

Building a Multidisciplinary Clinic Dedicated to Upper-Extremity Limb Loss

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Complete care of the patient with upper limb loss mandates a long-term, multifaceted approach. Increased functionality and quality of life require collaborative efforts between the patient's surgeon, prosthetist, hand therapists, mental health professionals, and peers. An individual surgeon may find that initiating and maintaining a practice offering total integrated treatment for upper-extremity amputees is a formidable task, but with specific, actionable recommendations, the process can be demystified. The upper-extremity surgeon must be facile with operative techniques such as targeted muscle reinnervation (TMR), regenerative peripheral nerve interface (RPNI), and soft tissue reconstruction and focus on team recruitment strategy and promotion of the clinic within the community. Consistent communication and team decision-making shape each patient's preoperative and postoperative course. We aim to relay effective interventions at each step of recovery from each clinic member and describe clinic workflow designed to reinforce holistic care. We present a blueprint for creating a functional and comprehensive multidisciplinary center for patients with upper-extremity limb loss for those providers interested in providing care, but who are missing the logistical roadmap for how to do so. (*J Hand Surg Am.* 2023;■(■):■–■. Copyright © 2023 by the American Society for Surgery of the Hand. All rights reserved.)

Key words Amputation, clinic, limb loss, prosthetics, surgical reconstruction, upper extremity.



APPROXIMATELY 41,000 AMERICANS currently live with an upper limb amputation.¹ These injuries are psychologically and functionally devastating across all demographics and etiologies.² Inadequate insurance, rural location, limited rehabilitation services, and long, arduous prosthetic fittings remain barriers to comprehensive treatment.^{3–5}

Innovative surgical management, with a focus on techniques for neuropathic pain mitigation and myoelectric prosthesis optimization, has been well described.^{6–10} Nonetheless, capable upper-extremity surgeons are dissuaded from treating patients with limb loss due to the lack of a comprehensive model for their care. Environmental and psychological factors are often tantamount to surgical challenges, necessitating a holistic approach.^{2,10,11} We provide a logistical roadmap for creating a successful clinic dedicated to patients with upper-extremity limb loss, with hopes of expanding access for patients with complex, yet often surmountable obstacles to recovery. Our purpose is to encourage recognition and promote discourse on the benefits of the multidisciplinary approach and ensure providers, employers, patients, and hospital systems have a better understanding of the optimal treatment of these conditions.

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Received for publication June 18, 2023; accepted in revised form November 30, 2023.

No benefits in any form have been received or will be received related directly to this article.

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0363-5023/23/■ ■ -0001\$36.00/0
<https://doi.org/10.1016/j.jhsa.2023.11.022>

THE ESTABLISHMENT OF THE CLINIC

Before the initiation of the clinic, the senior surgeon and therapist provided treatment to patients with limb loss without a comprehensive approach. Patients were often unable to identify and integrate necessary team members from other disciplines and, even if able to do so, were shuffled between providers, leading to a divided, discontinuous execution of the care strategy—it became evident that patients were experiencing suboptimal outcomes.

At this point, the clinic was established, with four essential disciplines identified as required for success—surgery, rehabilitation, prosthetics, and mental health. The initial iteration of the clinic included one member of each discipline. The clinic has evolved, inclusive of the surgeon and mid-level provider support, a certified hand therapy team, two prosthetists including one upper limb specialist, two onsite psychologists, and a peer support mentor, with nursing and scheduling support. Challenges have been encountered along the way, with many lessons learned.

IDENTIFYING THE CRITICAL DISCIPLINES

Surgery

The surgeon must have a mastery of limb preservation techniques, especially when anticipating prosthetic use. The surgeon must ensure that the amputation is performed to allow for structural stabilization of the residual limb and that the bone is covered with durable soft tissue to support a prosthesis in the long term. Deliberate selection of residuum length is predicated on the initial amputation level. Some scenarios will require shortening, whereas others will necessitate flap reconstruction to optimize final limb length.^{8,12}

Up to 25% of upper limb amputees develop symptomatic neuromas;¹³ up to 80% experience phantom limb pain.¹² Therefore, targeted muscle reinnervation (TMR) and regenerative peripheral nerve interface (RPNI) techniques improve myoelectric prosthetic control and diminish phantom pain. The upper limb surgeon must be adept at implementing these techniques at all amputation levels.

