Free Flap Monitoring, Salvage, and Failure Timing: A Systematic Review

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Abstract

Background Microsurgical free tissue transfer has become a reliable technique with success rates around 99% and around 5% requiring exploration for vascular compromise. Protocols for flap monitoring between plastic surgery units vary. We aimed to elucidate the time period when monitoring is crucial for flap salvage.

Methods A systematic search of literature was performed in PubMed, Cochrane Library, Medline, and Scopus databases from 1966 to July 2018 according to Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, identifying 3,844 studies with mention of free flap and monitoring or timing or salvage or compromise. Studies were screened for relevance according to predetermined inclusion criteria. Data was extracted from included studies relating to flap type, monitoring, timing and reason for failure, and success of salvage intervention.

Results A total of 109 studies featuring 44,031 free flaps were included. A total of 2,549 (5.8%) flaps required return to theater for compromise; 926 (2.1%) were lost and 1,654 (3.7%) were salvaged. In the first 24 hours postoperatively 93.8% of explored flaps are successfully salvaged, by day 2: 83.33%, day 3: 12.1%, and beyond day 4: none were successful. Of the 355 flaps where the cause of failure was reported, 59.5% was venous, 27.9% was arterial, 2.3% was a combination of both, and 10.2% was hematoma or infection. The proportion of flap failures at various recipient sites was highest in the trunk/viscera (7%, 95% confidence interval [CI] 0.00, 0.36), followed by limbs (5%, 95% CI 0.02, 0.08), head and neck (3%, 95% CI 0.02, 0.04), and breast (<1%; 95% CI 0.00, 0.02).

Conclusion Close flap monitoring is of most value in the first 48 hours postoperatively, facilitating rapid detection of vascular compromise, early salvage, and better outcomes. The location of the flap has implications on its success and certain recipient sites may need particular attention to improve chances of success.

Keywords
- free flap
- timing
- failure
- salvage

Microsurgical free tissue transfer has become an increasingly reliable technique in the past few decades and is now commonly used in breast, head, and neck and lower limb reconstruction.[1] Success rates typically range between 96 and 99%, with exploration required for vascular compromise in around 2 to 5% of flaps.[2–4] Methods to identify risk factors for flap failure and further improve flap survival are extensively discussed in recent literature and remains a popular topic.[5]

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Despite the widespread prevalence of free flap surgery, protocols for flap monitoring between plastic surgery units can vary significantly. Previous studies have shown that flap compromise mostly occurs within the first 72 hours and that salvage rate is often associated with the timing of vascular insult.[6,7] External Doppler and clinical observations at set time intervals is the most often used method, but it can be unclear how long the flap should be observed for and how frequently, especially in low-volume units where nursing staff may not be familiar with flap physiology. Patients also find it disruptive and uncomfortable to be frequently monitored for long periods of time.[7]

This paper aims to perform a systematic review of the incidence and timing of free flap failures within current literature to elucidate the postoperative period for when monitoring is most crucial to capture compromised flaps for salvage. We also aim to assess the differences in length of time between the initial surgery and revision surgery and correlate this with the rate of successful versus failed salvages, as well as look for any differences in failure rates based on flap location.

Methods

This review adheres to Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.

Search Strategy

A systematic search of the literature was performed in Ovid MEDLINE, PubMed, Cochrane Library, Scopus, American College of Physicians Journal Club, Database of Abstracts of Reviews of Effects, Allied and Complementary Medicine, Cumulative Index of Nursing and Allied Health Literature, and Excerpta Medica Database. The following free text search terms were used: (["free flap" OR "free flaps" OR "microvascular flap" OR "free tissue transfer"] AND [monitoring OR timing OR salvage OR compromise OR failure]). The reference lists of included studies were also examined.

Study Selection Criteria

The inclusion criteria aimed to gather English-language studies that featured descriptions of free flap surgeries with information about individual flap compromise or failure cases including a minimum of the timing of flap compromise. Flap compromise was defined as an event where the flap was noted by staff to have developed a change that precipitated consideration of return to theater. Partial flap failure, fat necrosis, or graft failure over the free flap was not included in our definition. Exclusion criteria were studies that were not about free flaps and those that did not provide description of individual flap compromise including timing. Non-English studies were excluded as we did not have access to translation services.

