

Hybrid Reconstruction Ladder

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Abstract

Combat operations expose military service members and civilians to the devastating effects of high-energy munitions that often lead to a complex pattern of injury. This complex injury pattern has initiated efforts to create new and innovative techniques in tissue regeneration. Multidisciplinary team has effectively adapted advanced reconstructive techniques merged with regenerative medicine modalities to improve outcomes in combat casualties. These treatments combine traditional reconstruction measures with regenerative medicine applications and has been termed 'hybrid reconstructions'. This review article gives an overview about hybrid reconstruction ladder.

Keyword: Reconstruction ladder; Wound; Hybrid.

Introduction

The reconstructive ladder is a concept familiar to all plastic surgeons. (Fig. 1)

Although it has undergone gradual evolution over time, the basic concept of methods of reconstruction ranked by complexity has been preserved and propagated in multiple forms. Most descriptions start with closure by secondary intention, followed by direct closure, local flaps, and distant flaps. Various authors have made finer distinctions among local, regional, and free flaps, and inserting tissue expansion somewhere in the spectrum.

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in tissue regeneration. Multidisciplinary team has effectively adapted advanced reconstructive techniques merged with regenerative medicine modalities to improve outcomes. These treatments combine traditional reconstruction measures with regenerative medicine applications and has been termed 'hybrid reconstructions'.¹

The hybrid reconstruction model aids in maximizing the function while minimizing the disability and morbidity associated with traditional reconstruction.

Background

The reconstructive ladder is an improper extension of a well known and appropriate concept

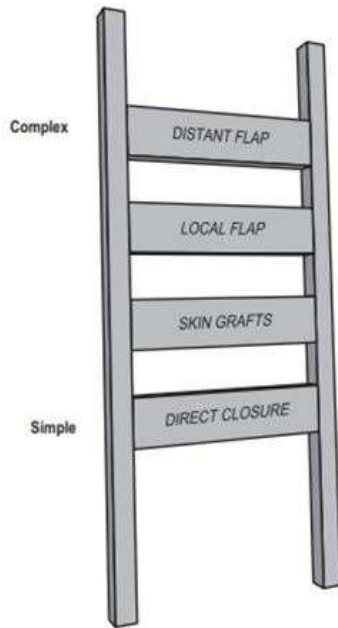


Fig 1: Reconstructive Ladder

Source: @ Neligan Textbook of Plastic Surgery Vol. 1

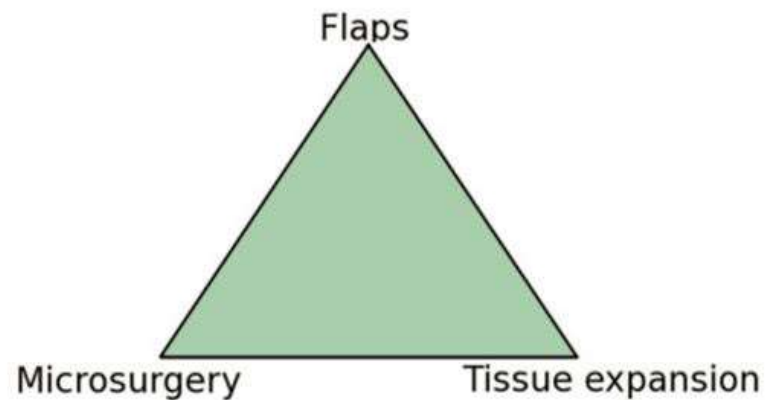


Fig. 2. The reconstructive triangle, as proposed by Mathes and Nahai. (Adapted from Mathes SJ, Nahai F. *Reconstructive Surgery: Principles, Anatomy & Technique*. Vol. 2. New York: Churchill Livingstone; St. Louis: Quality Medical; 1997.)