Hand surgeons are uniquely positioned to be the “champions” of clinics dedicated to upper-extremity limb loss because of their intersectional training in plastic surgery, orthopedic surgery, nerve surgery, and rehabilitation—other medical specialists cannot provide the same level of comprehensive expertise. The surgeon must be adept in working with each

member of the interdisciplinary team, possessing the knowledge to make decisions that optimize the overall experience of the patient. By working side-by-side with prosthetists, occupational therapists, and mental health experts, the surgeon can guide the patient through the best course of recovery.

Occupational therapy

Therapy for patients with upper limb loss is a critical factor in their postoperative functionality and quality of life. Certified hand therapists (CHTs) emphasize reintegration into society, return to work, and functional independence. They inventory the patients’ home and work environments, support systems, goals, and level of activity.

The therapist is responsible for prosthetic implementation. Early integration of the prosthesis promotes expedited, more facile functional control of the patient’s definitive device and decreases phantom limb pain. Graded motor imagery is used in the early postoperative period to increase prosthetic control and mitigate phantom limb symptoms. Gradual exposure prevents the brain from solidifying a maladaptive protective pain response.¹⁴

The experienced CHT will specifically address TMR by using exercises that “flood” the nerve transfers. These exercises allow for persistent activation of specific myosites that eventually strengthen the donor nerve signals, which can later contribute to acting as signals for the myoelectric prosthesis. Individualized protocols are carried out according to specific patient needs.

Prosthetists

Engaging a prosthetist who is a clinical upper limb specialist is critical for this setting. With few upper-extremity experts available, it is important to train and use a local prosthetist to facilitate adjustments, fitting, fabrication, casting, repairs, and general troubleshooting on a more frequent basis. In our experience, facilitating local expedited fittings, trainings, and adjustments is critical to provide convenient access to device consultations and encourage continued use.

The experienced upper-extremity prosthetic specialist will work closely with the surgeon and help guide in surgical decision-making. Prosthetists need to be familiar with reconstructive techniques at all levels of amputation. Specifically, they must be able to apply the principles of TMR and RPNI to manufacturing of the device and when assessing individual myoelectric prosthetic function, especially as it relates to pattern recognition control. Our patients

are offered a near-immediate postoperative prosthesis, which is a rapidly fabricated prosthesis created after taking measurements early after surgery (ideally within the first few days after surgery). Provisional 3D-printed near-immediate postoperative prostheses decrease the rates of abandonment, increase patient skill of use, and stabilize residual limb volume.¹⁵ The appropriateness of advanced prosthetics versus simpler options is determined in close concert with the hand therapist. Ultimately, prosthetists establish lifelong relationships with our patients, introducing adjustments and innovation when possible.

Mental health

Only recently has literature focused on the mental health of upper limb amputees, who commonly struggle with post-traumatic stress disorder, anxiety, agoraphobia, and depression. Chronic pain interference and compromised ability to communicate with the hands may serve as unrelenting contributors to daily distress.^{12,16} Early identification and intervention of a maladaptive mindset is associated with enhanced functional outcomes.¹⁷

The use of screening questionnaires at each visit is a crucial part of providing ongoing care. Any concerning data are noted by onsite psychologists, and each patient has a meeting with the psychologists at the end of their clinic session where issues may be further investigated. In addition to one-on-one evaluations, each clinic has a group therapy session available to patients. This environment provides an informational and emotionally supportive safe space in which patients can tackle psychosocial issues. The group setting encourages independence and hope for the future, as peers can validate the transitory nature of setbacks during recuperation.¹⁸

Peer mentorship is a major component of the mental health treatment protocol. Mentors must have a demonstrated desire, be empathetic, and be functionally engaged. Our peer mentors offer advice and camaraderie for patients in all phases of their recovery.