All duplicate publications were removed from the search results. Three authors (A.Y.S., H.F., S.L.) performed title and abstract screening of the remaining studies and utilized predetermined inclusion and exclusion criteria to select studies for full-text review. Articles that passed abstract screening then proceeded to full text screening, performed by two authors (A.Y.S. and S.L.), for consideration of final inclusion. Differences in opinion regarding inclusion of a study were resolved by discussion.

Data Extraction

Data extraction was performed in duplicate by two authors (A.Y.S., K.L.) and checked by a third author (S.L.). Study demographics such as first author, year of publication, and number of free flap patients as well as information about the free flaps such as type and indication of flap, timing of failure, cause of failure, and success of salvage intervention were extracted from each article. Data was grouped to compare success and failure based on the timing of intervention.

Data Analysis

Quantitative data suitable for meta-analysis underwent pooled and subgroup analysis by a statistician using STATA

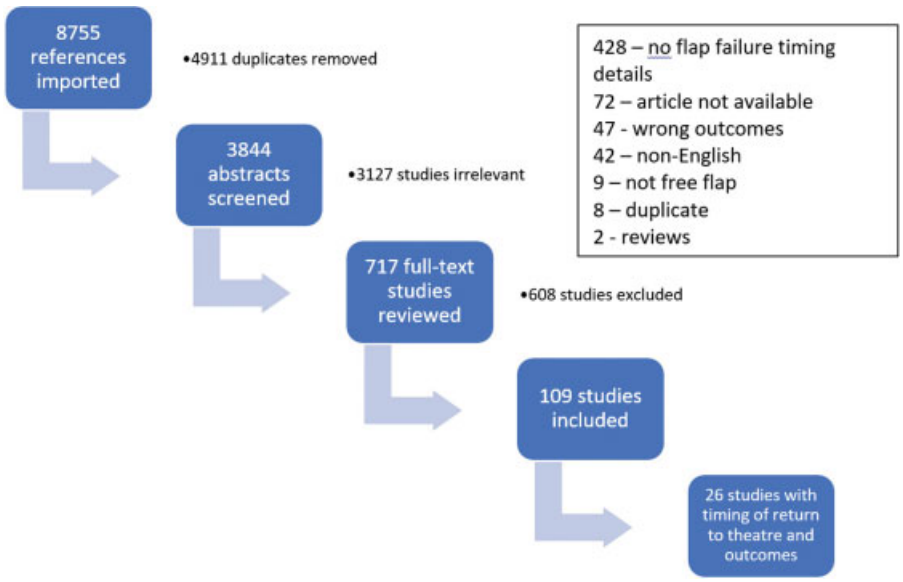

Fig. 1 Graphic representation of search strategy and papers included.

software. Qualitative data was presented in descriptive table format. A 95% confidence interval was used for data analysis and a *p*-value of 0.05 was considered statistically significant.

Results

Of 8,755 studies initially found on literature search, 4,911 were duplicates. A total of 3,844 abstracts were screened and