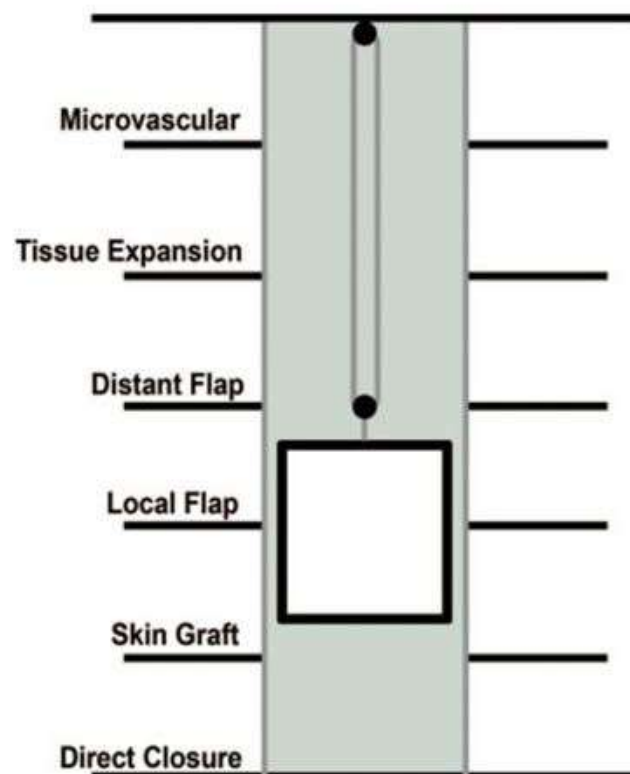


Fig. 3. The reconstructive elevator, as proposed by Gottlieb and Krieger. This formulation emphasizes the importance of selecting the most appropriate level of reconstruction as opposed to defaulting to the least complex. (Reprinted from Gottlieb LJ, Krieger LM. From the reconstructive ladder to the reconstructive elevator. *Plast Reconstr Surg*. 1994;93:1503–1504.)

Surgeons* skills								
es available	Bioengineered tissue					Super microsurgery	Patient requests	
	Oxygen therapy					Robotic Microsurgery		
	Extracellular matrix			Tissue expansion		Functional tissue transfer*		
	External tissue expansion			Perforator (laps)	Islanded flaps	Perforator free naps		Abdominal wait transplant
	Cell therapy & Growth Factors	Gene therapy & Tissue Engineering	Composite graft	Keystone naps	Composite flap	Composite tree nap		Face transplant
	NPWT	In-utero reconstruction	Component graft	Dermal flaps	Component flaps	Component free Hap		Hand transplant
	Secondary healing	Primary closure	Graft	Local flap	Distant flap	Free nap		Vascular Composite Allotransplant
Wound complexity								

Fig. 4: The Reconstructive Grid

Source: @ Viewpoints-Reconstruction 2.0: Restructuring the Reconstructive Ladder in Journal on Plastic and Reconstructive Surgery

of a wound closure ladder. It has its own limitations. Although there is virtue in using the simplest solution to a given problem, at times more complex methods of reconstruction may be preferred, even when simpler methods can achieve wound closure. To address these concerns, several modifications to the reconstructive ladder have been proposed. Mathes and Nahai² suggested the “reconstructive triangle,” which consisted of tissue expansion, local flaps, and microsurgery (Fig. 2).

Gottlieb and Krieger³ introduced the “reconstructive elevator” which, although still acknowledging the concept of increasing levels of complexity, suggests the freedom to ascend directly to the appropriate level if necessary (Fig. 3).

Wong and Niranjani⁴ recommended that the rungs be thought of as stages in the development of surgical skills, emphasizing that the difficulty of a reconstructive problem is related to the skill and training of the treating surgeon. Erba et al.⁵ integrated the concepts of surgical risk, technological complexity, and surgical complexity into a matrix to help organize the various reconstructive methods and provide a framework for further discussion.

The reconstructive grid⁶ is a dynamic construct that takes into account the multiple reconstructive options available to the plastic surgeon. It also takes into consideration factors that help the reconstructive surgeon determine the best possible option to achieve the three reconstruction goals, namely, form, function, and aesthetics. The factors that aid the judgment of a reconstruction specialist, including wound complexity, surgeon skill,

resources (and technology) available, and patient requests, form the boundaries of the reconstructive grid.

The bottom row of the reconstructive grid houses the traditional modalities of reconstruction that are available in the ladder and elevator and the newer reconstruction modality, vascular composite allotransplant which, though absent in the reconstructive ladder, is mentioned in the modified reconstructive elevator.⁷ (Fig. 4) The boxes above these primary reconstruction modalities show techniques available within each modality of reconstruction. The spatial nature of the reconstructive grid permits the specialist to select multiple options for a given defect. The reconstructive grid includes newer wound healing techniques such as bioengineered skin, cell therapies (e.g., adipocyte derived stem cells), and also still developing reconstruction techniques including tissue engineering⁸ and gene therapies.⁹ The blank boxes represent available space to accommodate newer techniques as they arise, under each modality, thus making the grid future-ready.