Monthly clinic workflow

Referrals for the clinic arrive from numerous locations including trauma centers, community hospitals, trauma surgeons, orthopedic surgeons, vascular surgeons, neurosurgeons, and other hand surgeons. Nonsurgeon referrals arrive from physical and occupational therapists, pain management physicians, physiatrists, and neurologists. Organic referrals arrive from marketing and the website dedicated to the program.

Clinic starts with a team meeting to discuss each patient. We systematically address surgical, rehabilitation, mental health, and prosthetic concerns. Social, psychological, and environmental challenges are considered. This provides a unique opportunity for a solution-focused, multidisciplinary brainstorming session and a review of outstanding items in a patient's global care plan.

After the morning conference is completed, the patients are evaluated according to their allotted time in the clinic. Patients are encouraged to spend time speaking to one another in the waiting area to facilitate peer support. Furthermore, patients are encouraged to attend the group therapy session and are shuttled in and out of group therapy according to their scheduled appointment time. Each patient is then seen by each team member from each discipline. The behavioral health team subsequently sees each patient in the absence of the remaining team members to facilitate discussion of mental health concerns. We end the day by discussing each patient as a team. This process engenders team and individual accountability for each patient's goals of treatment. Between clinic dates, the team comes together several times to assess progress and troubleshoot any unexpected hindrances to forward movement (Fig. 1).

BENEFITS OF THE MULTIDISCIPLINARY MODEL

Multidisciplinary care is highly effective in treating patient populations dealing with chronic illness.^{19,20} These advantages are demonstrated within our clinic, with benefits to patients, providers, and the overall health care system (Fig. 2).

For patients

In a traditional model, patients may have to identify nonsurgical components of their care (ie, rehabilitation, prosthetics, and behavioral health) on their own. It is difficult for those without adequate resources or knowledge to find appropriate team members to aid in their recovery, especially in light of the significant physical and psychological distress they may already be experiencing.^{21,22} Having a singular location in which these resources are all readily available is an important step forward in the recovery process.

Decision-making by a cohesive team in constant communication is arguably the strongest facet of the multidisciplinary approach, which directly benefits the patient. With each team member working in concert, the group can formulate solutions and anticipate problems as a unit. Identification of pitfalls or anticipation of potential roadblocks is more efficient as multiple voices with specific expertise exist;