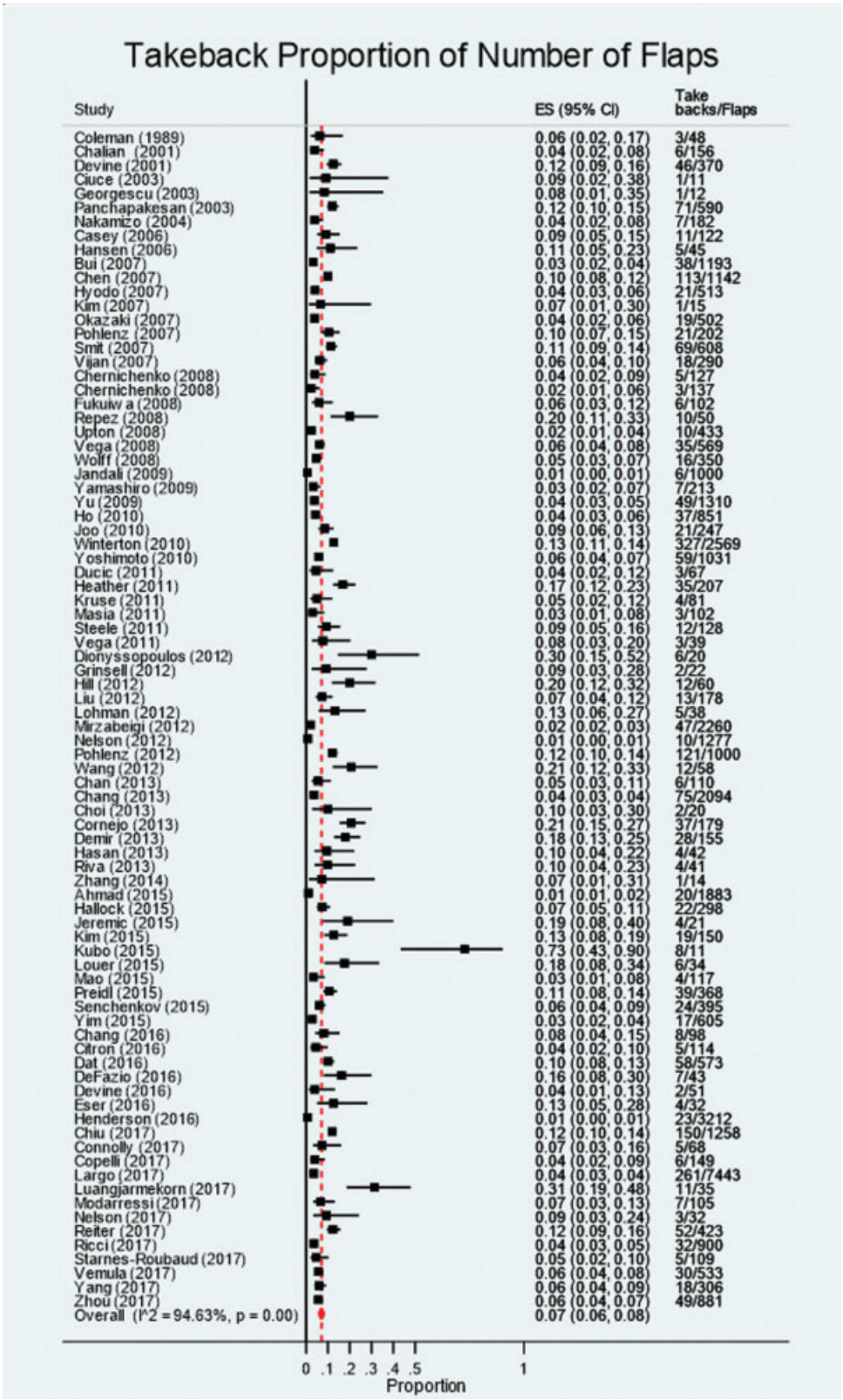

Fig. 2 Takebacks as a proportion of free flap total.

3,127 irrelevant studies excluded. Full text screening was performed for 717 studies, resulting in a total of 109 studies included in our final analysis. The study selection process is illustrated in ►**Fig. 1** with details on the reason for exclusion of the 608 full text studies.

Compromise Timing

Amongst all flaps there was an incidence of flap compromise prompting return to theater in 2,549 (5.8%) flaps, with 1,627 of these having a description when the compromise was detected. Timing of compromise was most commonly in the first 24 hours (439 flaps, 53.9% of flaps returned to theater), then day 2 (138, 16.9%). From day 3, 72 returned to theater (8.8%); day 4, 76 (9.3%); day 5, 39 (4.8%); day 6, 6 (0.7%); and beyond day 7, 45 (5.5%). Only eleven studies reported flap monitoring methods—seven utilized clinical assessment alone, three used light spectroscopy and one used implantable dopplers.

Failure

Of the 4,4031 flaps included in this study, the number of flaps that resulted in total failure was 926 (35.9%) and the number that were successfully salvaged was 1,654 (64.1%) flaps. Thirty-one failed flaps were not explored due to patient comorbidities or other reasons which were not specified. ►**Fig. 2** shows the number of takebacks as a proportion of the total number of free flaps. The cause of failure was specified in 355 of the 512 flaps, most commonly venous problems ($n = 212$, 59.5% of failures) followed by arterial problems ($n = 99$, 27.9%), haematoma ($n = 23$, 6.5%), infection ($n = 13$, 3.7%) then combined arterial and venous problems ($n = 8$, 2.3%).

The location of flap failures in the included studies was explored using subgroup analysis. The proportion of flaps in each area that failed was highest in trunk/viscera (7%, 95% confidence interval [CI] 0%, 36%), followed by limbs (5%, 95% CI 2%, 8%), head and neck (3%, 95% CI 2%, 4%) and finally breast (<1%; 95% CI 0%, 2%). Heterogeneity was low in the limbs subgroup ($I^2 = 35.6\%$, $p = 0.07$) and substantial in trunk/viscera ($I^2 = 80.1\%$, $p = 0.00$), head and neck ($I^2 = 84.2\%$, $p = 0.00$), and breast ($I^2 = 86.0\%$, $p = 0.00$). ►**Figs. 3** to **6** demonstrate this information.

