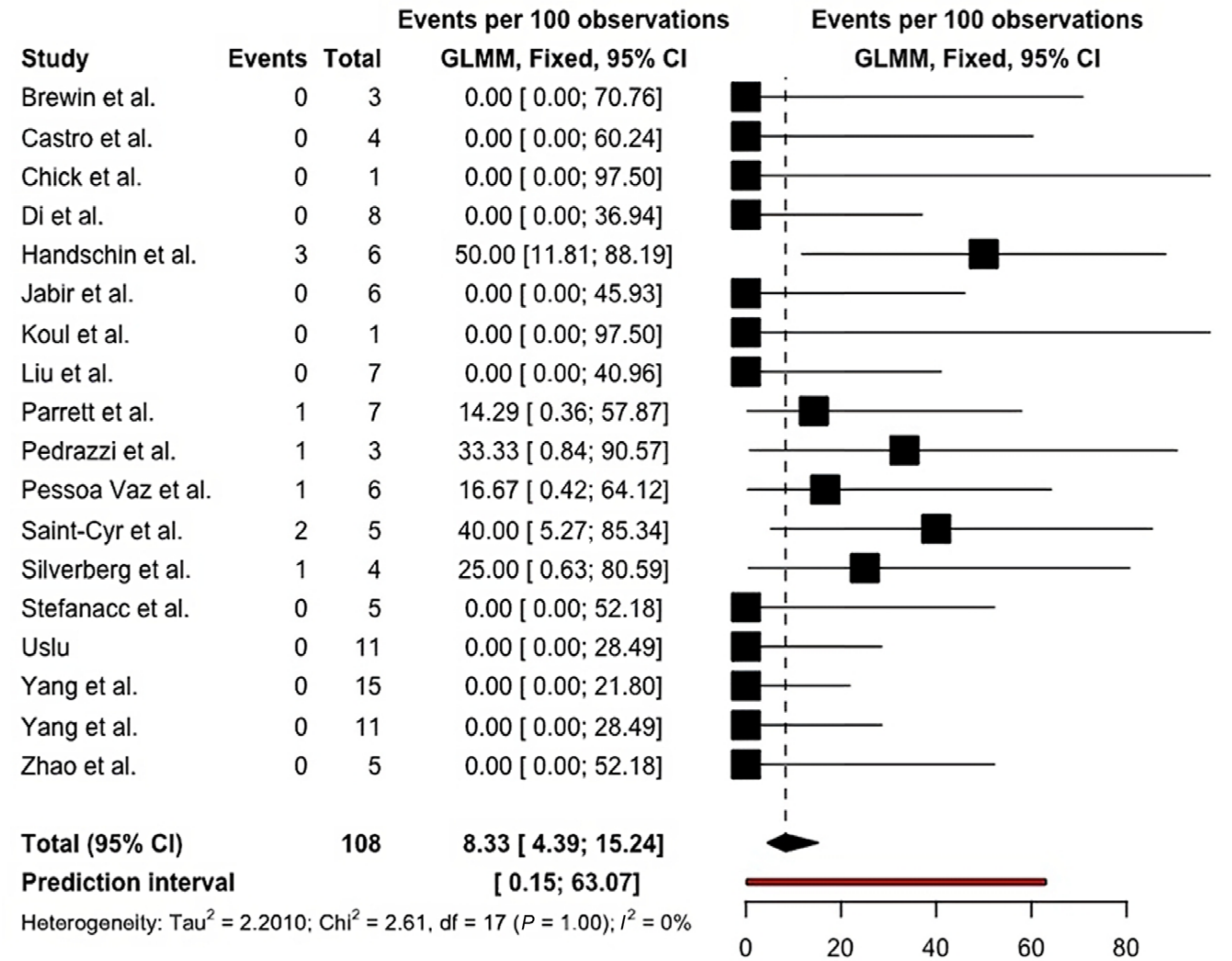

Fig. 9. Forest plot showing the prevalence of total free flap loss in lower extremity acute burns.