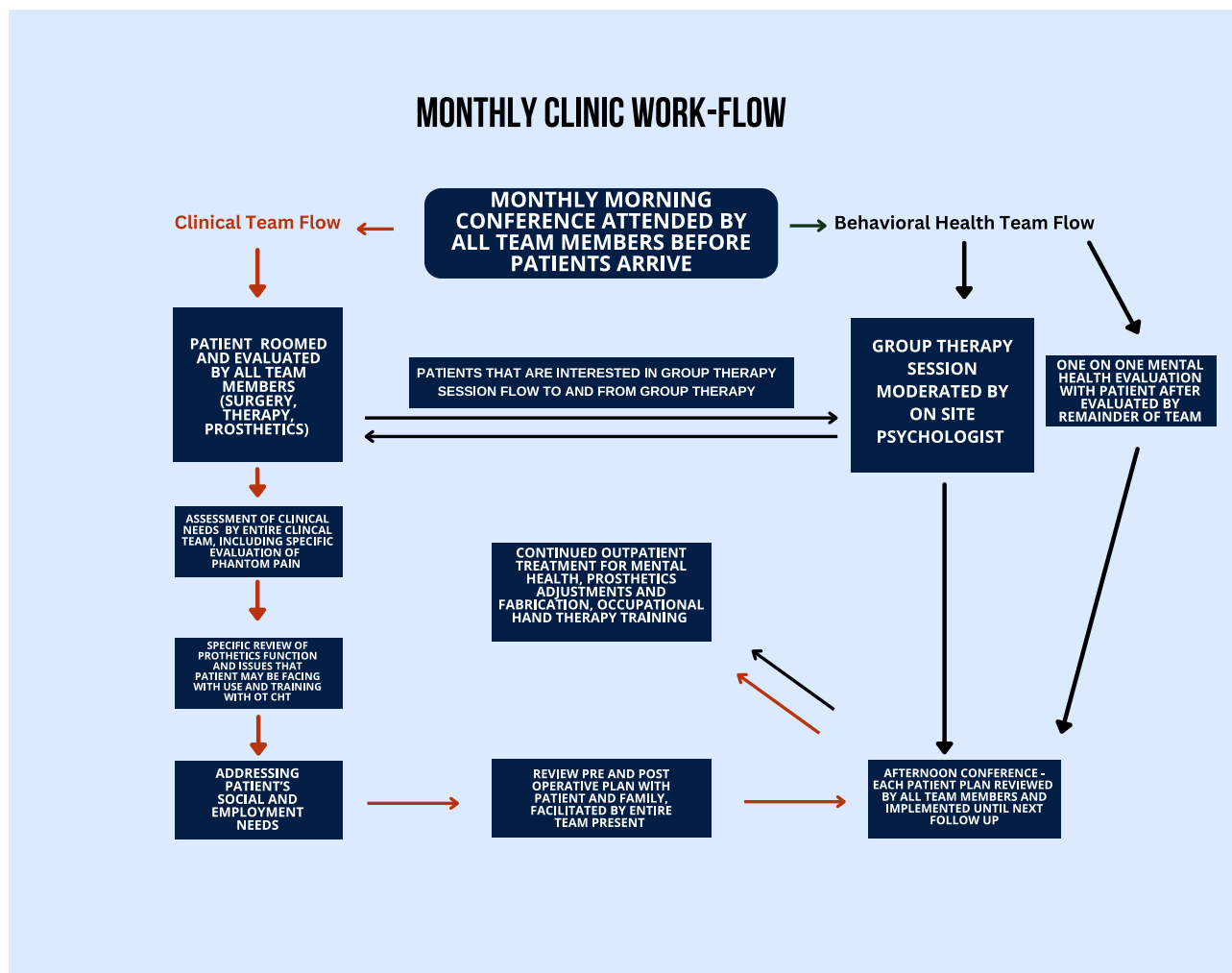


FIGURE 1: Diagram of the monthly clinic workflow.

any source of unwarranted bias or dogmatic approaches to limb loss care is thereby minimized. Each care plan is formulated with every discipline present, which avoids discordance among treatment providers.

For providers

Providers also benefit from the multidisciplinary approach. The prompt feedback and group discussion encourage the best practices from the entire team. Stressors can be mitigated by having a plan of action with which each provider can brainstorm ideas and solutions in a group setting, rather than as individuals. For example, our surgical team does not make decisions regarding the level of amputation without the direct input of the prosthetics and rehabilitation team members. By doing so, we minimize any unexpected consequences regarding the type of prosthesis that can be applied, limb length discrepancy, and a patient's ability to

participate in the rehabilitation program. Increased efficiency and greater cohesion between the team members increase provider satisfaction, preventing burnout and thus improving patient outcomes.^{23,24}

With all members of the care team housed within one organization, little confusion or time spent establishing continuity of care between multiple providers exists. By creating a singular system that works as a cohesive unit, many logistical issues of the traditional model are circumvented, specifically related to documentation or the potential for miscommunication.

For the system

Numerous benefits for the hospital system exist. By hosting a multidisciplinary center, the hospital system attracts recognition from the community and the entire region. The center will become known for providing this type of care and will attract referrals from its surrounding areas. These patient referrals and