Timing of Salvage and Outcomes

Exact details of timing of compromise and return to theater and salvage outcomes were given for 11 studies, with a total of 831 flaps (►**Table 1**). Successfully salvaged flaps were noted to have compromise earlier than failed flaps (mean 30.8 vs. 51.5 hours) and also had a shorter period of time from detection of compromise to return to theater (mean 16.9 vs. 31.5 hours). Salvage success according to number of days postoperatively when exploration occurred is depicted in ►**Fig. 7**. This demonstrates that within the first 24 hours postoperatively 93.8% of explored flaps are successfully salvaged, by day 2 only 83.33%, day 3 12.1%, and then beyond day 4 none were successful.

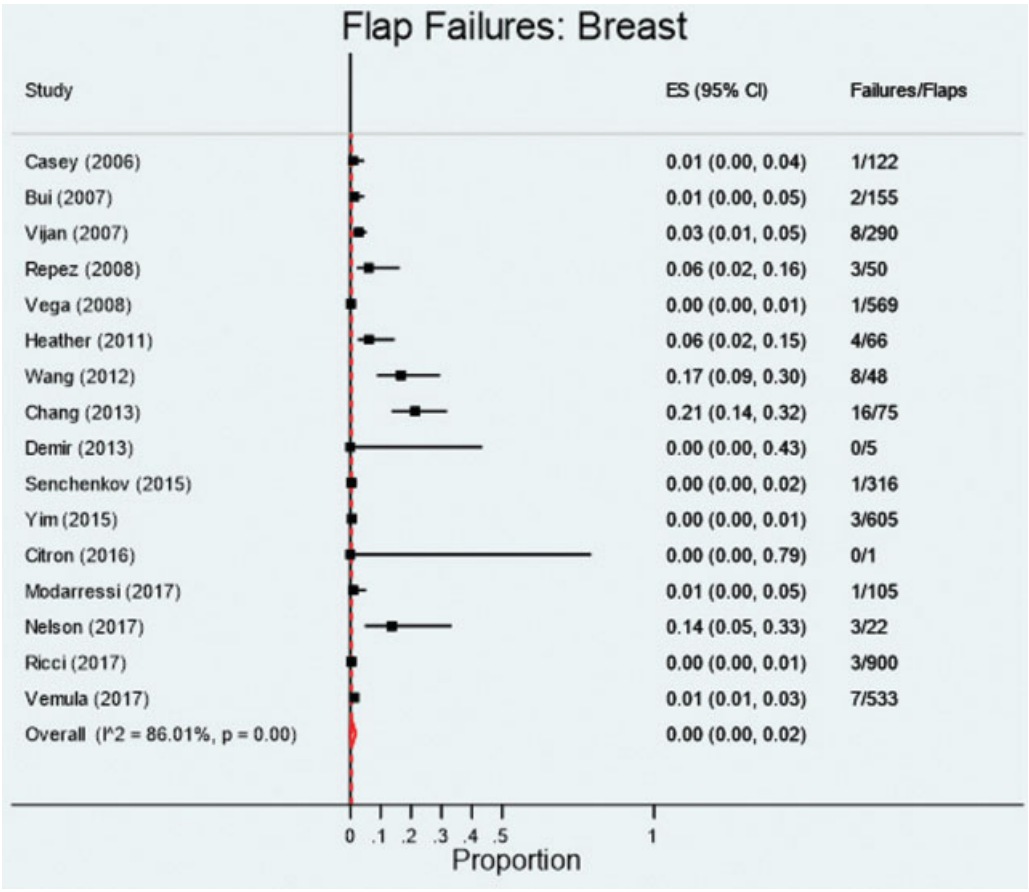

Fig. 3 Subgroup analysis of the breast location: flap failures.