populations, such as patients undergoing elective postoncological reconstruction.[50,51]

Currently, there is also a paucity of literature regarding predictive factors associated with adverse outcomes in free flap reconstruction in acute burns. Perrault et al analyzed data on burn patients from a national database (National Inpatient Sample database) and reported a significantly higher risk of flap loss in electrical compared with thermal burns.[10] However, their study included all types of flaps, not free flaps only.[10] High-voltage source injuries often cause more damage to deeper tissues, while relatively sparing the skin surface. Therefore, damage to the vessel walls may occur and potentially increase the risk of intravascular thrombosis and flap loss.[52,53] However, further research is needed to compare the risk of free flap loss in electrical versus nonelectrical burns. In fact, in this study, despite the pooled prevalence of free flap loss in electrical burns being slightly higher than nonelectrical, no direct comparison could be performed due to the lack of comparative studies. Thus, conclusions were limited. Similarly, no conclusions could be made about the rate of free flap loss based on the anatomical location of the injury or the choice of flap type used for reconstruction. Additionally, the influence of TBSA as a predictive factor of free flap complications could not be assessed due to unreported data. Further research is also necessary to determine whether the time elapsed because injury influences the free flap failure rate. Ongoing investigation is needed to clarify these potential relationships.

Potential explanations for the high failure rate in acute burns include the local and systemic hyperinflammatory state which follows burn injuries. Acutely burned patients typically present high levels of inflammatory and thrombogenic cytokines.[54–56] Indeed, burn injuries increase vascular permeability and decrease vascular integrity, leading to elevated interstitial pressure and edema.[56] This can potentially affect venous outflow, as the interstitial edema exerts compressive forces. The increased expression levels of the extracellular matrix within the vessels wall and impaired perivascular smooth muscle contractility may also reduce the vasodilatory capacity of the vessels.[57] Moreover, the trauma and inflammation caused by the burn can result in increased perivascular scarring, compromising the pliability and flexibility of blood vessels. A hypercoagulable state is observed in severely burned patients between 24 and 48 hours after

Study	Events	Total	Events per 100 observations GLMM, Fixed, 95% CI
Barisoni et al.	1	4	25.00 [0.63; 80.59]
Baumeister et al.	4	18	22.22 [6.41; 47.64]
Castro et al.	0	5	0.00 [0.00; 52.18]
Cerkes et al.	0	6	0.00 [0.00; 45.93]
Chick et al.	0	3	0.00 [0.00; 70.76]
Di et al.	0	6	0.00 [0.00; 45.93]
Hsiao et al.	1	5	20.00 [0.51; 71.64]
Jabir et al.	0	3	0.00 [0.00; 70.76]
Koul et al.	1	16	6.25 [0.16; 30.23]
Liu et al.	0	3	0.00 [0.00; 70.76]
Monga et al.	3	20	15.00 [3.21; 37.89]
Pan et al.	0	26	0.00 [0.00; 13.23]
Pedrazzi et al.	2	10	20.00 [2.52; 55.61]
Pessoa Vaz et al.	0	3	0.00 [0.00; 70.76]
Saint-Cyr et al.	3	15	20.00 [4.33; 48.09]
Sauerbier et al.	4	11	36.36 [10.93; 69.21]
Silverberg et al.	1	2	50.00 [1.26; 98.74]
Stefanacci et al.	0	5	0.00 [0.00; 52.18]
Uslu	0	11	0.00 [0.00; 28.49]
Yang et al.	0	3	0.00 [0.00; 70.76]
Yu et al.	0	2	0.00 [0.00; 84.19]
Zhang et al.	0	14	0.00 [0.00; 23.16]
Zhao et al.	0	12	0.00 [0.00; 26.46]
Zhou et al.	0	12	0.00 [0.00; 26.46]
Ziegler et al.	0	4	0.00 [0.00; 60.24]
Total (95% CI)		**219**	**9.13 [5.97; 13.73]**
Prediction interval			**[0.58; 41.67]**

