

Interdisciplinary Care for Amputees Network: A Novel Approach to the Management of Amputee Patient Populations

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Summary: Extremity amputation remains a common intervention for limb-threatening conditions. With advancement in surgical technique to address deleterious postoperative sequelae of limb removal, there is a salient need to develop and operationalize interdisciplinary care frameworks to provide more comprehensive care to an otherwise challenging patient population. Herein, we describe our interdisciplinary approach to the management of amputee patient populations at our institution, referred to as the Interdisciplinary Care for Amputees Network (ICAN). This novel framework focuses on 3 fundamental areas: combined preoperative patient evaluation, orthoplastic surgical intervention, and multi-specialty postoperative functional and psychosocial rehabilitation. Importantly, the successful implementation of a combined orthoplastic clinic requires establishing a working relationship among providers to leverage increased provider familiarity. This, coupled with sufficient clinic space, dedicated operating room time, and standardized patient workflow, serves to improve care and meet patient goals of pain minimization, return to desired functional status, and improvement in quality of life. (*Plast Reconstr Surg Glob Open* 2021;9:e3384; doi: [10.1097/GOX.0000000000003384](https://doi.org/10.1097/GOX.0000000000003384); Published online 15 February 2021.)

INTRODUCTION

Despite recent advances in limb salvage techniques, the number of amputations performed within the United

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Informed consent: IRB approval was obtained with a waiver of informed consent, per routine standard of care. No additional consent is needed for prospective assembly of a patient registry that meets standard of care.

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States continues to rise, with nearly 200,000 lower extremity amputations performed per year.¹ It has been estimated that the number of American amputees will exceed 3.5 million by the year 2050, a nearly 2-fold increase in population prevalence over the next 30 years.² There are many reasons why patients undergo amputation, with the majority occurring as a result of neurovascular compromise secondary to peripheral arterial disease (PAD) or diabetes mellitus (DM).³ However, even with improvement in wound care and revascularization techniques, a large proportion of patients with chronic wounds suffer limb loss.⁴ Given the growing incidence of PAD and DM, coupled with acute traumatic and oncologic indications, amputation remains a common intervention for patients with limb-threatening conditions.

Before the advent of modern antiseptic technique, a lack of adequate peri-operative hemostasis and analgesia necessitated that amputations be carried out expeditiously, often with significant complications resulting in functional impairment.⁵ It was not until the turn of the twentieth century that, with the advancement in anesthesia and antiseptic techniques, the surgical practice of amputation became more refined.⁶ Due to the rising incidence of amputation for traumatic injuries during World War I, focus shifted toward improving operative technique and functional rehabilitation, prompting innovation in

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residual limb care and prosthesis development.⁷ With the subsequent decline in mortality, amputations became more commonplace by the time of World War II. What was once considered a complicated and life-threatening operation became regarded as a seemingly simple procedure, often relegated to the most junior member of the surgical team. The focus on expediency frequently superseded consideration for bone length, myodesis, postoperative reconstruction, or potential for residual limb pain.^{8,9}

Recently, there has been a concerted effort to innovate surgical technique to address some of the deleterious postoperative sequelae associated with amputation (namely, chronic limb pain and neuroma formation) that may limit the ability to utilize prostheses.^{10–13} Three of the most promising surgical innovations of the past decade include targeted muscle reinnervation (TMR), regenerative peripheral nerve interfaces (RPNI), and osseointegration (OI). TMR refers to the process of residual donor nerve coaptation to motor nerves of nearby muscle targets, thereby providing a functional destination to the transected nerve and introducing a scaffold for organized axonal growth.^{14–17} Similarly, RPNI relies on the implantation of severed peripheral nerve ends to devascularized muscle grafts, which may prevent neuroma formation and mitigate postamputation residual limb pain.^{18,19} OI refers to the surgical anchoring and incorporation of a metal prosthesis to the native bone of the residual limb, thereby obviating the need for traditional socket-based prostheses and minimizing associated discomfort.^{20,21} Importantly, the implementation of these novel surgical techniques, either at the time of amputation or subsequently thereafter, has significantly improved psychosocial functioning, use of prostheses, and quality of life for amputees.^{22,23}

Central to these contemporary surgical strategies is the use of a multi-specialty team, which requires extensive collaboration among providers across varied medical and surgical domains.^{24–26} Compared with traditional amputation pathways, where a patient may receive disparate and siloed information by individual providers, an interdisciplinary framework can instead offer a patient-centered approach, with multiple specialists collaborating to provide a more unified care plan that avoids ambiguity and improves efficiency. In this article, we describe our interdisciplinary approach to the management of extremity amputation at our institution, referred to as the Interdisciplinary Care for Amputees Network (ICAN), which provides a framework for conferring integrated and comprehensive amputee care.