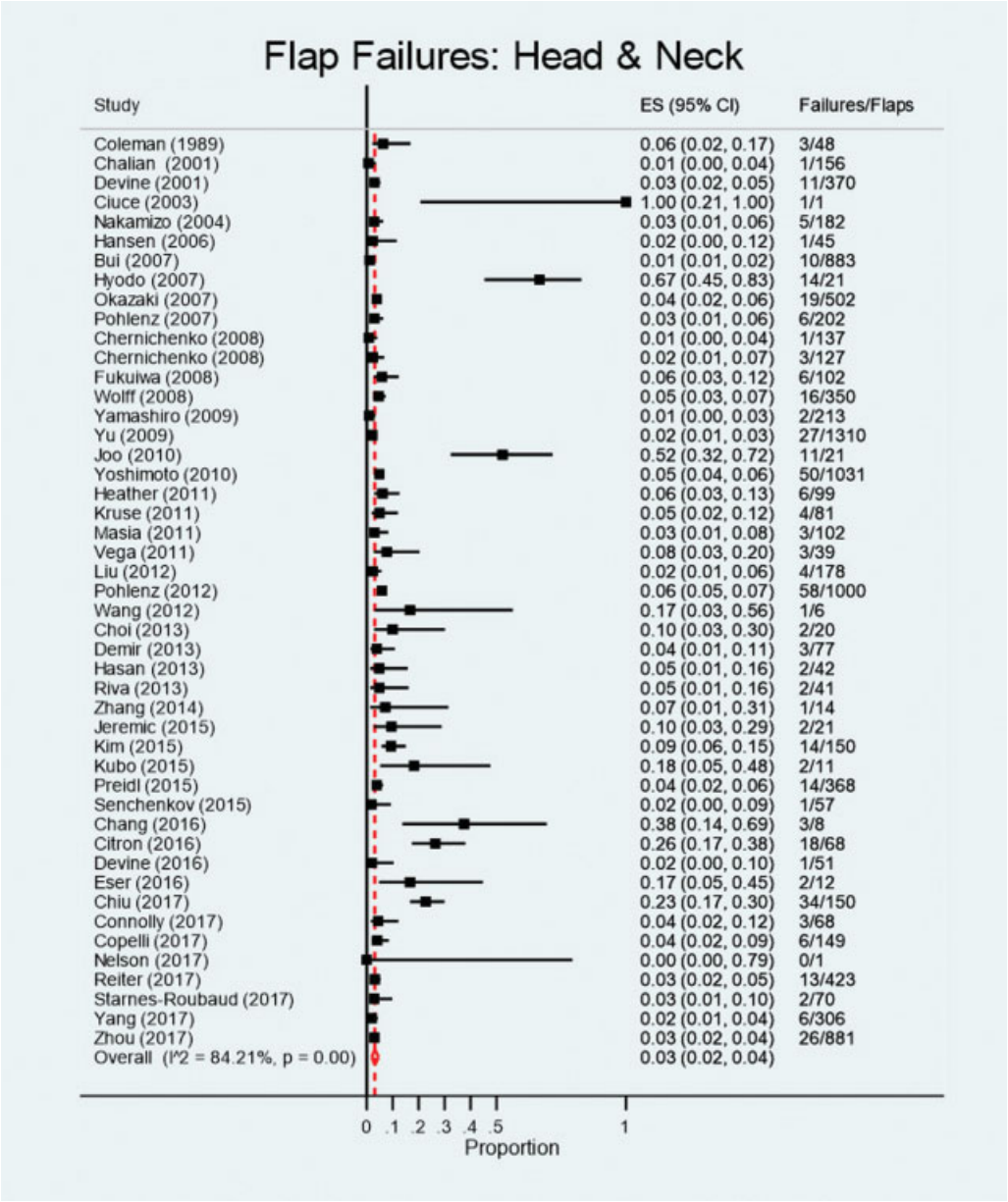

Fig. 4 Subgroup analysis of head and neck locations: flap failures.

Discussion

This study reviewed the literature on free flap compromise and failure and analyzed a total of 44,031 free flaps surgeries from 109 studies. Of these, 2,549 experienced flap compromise, with approximately two-thirds being successfully salvaged. From a sample of 355 individual flaps that specified the cause of failure, venous problems were by far the most common underlying cause of flap demise as identified in almost 60% of the cases. Arterial and combined arterial-venous issues made up a further 30% of failures; this left approximately 10% of flap failures being caused by hematoma or infection. The total flap failure rate in our sample of studies was 2.1%.