	MULTI-DISCIPLINARY	TRADITIONAL
APPROACH TO SURGERY	Surgeon works hand in hand with in-house prosthetist and occupational therapists in planning an appropriate surgery to facilitate prosthetic fitting and minimize risk of sub-optimal outcomes. Collaboration ultimately leads to improved rates of prosthetic retainment and improved control of phantom limb syndrome.	Surgeon makes a decision on his or her own regarding the best approach to an amputation, with or without consultations from third party source. Leads to disjointed care approach where therapist or prosthetist has to adjust their treatment plans based on already completed surgery, which may lead to sub-optimal outcomes
PROSTHETIC FITTING, REHABILITATION, AND POST-OPERATIVE MANAGEMENT	In house prosthetists and occupational therapists who work with surgeon to provide more efficient prosthetic fitting, prosthetic training, and return to functionality. Collaboration leads to holistic approach to address specifics of patients needs	Prosthetic fitting and occupational therapy outsourced to other clinics without appropriate communication from surgeon or appropriate communication between therapist and prosthetist. Training program is disconnected from prosthetic fitting. Disjointed care model where one discipline is unaware of what the other discipline is doing.
FOLLOW UP	Follow ups with an entire dedicated team allows for questions and concerns to be addressed all at once, and plans to be communicated effectively. These plans are then executed between follow ups amongst the treatment providers in a streamlined fashion, giving the patient confidence.	Separate visits to multiple providers and clinics requires a concerted effort from all involved to remain up to date with the other disciplines plans. Patients are required to coordinate their own care and facilitate communication, which leads to limitations in the effective implementation of care plans.
PATIENT OUTCOMES AND PROVIDER SATISFACTION	Cohesive team dynamic improves decision making ability of all providers and facilitates better outcomes for patients, while preventing burnout and frustration in providers. Improved rates of prosthetic retainment and mitigation of phantom limb syndrome, in addition to greater rates of satisfaction and improved mental health scores	Potential for loss of follow up leading to unknown outcome or physician/provider frustration and burnout. High rates of prosthetic abandonment in the traditional care model, which is evidenced in numerous studies. High rates of depression, anxiety, agoraphobia as mental health is often not addressed in traditional care models

FIGURE 2: Benefits of the multidisciplinary model over the traditional care model.

transfers will then engage numerous departments within the hospital system itself. Furthermore, all surgeries are performed within the institution in which the clinic is hosted, thereby generating extra

revenue for the system. The hospital system may become a center for “destination care” as patients seek out solutions to the challenges they faced in their home environment.



FIGURE 3: **A** Clinical picture of the patient with traumatic amputation and left shoulder disarticulation. **B** Identification of infraclavicular brachial plexus donors in preparation for targeted muscle reinnervation. **C** Wound closure after external tissue expansion, no flaps or grafts required. Tissue expansion was performed at the same time as targeted muscle reinnervation. **D** The patient also has a cosmetic passive prosthesis in addition to his myoelectric prosthesis. The multidisciplinary approach and life long relationship facilitates the identification of any further desires a patient may have after the initial prosthetics have been optimized. **E** Patient wearing myoelectric prosthesis.

CHALLENGES AND LESSONS LEARNED

Patients who cannot participate in the multidisciplinary approach are at risk for suboptimal outcomes. Lack of communication between providers and limited opportunities for group thinking set the stage for individual decision-making that may be at odds with global goals for patient care. Patients may suffer from avoidable decisions that need to be reversed secondarily.

The evolution of the clinic to its current form came with a multitude of challenges and many lessons learned. Convincing the necessary administrators regarding the model, its benefits to patient care, and its financial viability was a significant challenge. Initially, for example, behavioral health administrators were unwilling to allow providers to dedicate time away from their other clinical duties. To facilitate engagement, the senior surgeon needed multiple meetings with hospital administrators, psychology and psychiatry department heads, chief of surgery, and the vice president of clinical affairs, all to convince the respective parties that this was not only a worthy cause but also financially viable. Eventually, by inviting the behavioral health team to the

clinic, their attention was drawn toward the overwhelming need for mental health care. This demand for behavioral health services also translated to an increased rate of referrals to the outpatient behavioral health department, thereby alleviating concerns regarding financial viability.