MULTI-SPECIALTY ORTHOPLASTIC CARE MODEL

Establishing a Combined Orthoplastic Approach

The development of an interdisciplinary care network for the management of complex orthoplastic cases requires significant investment of time and resources from multiple specialties. It has been previously reported that increased familiarity among members of a surgical team can significantly improve patient outcomes.²⁷ As such, it becomes easier to construct an effective multi-specialty

framework with an already established working relationship among providers. Having performed several limb salvage and amputation cases together, members of our plastic surgery and orthopedic surgery teams became interested in leveraging their working relationship to establish a mutually beneficial, standardized workflow for amputees. We endeavored to develop a combined orthoplastic clinic for the comprehensive care of amputee patient populations that would better consolidate treatment, optimize resource utilization, and improve postoperative outcome.

Clinic-specific Parameters

Consideration of clinic-specific parameters such as location, timing, and patient volume is critical to the successful implementation of a multi-specialty orthoplastic framework. Clinic spaces reserved for patient evaluation must be of sufficient size to accommodate a large, interdisciplinary team (orthopedic surgeon, plastic surgeon, physiatrist, other specialty consultants, prosthetist, and physical therapist) in addition to the patient and his or her support network. Additionally, it is important to use a central location to ensure reliable participation among providers. Similarly, clinic timing should remain consistent on a week-to-week basis to improve coordination among large clinical teams and avoid potential scheduling conflicts. Operating room time should be reserved to accommodate both elective and/or revision procedures and urgent amputations. These parameters serve to augment clinic capacity, that, when coupled with a robust referral system, can ensure maximal patient volume and population diversity.

Interdisciplinary Care for Amputees Network

The ICAN, a combined orthoplastic clinic, was developed in collaboration with a multi-specialty team at the Massachusetts General Hospital (MGH) for the evaluation and management of amputee patients. Our interdisciplinary approach was informed by existing military amputee care programs and modified to meet the demands of a civilian patient population.^{28,29} This novel interdisciplinary framework focuses on 3 fundamental areas: combined preoperative patient evaluation, orthoplastic surgical intervention, and multi-specialty postoperative functional and psychosocial rehabilitation. Essential to the success of the ICAN clinic is the use of a standardized patient workflow and multi-specialty provider network to help guide operative or nonoperative amputation management, with appropriate follow-up and rehabilitation to meet patient goals of pain reduction, return to desired function, and improvement in quality of life (Fig. 1).

Preoperative Patient Evaluation

The number of scheduled ICAN clinic sessions is largely dependent on patient volume, currently held once weekly (and likely to increase in frequency with our growing patient census). Patient visits are led by an interdisciplinary team, including plastic surgery, orthopedic surgery, and physiatry. By having both plastic and orthopedic surgeons simultaneously involved in the preoperative