Earlier detection and hence earlier salvage attempts were significantly more successful than if there was a delay to return to the operation theater. The mean number of hours to intervene in successfully salvaged free flaps was 30.8 hours compared with 51.5 hours for flaps that were unable to be salvaged. Almost 71% of the compromised flaps were taken back to theater within the first 48 postoperative hours, suggesting that frequent monitoring is especially vital within this time period but can be reduced thereafter. The chance of flap compromise decreases as the number of postoperative days increases, but from day 3 onward there is a relatively constant risk of compromise which continues on to day 7 and beyond, making the yield of intensive monitoring less likely to be fruitful. The later the flap compromise occurs, the less likely it is to be salvaged even if return to theater is rapid.

It is clear from our analysis that shorter time to both detection and salvage intervention is associated with improved salvage rates. Facilitating this would have significant ramifications for the wellbeing of the patient, as successful

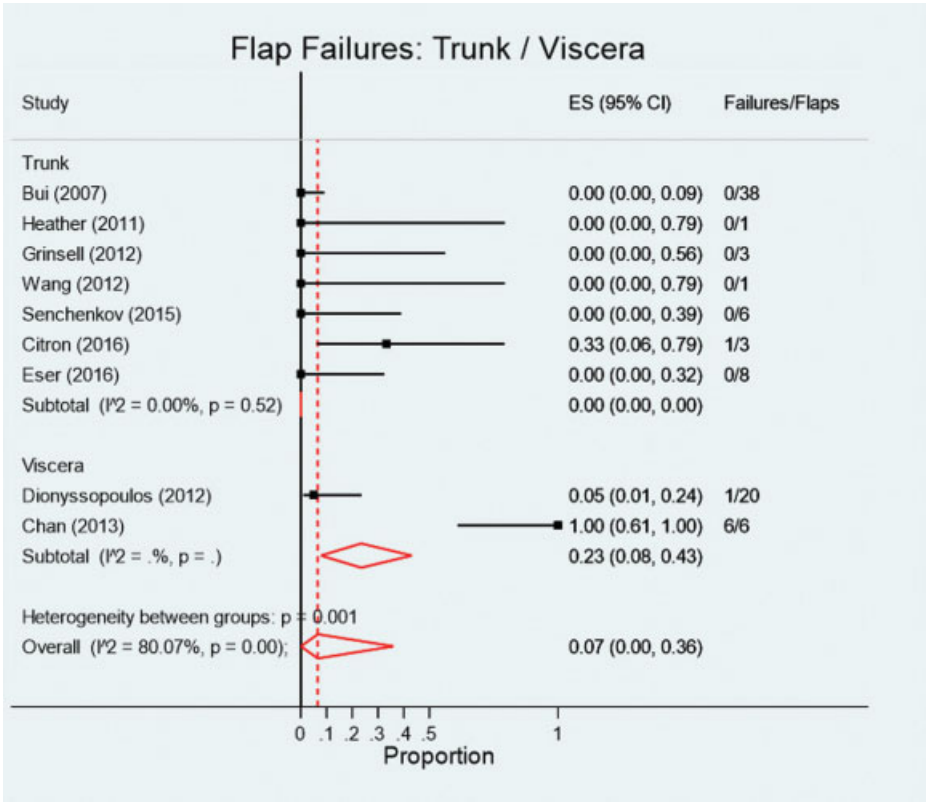

Fig. 5 Subgroup analysis of trunk/viscera location: flap failures.