Heterogeneity: $Tau^2 = 1.1162$; $Chi^2 = 4.65$, df = 24 ($P = 1.00$); $I^2 = 0\%$

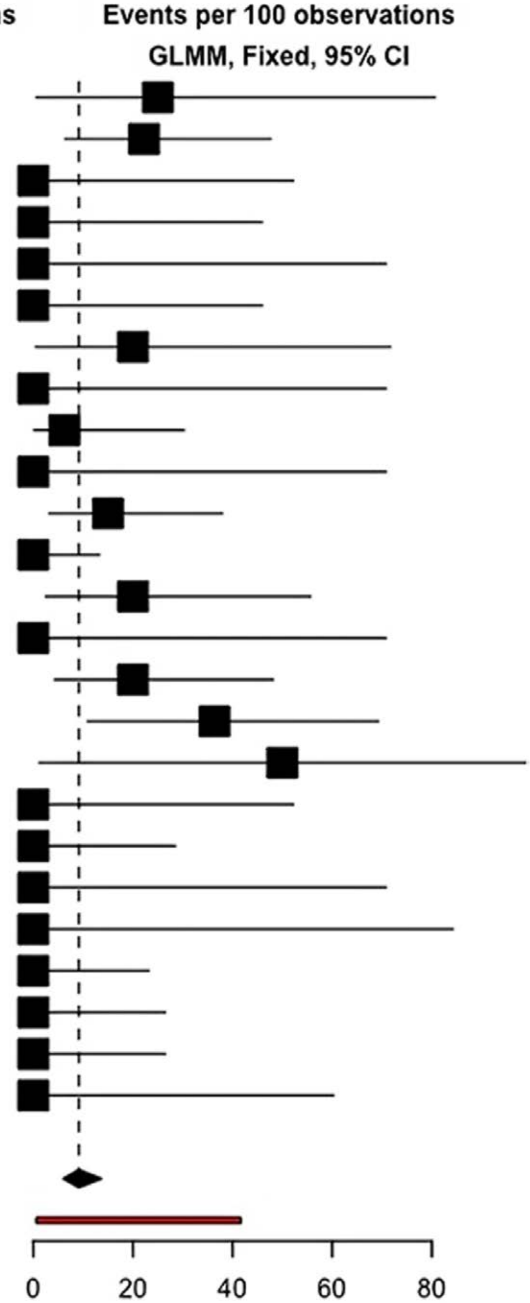

Fig. 10. Forest plot showing the prevalence of total free flap loss in electrical acute burns.

injury.[58–60] Therefore, the compromised arterial inflow and venous outflow, in concert with coagulation disorders associated with severe burns, may contribute to the high rate of both arterial and venous thrombosis and free flap loss observed in acute burns. Efforts to perform microvascular anastomosis in less traumatized and inflamed tissues outside the zone of injury may improve reconstructive outcomes and warrant further investigation. The use of antiplatelet and anticoagulant agents may also serve as a possible therapeutic strategy, aiming to minimize the risk of thrombosis within the flap. Comparative studies assessing the efficacy of these agents in acute burn reconstruction are needed.

This study has some limitations. The main weaknesses include the small available sample size and the inclusion of retrospective and underpowered studies. In addition, no standardized criteria and indications for free flap reconstruction were reported. Therefore, variation in severity among the cases may have contributed to the wide range of free flap loss rates observed in single studies.

The overall low level of evidence in the available literature and the poor outcomes associated with free flap reconstruction in acute burns should motivate the plastic surgery community to conduct further research on this topic.

