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Extracorporeal Perfusion of Vascularized Composite Tissues: The Bridging Role of an Emerging Technology in Reconstructive Microsurgery

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Complex defects with exposed critical structures after trauma or tumor resections are routinely reconstructed with free flaps. In the current practice of reconstructive microsurgery, the success rate at high-volume centers is above 95%. However, despite high success rates, free tissue transfer is not without challenges and limitations. The high degree of technical skill and resources needed to perform these lengthy procedures are not fulfilled at every institution globally. In some cases, the availability of recipient vessels can be limited due to vascular disease or prior treatments. Additionally, perioperative patient decompensation could affect outcomes, especially in complex multitrauma patients. Therefore, an improved approach is still needed to ensure reliable flap transfer even in the presence of unanticipated events and compromised recipient vasculature.

Considering the major advancements over the past few decades, further improvement at this point requires a paradigm shifting approach. Machine perfusion, classically used in the preservation of solid organs, offers a wide variety of implications for vascularized composite tissues. An extracorporeal perfusion system (EPS), similar to that used during cardiopulmonary bypass, can be used to isolate the tissue via cannulation of the primary artery and vein and provide temporary support. The research on this topic[1] can be furthered to enable clinical use of such technology in three distinct purposes (Fig. 1).

•Bridge-to-anastomosis: An EPS could be used to maintain support of the tissue until transplantation and successful anastomosis to mitigate ischemia/reperfusion injury. This purpose could support the tissues during delays between harvesting and anastomosis such as transportation of composite allografts, temporizing replants, or stabilization of decompensating patients.[2,3]

•Bridge-to-neovascularization for traditional flaps: A portable/wearable EPS could be maintained following inset of the tissue over a wound bed and obviate the need to isolate and connect to recipient vessels. Extracorporeal support would continue until sufficient vessel ingrowth and tissue integration has occurred and can be weaned once the neovascularized network itself can provide full tissue support. The basic feasibility of the bridge-to-neovascularization approach in a vessel depleted wound was demonstrated in a small case series and showed that less than 2 weeks of external perfusion could allow sufficient neovascularization.[4]

•Bridge-to-neovascularization for bioengineered flaps: The third application has the broadest implications for clinical impact and the field of bioengineered vascularized composite tissues. Currently, although there are limited studies, a major obstacle in engineered vascular networks is thrombosis.[5] An EPS would be crucial to ensure successful transfer of engineered constructs with the benefit of closed-system isolated drug delivery (eg, heparin, vasodilatory agents) and conditioned perfusate (eg, platelet depletion) to prevent intravascular thrombosis. Similarly, this closed circuit could be used for delivery of growth factors to induce angiogenesis and facilitate integration of the transferred tissue.

In summary, an EPS would address immediate and future problems in complex soft-tissue reconstruction. Recent advancements in the machine perfusion field and its integration with reconstructive microsurgery could open doors for a novel subspecialty. The challenging scenario of extensive tissue loss could be managed without the need for microsurgery using a compact perfusion system.

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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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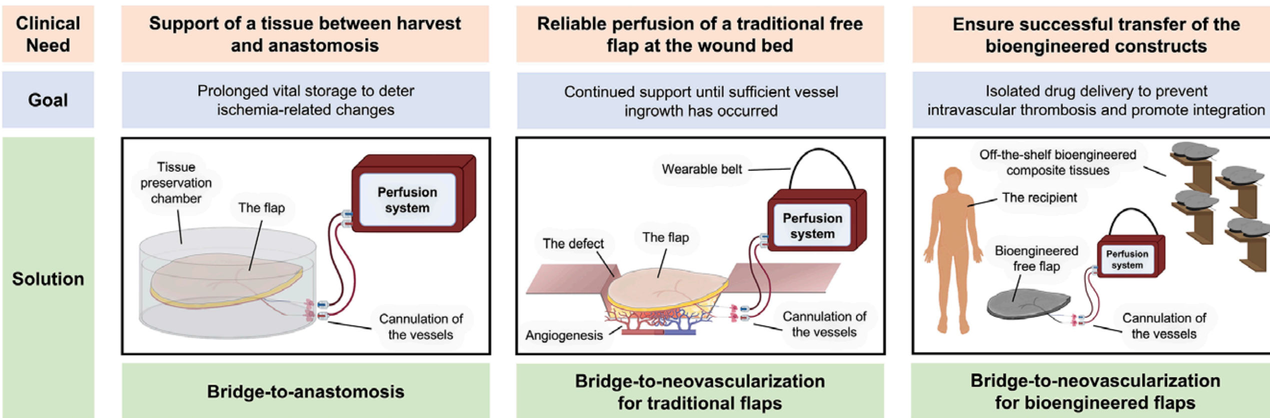

Fig. 1. Conceptual schematic of the potential clinical needs that an extracorporeal perfusion system could address. Machine perfusion support could serve three distinct purposes in reconstructive microsurgery: (1) bridge-to-anastomosis, (2) bridge-to-neovascularization for traditional flaps, and (3) bridge-to-neovascularization for bioengineered flaps. Even the uses for purposes 1 and 2 might be rarer occurrences; once the technology is established for purpose 3, its indications will continually expand to cover purposes 1 and 2. Created with BioRender.com.