

A REVIEW OF MINIMALLY INVASIVE TECHNIQUES FOR PERFUSION OPTIMIZATION IN FLAPS

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BACKGROUND

- Ischemia after reconstructive surgery can lead to tissue necrosis with total flap loss occurring in 1%-7% of cases and partial necrosis in 7%-33% of cases.^{1,2}
- Traditional surgical delay methods improve flap survival by inducing relative ischemia, but are invasive and carry additional risks³
- Noninvasive and minimally invasive techniques for preoperative surgical delay are being explored as safer alternatives. While promising, these methods are supported by small-scale animal studies.

AIMS

- This systematic review seeks to (1) characterize the literature on preoperative noninvasive and minimally invasive surgical techniques in adults undergoing flap-based procedures; and (2) assess the efficacy of these techniques in reducing ischemia-related complications.

METHODS

- Conducted in accordance with PRISMA guidelines, protocol registered on PROSPERO (CRD42024560362).
- MEDLINE (PubMed), EMBASE (OvidSP), and Cochrane Library were searched in July 2024 with the search terms: "precondition", "nonsurgical delay", "prehabilitation", and "embolization", combined with "flap" and "pedicle" using Boolean operators.
- Clinical studies on minimally invasive or noninvasive perfusion optimization techniques in adults were included. Animal studies, cadaveric studies, abstracts, commentaries, and non-English studies were excluded.
- Studies were selected with a 2-stage screening process via Covidence
- A predefined template was used to extract details including study design, sample size, intervention, control measures, and outcomes.
- Risk of bias was assessed using the NIH quality assessment tool.
- Due to study heterogeneity, findings were synthesized qualitatively and compared by means.

Figure 1. Illustrations of Different Perfusion Optimization Techniques showing (a) selective embolization of DIEA; (b) heat preconditioning; and (c) remote ischemic preconditioning