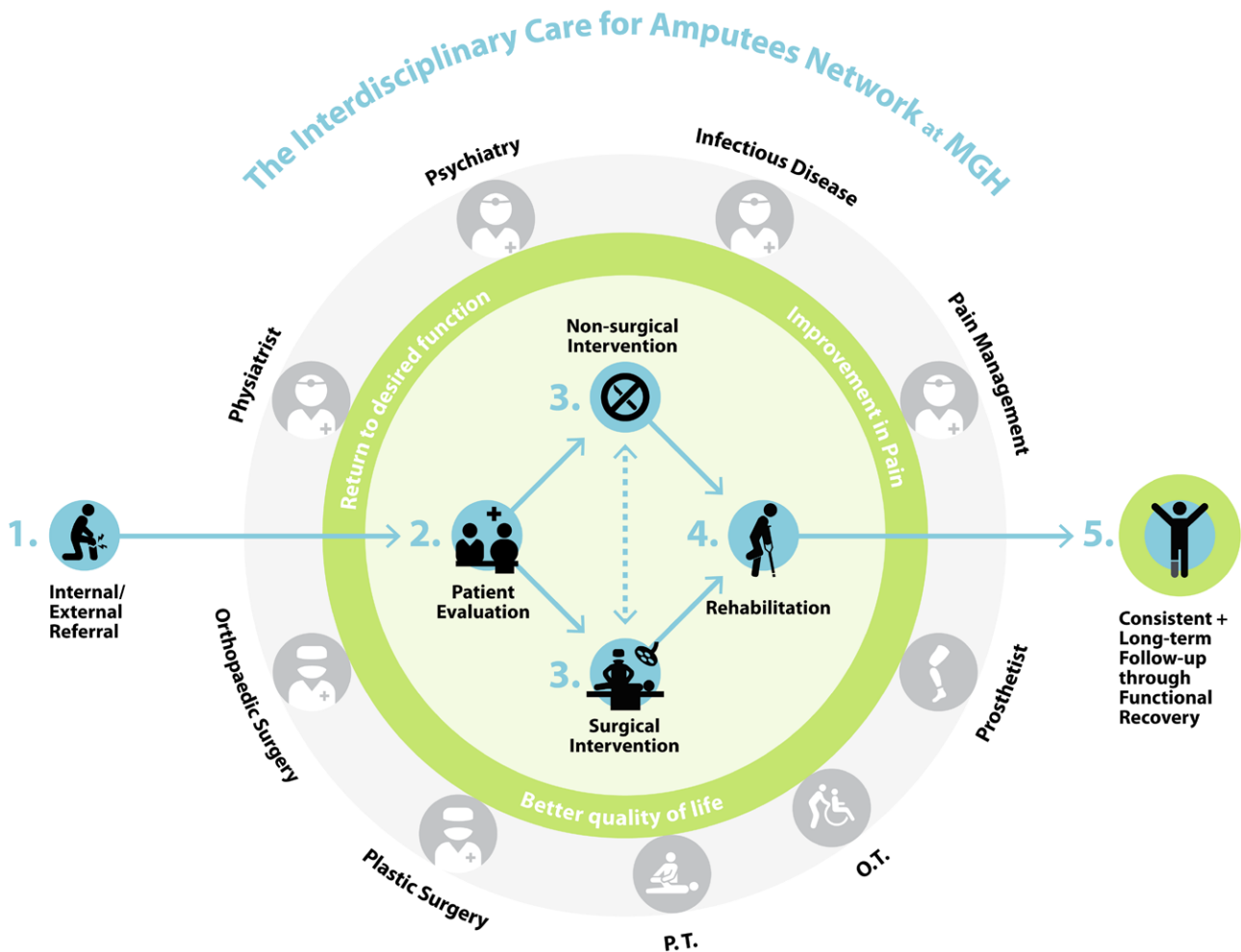


Fig. 1. ICAN. Preoperative patient evaluations are conducted by an interdisciplinary team, primarily led by plastic surgeons and orthopedic surgeons. Shared clinical reasoning among core members of the interdisciplinary team guides amputation management, choice of adjunct surgical procedure, or nonsurgical intervention. Postoperatively, physical and psychosocial rehabilitation services are recruited to improve patient functionality and well-being.

patient evaluation, an interdisciplinary surgical plan can be developed that not only obviates the need for separate clinic visits, but also capitalizes on shared clinical decision-making. Other individuals commonly involved in the initial consults and surgical evaluation include the patient’s support system and his or her prosthetist. Integrating prosthetic partners early in the course of patient evaluation allows for the surgeons and the prosthetists to work in tandem to optimize timing of the amputation, TMR, and RPNI to maximize postoperative physical function and prosthesis compliance. Patients with previous amputation are evaluated to mitigate symptoms that may interfere with the quality of life. These patients may be candidates for adjunct surgical interventions, including TMR, RPNI, or OI, and are counseled on the relative risks and benefits of such procedures. Patients who may require future amputation are evaluated in the outpatient setting by a multi-specialty team, where they are informed of the longitudinal care structure and educated as to available surgical interventions to maximize function after limb removal. For patients who may require amputation acutely, either

secondary to trauma or infection, preoperative evaluations are performed in the inpatient setting with a similar interdisciplinary care structure.

Orthoplastic Surgical Intervention

A combined orthoplastic approach allows for effective peri-operative management to both minimize risk factors and optimize surgical technique. With appropriate consideration of bone length, functional myodesis, soft-tissue coverage, and postoperative chronic limb pain, members of the interdisciplinary team can better develop comprehensive surgical care plans. This proactive approach to augment immediate postoperative functionality may reduce the incidence of prosthesis failure and improve baseline postamputation physical function. Importantly, for those patients who present for evaluation of revision surgery for previous limb removal, the use of a combined orthoplastic amputation clinic can confer the benefit of longitudinal interdisciplinary care, with surgeons experienced in complex peripheral nerve management and osseointegration techniques.