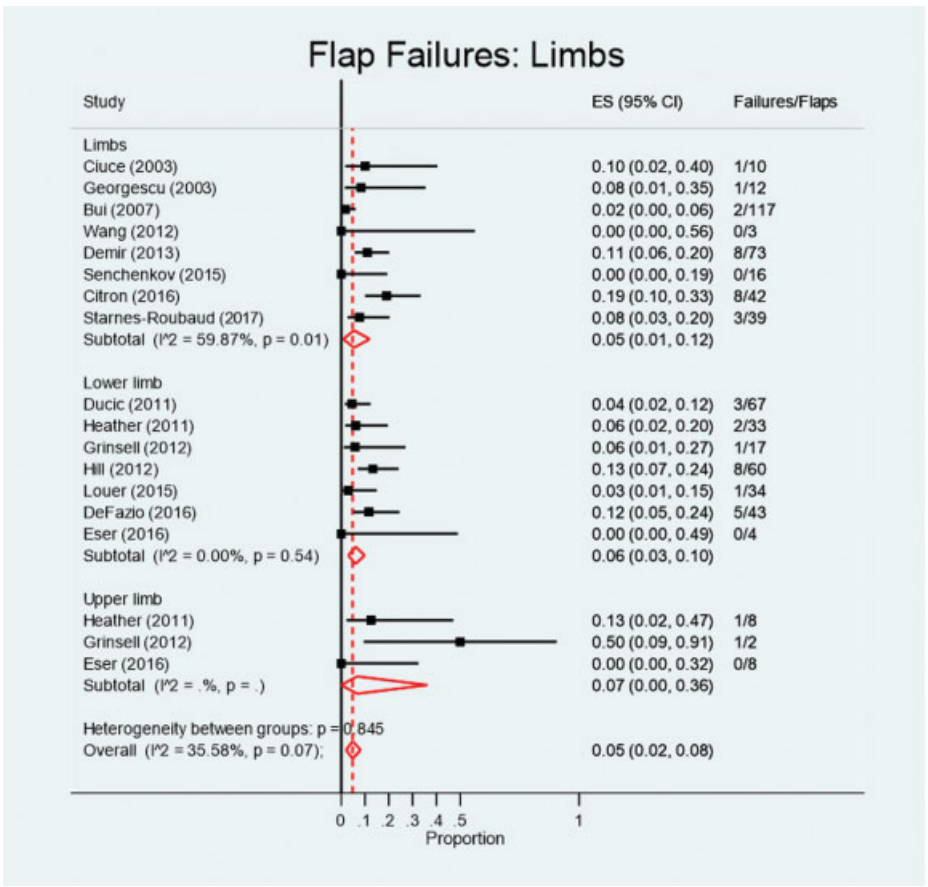

Fig. 6 Subgroup analysis of limbs location: flap failures.

Table 1 Studies with the details of exact timing of detection of compromise and time from compromise to return to theater for successful and unsuccessful salvage

Study	Total flaps	Number of flaps RTT	Salvage (% of take back)	Failed (% of take back)	Mean hours post-op of compromise if success (mean hours from detection to RTT)	Mean hours post-op of RTT if failed (mean hours from detection to RTT)
Ahmad et al[12]	1,883	20	15 (75.0%)	5 (25.0%)	35.3 (2.4)	91.6 (12.4)
Bui et al[13]	1,193	38	24 (63.2%)	14 (36.8%)	46 (4)	27.5 (9)
Chiu et al[14]	1,258	150	116 (77.3%)	34 (22.7%)	72.5	62.2
Devine et al[15]	370	46	35 (76.1%)	11 (23.9%)	17.5 (71)	51.0 (103)
Hyodo et al[16]	513	21	7 (33.3%)	14 (66.7%)	31.2	93.6
Mirzabeigi et al[17]	2,260	47	36 (76.6%)	11 (23.4%)	35.3	70.1
Panchapakesan et al[18]	590	71	46 (64.8%)	25 (35.2%)	22.6 (2.5)	39.8 (3.9)
Smit et al[19]	608	69	43 (62.3%)	26 (37.7%)	46.5	82
Vijan et al[20]	290	18	10 (55.5%)	8 (44.5%)	2.1	3.2
Winterton et al[21]	2,569	334	298 (89.2%)	362.4 (10.8%)	13	42.7
Yim et al[22]	605	17	14 (82.4%)	3 (17.6%)	16.6 (4.8)	3 (29)
Total	**12,139**	**831**	**644 (77.5%)**	**187 (22.5%)**	**30.8 (16.9)**	**51.5 (31.5)**

Abbreviation: RTT, return to theater.

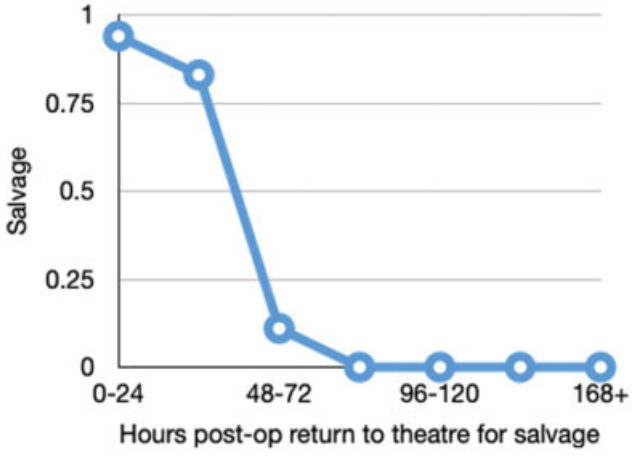

Fig. 7 Success of salvage attempts according to the time of compromise.

salvage of a compromised flap could drastically reduce their hospital stay and reduce the risk of needing a second large operation to replace the failed flap with further reconstruction, free flap, or otherwise. A recent study[8] in their process of evaluating the ideal postoperative free flap monitoring time frames, looked at continuous near infrared spectroscopy in free flap monitoring and found that concerns of flap compromise are identified earlier when compared with clinical monitoring, suggesting that there may be a role in utilizing other adjunct monitoring methods in improving flap salvage in the future. Within our sample of studies, only a handful mentioned the use of monitoring adjuncts such as Dopplers and there was no analysis of differences between Doppler use and clinical observation only; this would be a topic of interest of future research.