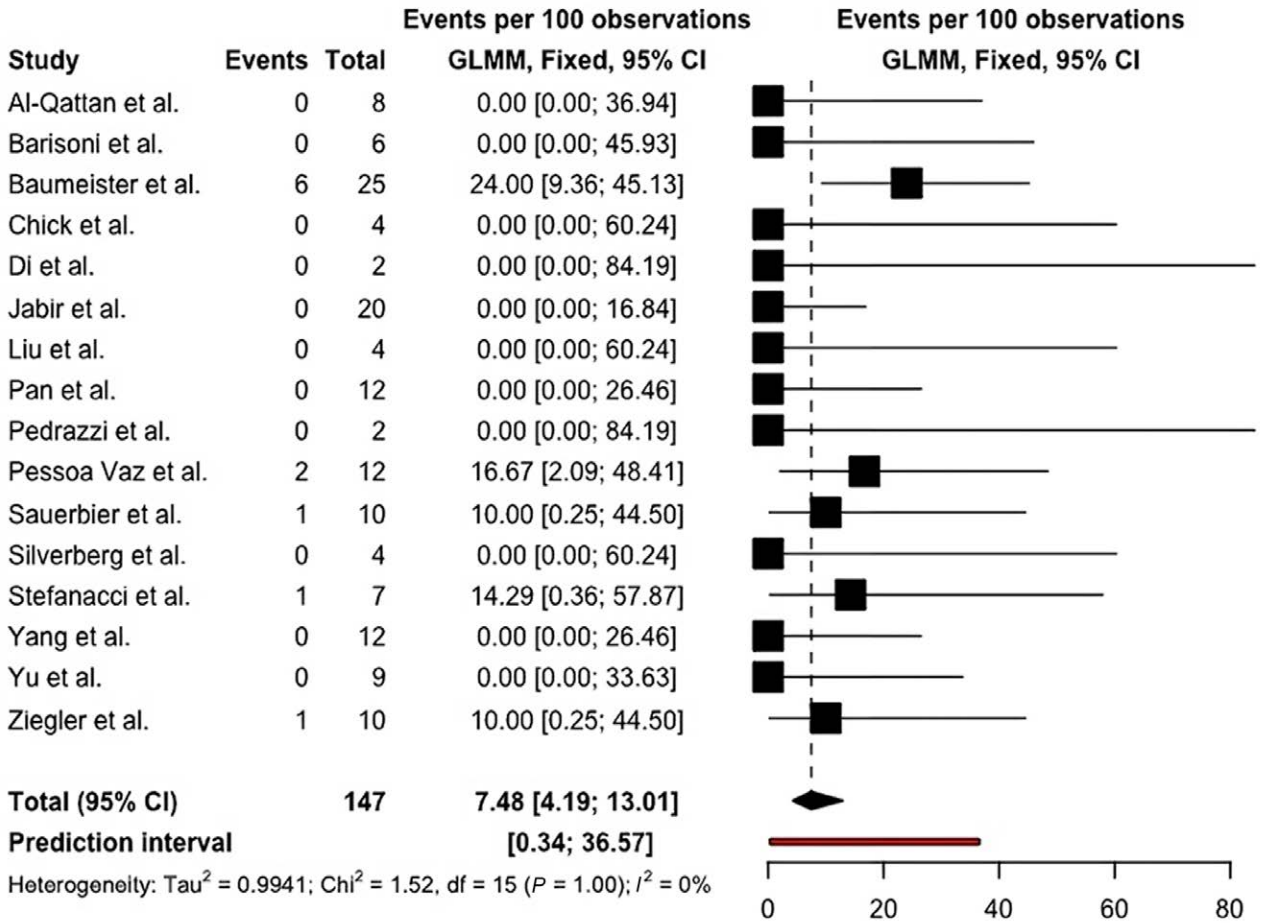

Fig. 11. Forest plot showing the prevalence of total free flap loss in nonelectrical acute burns.

CONCLUSIONS

A 9.91% rate of free flap failure in acute burn reconstruction is reported in the literature. Despite being rarely used, free flaps may be the only reconstructive option for certain complex defects and for limb salvage situations. Thus, further research is needed to identify predictive factors and strategies to reduce the free flap loss and complication rate in this population.

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DISCLOSURE

The authors have no financial interest to declare in relation to the content of this article.

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