Further lessons learned include, but not limited to, the following:

- (*Prosthetics*) Initially, the model called for one prosthetist. However, due to the limited nationwide availability of clinical upper limb specialists, it was recognized that two prosthetists would be ideal—one clinical upper limb specialist and one local prosthetist to facilitate all aspects of local care.
- (*Behavioral Health*) Early consideration was given to social workers as the primary behavioral health team members, but the patients demonstrated an early need for onsite clinical treatment and therapy. Therefore, two psychologists were added to the treatment team.
- (*Logistics*) Initially, the clinic was established without affiliation with an academic or large hospital institution. However, the clinical resources



FIGURE 4: **A** Patient presents for consideration of elective amputation and bionic reconstruction after suffering an injury to his non-dominant hand 10 years earlier, which was treated at an outside institution. The patient underwent nine surgeries without success and was left with a nonfunctional and painful left upper extremity. **B** After undergoing the preoperative protocol to qualify for bionic reconstruction including preoperative prosthetics evaluation, preoperative rehabilitation, and preoperative psychology/psychiatry treatment, the patient underwent a trans radial amputation with targeted muscle reinnervation (TMR) and regenerative peripheral nerve interface (RPNI) (pictured is the TMR of the median nerve to the AIN-PQ and ulnar nerve RPNI before further internal neurolysis of the ulnar nerve and dividing the nonvascularized muscle graft to house each of 2 group fascicles. Not pictured is RPNI for radial sensory and lateral antebrachial cutaneous nerves). **C** The patient was fit with a near-immediate postoperative prosthesis and entered the prosthetics training protocol. He was then approved for a myoelectric hook and eventually, a Taska hand. **D** The patient was diligently engaged in the multidisciplinary program and not only demonstrated tremendous aptitude regarding his prosthesis but also recovered multiple components of his life that were lost after his injury. The patient's pain was completely resolved after using the aforementioned techniques, and he integrated his prosthesis into his daily life.

and legitimization provided by a large institution allowed for increased visibility within the community and better relationships with surrounding hospital systems.

- *(Logistics)* A financial *pro forma* is necessary to ensure that administrators affiliated with different team members understand not only the benefits to patient care but also the financial viability of the care model to their respective departments.
- *(Rehabilitation)* One of the greater unanticipated challenges has been the limited ability to engage hand therapists outside of the primary network. Many therapists either lack the necessary training or desire to work with patients with upper-extremity limb loss. Our CHTs have hosted

educational seminars to expand the clinical network.

- *(Surgery)* Patient management from referring facilities was initially performed by the surgeons at the outside institution. This led to unnecessary shortening procedures, often to facilitate a closed wound for transfer and secondary management. To perform primary TMR/RPNI and provide options to maintain length (ie, free tissue transfer to prevent higher level amputation), our surgical team has informed regional facilities that after patients are stabilized, and they can be transferred to our institution for definitive management, even if this involves temporizing the definitive amputation.

- (*Clinic Awareness*) Despite the initiation of the clinic, patients and providers remained unaware of the comprehensive approach to patient care. To combat this hurdle, the senior surgeon spent many necessary hours performing community outreach to promote awareness. This outreach included presentations at regional trauma conferences, hospital and academic grand rounds, regional rehabilitation centers, and local physical and occupational therapy centers, to name a few. The surgeon must promote their clinic to all hospitals and regional trauma centers and ensure that all trauma providers are aware of this care model.

CONCLUSION

A multidisciplinary approach is imperative to foster optimal outcomes for patients with upper-extremity limb loss. Ultimately, comprehensive care of patients with upper limb loss can work to return patients to a happy, productive life (see Fig. 3, [Supplementary Video 1/2](#) and Fig. 4, [Supplementary Video 3](#), available online on the *Journal's* website at www.jhandsurg.org).

ACKNOWLEDGMENTS

The authors would like to thank Michelle Batista BS (Hanger Clinic) for her efforts in developing the clinic, and Mike Rayer and Jon Tuazon (ProLimb) for their prosthetic contributions in the care of the patient demonstrated in Figure 3. Authors would also like to thank Brian Monroe CPO (Hanger Clinic), Bryan Loeffler MD and Glenn Gaston MD (Ortho Carolina), whose inspiration and guidance served as the catalyst for the development of this clinic.

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