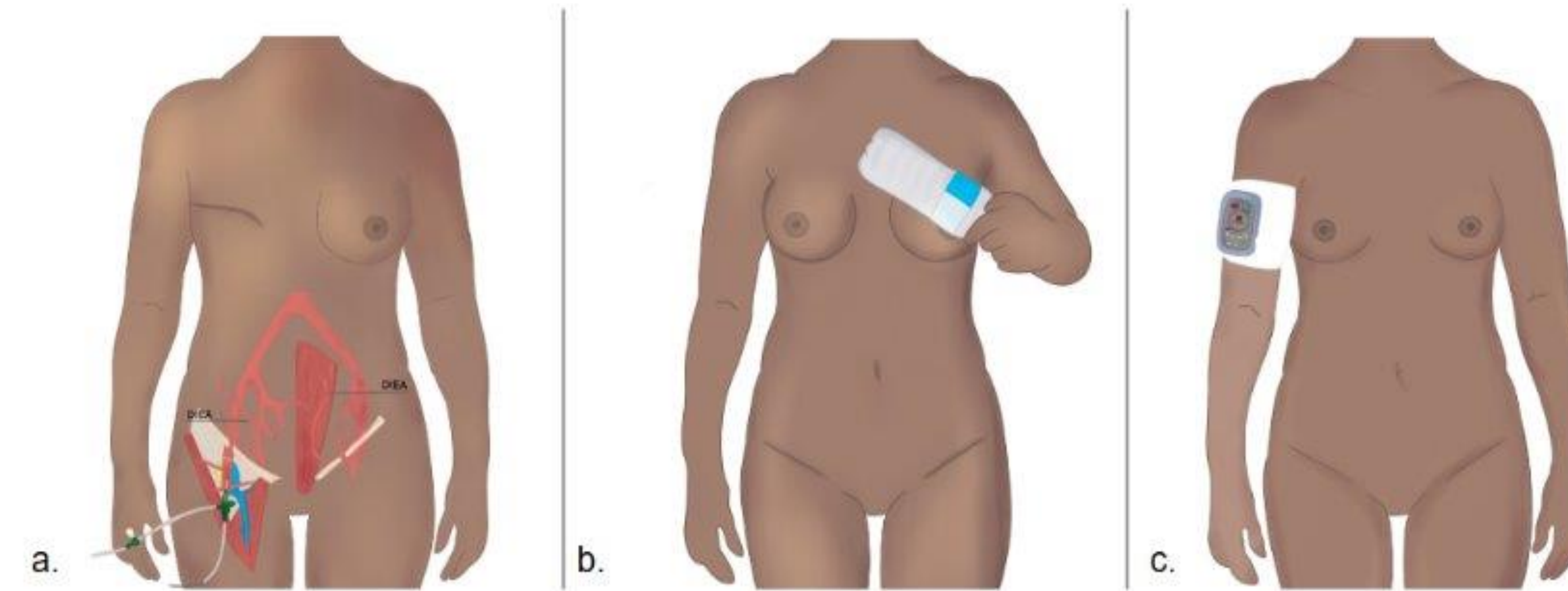


Table 1. Protocols and Reported Outcomes in Included Studies

Author, Year	Intervention	Control Group	Treatment Group Outcomes	Control Group Outcomes
Scheufler, 1999 ⁴	Selective Embolization of DIEA	Earlier patient group without flap delay	Partial flap necrosis in 3/40 patients (7.5%); fat necrosis in 1/40 patients (2.5%), no events of total necrosis	13.5% rate of partial flap necrosis
Sever, 2016 ⁵		Historical controls of those delayed by traditional surgical means and those with non-delayed flaps	Partial flap necrosis in 1/15 patients (6.7%); no patients experienced total flap necrosis; 2/15 patients (13.3%) experienced fat necrosis	26.7% of patients (n=12) in the non-delayed group experienced skin/fat necrosis. 11.2% of patients (n=2) in the surgically delayed group experienced skin/fat necrosis
Aboutanos, 2012 ⁶			No patients with skin flap necrosis; 12/88 patients (13.6%) experienced fat necrosis	5-33% of non-delayed pedicled TRAM flaps for breast reconstruction are complicated by partial flap necrosis. Surgically delayed flaps have rates between 4.3-13%
Krag, 2020 ⁷	Remote Ischemic Preconditioning	Sham intervention	Flap necrosis rate of 7% (n=2)	Flap necrosis rate of 3% (n=1)
Mehta, 2013 ⁸	Heat Preconditioning	Standard care	Proportion of patients experiencing skin flap necrosis was 12% (n=3) in the heated group	Proportion of patients experiencing skin flap necrosis was 36% (n=9) in the heated group
Mehta, 2019 ⁹			Proportion of patients experiencing necrosis was 26% (n = 18) in the heated group. 11% (2/18) of patients experienced necrosis that required surgical intervention	The proportion of patients experiencing necrosis in controls was 35% (n = 23). 17% (n=4) experienced necrosis that required surgical intervention

RESULTS

- Six studies (1999–2020) involving 394 patients were analyzed across three intervention categories: angiographic delay, heat preconditioning, and remote ischemic preconditioning
- Key Findings:
 - **Angiographic Delay:** Reduced flap necrosis (13%) compared to non-delayed procedures with outcomes comparable to surgical delay.
 - **Heat Preconditioning:** Significantly reduced flap necrosis (P=0.04) and improved vascularity.
 - **Remote Ischemic Preconditioning:** Showed no significant benefits (P=1.0) in flap outcomes or complications.

CONCLUSION

- Angiographic embolization, heat preconditioning, and remote ischemic preconditioning are promising alternatives to surgical delay, with potentially comparable outcomes in optimizing flap perfusion and survival.
- Larger studies are required to compare these minimally invasive methods with no-delay and surgical-delay controls to establish definitive effectiveness and reliability.

REFERENCES

1. Khouri RK, Cooley BC, Kunselman AR, et al. A prospective study of microvascular free-flap surgery and outcome. *Plast Reconstr Surg.* 1998;102(3):711-721
2. Fischer JP, Wink JD, Nelson JA, et al. A retrospective review of outcomes and flap selection in free tissue transfers for complex lower extremity reconstruction. *J Reconstr Microsurg.* 2013;29(6):407-416
3. Restifo RJ, Ward BA, Scoutt LM, Brown JM, Taylor KJ. Timing, magnitude, and utility of surgical delay in the TRAM flap: II. Clinical studies. *Plast Reconstr Surg.* 1997;99(5):1217-1223
4. Scheufler O, Andresen R, Kirsch A, Banzer D, Vaubel E. Clinical results of TRAM flap delay by selective embolization of the deep inferior epigastric arteries. *Plast Reconstr Surg.* 2000;105(4):1320-1329
5. Sever AJ, Patel C, Albeer Y, Darian VB. The Technique and Benefits of Angiographic Embolization of Inferior Epigastric Arteries Prior to Pedicled TRAM Flap Breast Reconstruction: Results from a Single Center. *Cardiovasc Intervent Radiol.* 2017;40(12):1845-1850
6. Aboutanos SZ, Spinos E, Blanchet NP. Angiographic delay: a viable alternative to surgical delay. *Ann Plast Surg.* 2012;68(6):562-567
7. Krag AE, Hvas AM, Hvas CL, Kil BJ. Remote Ischemic Preconditioning in Microsurgical Head and Neck Reconstruction: A Randomized Controlled Trial. *Plast Reconstr Surg Glob Open.* 2020;8(1):e2591.
8. Mehta S, Rolph R, Cornelius V, Harder Y, Farhadi J. Local heat preconditioning in skin sparing mastectomy: a pilot study. *J Plast Reconstr Aesthet Surg.* 2013;66(12):1676-1682
9. Mehta S, Cro SC, Coomber B, Rolph R, Cornelius V, Farhadi J. A randomised controlled feasibility trial to evaluate local heat preconditioning on wound healing after reconstructive breast surgery: the preHEAT trial. *Pilot Feasibility Stud.* 2019;5:5.