The standard treatments for extremity injuries with massive composite tissue loss (bone, skin, soft tissue, nerves) require a spectrum of therapies. These therapies include extremity amputation, limb-shortening to assist in residual limb soft tissue coverage, free tissue transfers, pedicle flaps, local flaps, skin grafting, bone reconstruction, nerve repair or reconstruction and vascular repair. The traditional therapies may subtract from an already decreased functional capacity and may



Fig. 5: Hybrid Reconstructive Ladder.

Source: @ Article- Plastic Surgery Challenges in War Wounded II: Regenerative Medicine

result in significant donor site morbidity. Revised amputations may have non-pliable and/or nondurable surface areas prone to erosive wear with prosthetic use. Furthermore, the multiple limb injuries and amputations seen in combat casualties typically involve expanded zones of injury that extend beyond the directly affected extremities that can complicate reconstructive efforts.⁷ Furthermore, in the multiple extremity injured service member, the common accepted donor sites for autologous tissues become increasingly limited.

Consequently, this has led to increased use of regenerative medicine modalities to enhance tissue regeneration and improve reconstructive outcomes. Hence the term “Hybrid Reconstruction Ladder”. (Fig. 5)

The reconstructive ladder was a term coined by plastic and reconstructive surgeons to describe levels of increasingly complex management of soft tissue wounds.¹⁰ Theoretically, the surgeon would utilize the lowest rung of the ladder – that is, the simplest reconstruction technique – to address a clinical reconstructive problem.¹¹ The reconstructive surgeon would move up the ladder as a more complex or suitable method was required for a given reconstruction problem. A hybrid reconstructive ladder that augments the traditional reconstructive ladder with regenerative medicine modalities.¹² There were improved outcomes at each rung on the reconstruction ladder and these modalities may allow for the expansion of indications for each rung on the reconstruction ladder.

The study effectively employed dermal regenerates, soft tissue regeneration techniques, biologic scaffolds, fat grafting techniques and adipose derived stem cells in a number of reconstructions.¹³

Indications

The utilization of high-concentration allogeneic mesenchymal stem cell (MSCs) for segmental and severely comminuted osseous deficits.¹⁴

The dermal regeneration templates for preparation and to improve the durability of wound beds for skin grafting.

The biologic scaffolds such as urinary bladder matrix to provide for soft tissue regeneration, surgical wound bed preparation and muscle regeneration.¹⁵

The decellularized allograft nerves to serve as nerve regeneration templates or conduits for segmental nerve defects in patients lacking adequate auto-graft nerve sources.

Advantages

The dermal regenerates have reduced skin erosion rates compared with those patients with skin grafting alone.

It has reduced wound healing issues surrounding the prosthetic wear sites by increasing durability.

Orthopedic union rates and nonunion rates have

been reduced by adjunctive use of these measures when compared with traditional reconstructions without bony regenerates.¹⁶

These regenerative techniques have addressed bony healing and wound healing as well as salvage failed cases, which includes improving limb salvage rates, amputation preservation of length, and carefully selected cases.^{17,18}

Even in patients with limb loss and multiple extremity amputations, using these modalities has allowed residual limbs to be preserved at a length suitable for prosthetic fitting.¹⁹

It may be extracted to treat lesser severe injuries from trauma, burn or oncologic cases using hybrid reconstructions.^{20,21}

Disadvantages

High cost

Requirement of high infrastructure

Training to learn the skill.

Recent Advances

For large peripheral nerve defect reconstruction include tolerance induction and minimal immunosuppression for nerve allografting, cell based supportive therapies and bioengineering of nerve conduits.²²

The future of dermal regenerates includes enhancing existing technologies and adapting them to single-stage procedures to manage soft tissue avulsion injuries.²³

Spray skin technologies include the use of non-culture autologous cells to promote wound healing and reconstructive procedures.²⁴

Vascularized composite tissue allograft transplantation is another possible therapy in combat casualties.²⁵

Conclusion

The application of regenerative medicine therapies in the treatment of complex injuries has significantly aided in improving reconstructive outcomes. Hybrid Reconstruction Ladder is continuing to evolve and may become the standard of care for effective management of composite tissue wounds.

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