Flap failure rates in recent published literature range from as low as 0.55%[4] to 5.1%[1] with the majority of others falling somewhere in between, even in low volume centres.[3,9,10] Risk factors associated with flap failure include head and neck free flaps, prolonged operative time, and a high American Society of Anesthesiologist score.[1] While the included studies did not typically specify all of these details, the failure rate that we concluded appears to be consistent with other international studies. In particular, our study mirrors findings by Devine et al[7] who sought to analyze head and neck free flaps and thus devise a monitoring protocol, from which they found similar results and implemented a 72-hour postoperative flap observation chart.[7] Our results show that the majority of flap compromise occurs even earlier than 72 hours and intensive monitoring is of most benefit during the first 48 hours, after which there is a sharp drop in both risk of compromise and chance of salvage. Education of medical and nursing staff on how to perform accurate flap observations, when to escalate for help, and also having clear communication lines to enable rapid access to theater is similarly paramount during this critical period.

Our analysis of the recipient location of failed free flaps showed that among the included studies, trunk and visceral flaps (excluding breast) had the highest proportion of failures, followed by limbs, head and neck, and breast. This may be because breast free flaps are almost exclusively elective procedures typically on younger, healthy patients and are often performed in large volumes, especially in specialty centers.

While head and neck flaps are also usually elective procedures, the patient population is often elderly and have numerous comorbidities which affect both the quality of the tissues and the ability to perform salvage procedures. In free flaps on limbs for post-traumatic reconstruction, it was noted that flap complications are closely associated with the initial nature of injuries. In lower limbs, injury to the posterior tibial artery is linked with a higher complication rate and a higher incidence of requiring secondary amputation. This highlights the importance of a multidisciplinary approach before embarking on lower limb salvage surgery.[11] The low number of trunk and visceral flaps within our sample may reflect the fact that they are not often performed and hence explain the relatively higher proportion of failure.

Strengths and Limitations

While there are numerous articles describing free flaps outcomes, including many that we encountered in our screening process, we found that the vast majority of them discussed a sample of free flap patients from a single surgeon or institute, or utilize a database to describe general trends and failure rates. Our study combines data from dozens of articles with detailed information about free flap compromise and failure to obtain specific information about the timing and cause of compromise as well as the relation of this information to the success of salvage attempts. We were also able to gain insight into the rate of flap failures in different recipient locations, which provides useful benchmark information for surgeons. We believe this is highly important information that previously has not been analyzed and can help rationalize and refine the postoperative monitoring protocols that are currently used for free flaps.

The main limitations of our study was that many included studies did not include specific flap compromise or failure data at the patient level (often due to the nature of the study and the large number of included flaps) which made it impossible to perform quantitative statistical analysis of timing of compromise and time between detection of compromise and return to theater for most studies. This data could possibly be obtained by asking the authors for their raw data but they may not have this specific information and it would likely be very time consuming to conduct a meaningful analysis. We were also unable to include non-English studies that did not also have an English version provided, as we did not have access to translation services. While these studies made up a small proportion of the screened studies and many were excluded by abstract screening, it would have been interesting to see what our colleagues in those countries were finding in their own practices and whether there were any significant differences.

Conclusion

Overall, free flaps are a reliable method of reconstruction with a very low rate of failure. Flap compromise is uncommon but must be detected early by educated staff, especially in the first 48 hours where salvage is likely to be successful. Beyond this period, frequent monitoring yields decreasing returns and flap salvage is often not possible. Surgical units performing free flap surgery can use the information found in this review to help guide them in forming evidence-based flap monitoring protocols that will allow for efficient resource use and improved flap outcomes.

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All authors are in agreement with the content of this manuscript. This manuscript has not been published previously and is not under consideration elsewhere.

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Conflict of Interest
None declared.

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