Postoperative Functional and Psychosocial Rehabilitation

Effective care of amputees is not just limited to surgical intervention; rather, it requires a comprehensive approach that recruits services focused on functional and psychosocial rehabilitation. Our interdisciplinary team includes physiatrists (physical medicine and rehabilitation physicians), physical therapists, occupational therapists, pain management specialists, infectious disease specialists, and psychiatrists at our institution. Importantly, through collaboration with local rehabilitation centers and prosthetic professionals, we can begin to optimize physical function from the very first postoperative visit, through comprehensive residual limb care, adjustment of prosthesis fit, and initiation of physical therapy and/or occupational therapy (for upper limb loss/dysfunction). In addition, by incorporating adjunct surgical techniques for the prophylactic management of chronic limb pain and optimizing prosthesis fit and utilization, patients can closely work with pain management specialists to develop a regimen that minimizes opioid burden, while still achieving appropriate analgesia. This, coupled with a focus on patient psychosocial well-being, allows for a coordinated approach to amputee management that is aimed to decrease functional limitation and mitigate the mental health burden often associated with limb loss.³⁰ Over time, greater familiarity among specialists will serve to improve the provision of amputation care through more robust integration of services and a better understanding of postoperative patient need and expectations.

MGH ICAN EXPERIENCE

Patient Registry

The ICAN clinic represents a transition in the standard of care for amputee patients at our institution. Our comprehensive care model has largely replaced individualized, specialty-specific approaches to peri-operative amputation management. Institutional review board (IRB) approval to maintain a registry of our patients was obtained with a waiver of informed consent.

Clinic Demographics

Since October 2019, 65 new patients have been evaluated at the ICAN clinic, either for primary amputation or revision of prior limb removal, or local stump or wound care. The majority of patients are men (n = 48, 73.8%), with an average age of presentation to the clinic of 49.1 ± 16.2 years (Table 1). The primary source of referral was external to our institution, either through international referral or via community and academic practice outside our hospital system. Nearly 20% of patients were referred from outside of the New England area, with several (n = 9) referred from countries outside the United States. The most common medical comorbidities observed in our patient population were history of tobacco use (60.0%), obesity (24.6%), diabetes mellitus (7.7%), and peripheral vascular disease (4.6%).

ICAN Operative Intervention

Twenty-six unique multi-specialty operations have been performed during the interval of observation, with 5 primary amputations, 10 therapeutic TMR or RPNI for chronic limb

Table 1. Patient Demographics

Variable	Total (%)
No. patients	65
Average age ± SD (y)	49.1 ± 16.2
BMI ± SD (kg/m ²)	28.4 ± 6.2
Men	48 (73.8)
Women	17 (26.2)
International	12 (18.5)
National	53 (81.5)
Medical history	
Smoking	39 (60.0)
Diabetes	5 (7.7)
Obese	16 (24.6)
Peripheral vascular disease	3 (4.6)

BMI, body mass index; SD, standard deviation.

Table 2. Amputation Characteristics

Variable	Total (%)
No. evaluated for ICAN primary amputation	10 (15.4)
No. underwent ICAN primary amputation*	5 (50.0)
Underwent prophylactic TMR	4 (80.0)
Underwent prophylactic RPNI	0 (0.0)
Procedure laterality	
Unilateral	4 (80.0)
Bilateral	1 (20.0)
No. amputated limbs	
Single	4 (80.0)
Multiple	1 (20.0)
Level of amputation	
Transfemoral	4 (80.0)
Transstibial	0 (0.0)
Hip disarticulation	0 (0.0)
Transhumeral	0 (0.0)
Partial hand	1 (20.0)
Indication for ICAN primary amputation	
Trauma	1 (20.0)
Oncologic	0 (0.0)
Neurovascular	0 (0.0)
Infection or sepsis	3 (60.0)
Other	1 (20.0)
No. previous primary amputation	55 (84.6)
Underwent previous adjunct surgical procedure	11 (20.0)

*Percent of patients evaluated for ICAN primary amputation who subsequently underwent multidisciplinary limb removal.

pain, and 11 stump revisions for improved soft tissue coverage or residual bone length (Tables 2 and 3). The most common indication for primary amputation in our patient population was infection (60.0%), followed by trauma (20.0%). One patient experienced multiple primary amputations, with bilateral removal of the lower extremity. Although the most common level of primary amputation performed during the interval of observation was transfemoral (n = 4, 80.0%), a large proportion (n = 26, 40%) of patients presenting to the ICAN clinic were evaluated for below-the-knee amputation (BKA) or revision of previous BKA. Of note, thus far, the majority of patients evaluated in the ICAN clinic had undergone amputation at MGH or at another institution before the implementation of our orthoplastic clinic. Several of these had experienced years of residual limb pain and/or neuropathic pain and were seeking interdisciplinary care to address chronic limb pain or wound breakdown. The larger proportion of established amputees referred to our clinic was not unexpected; however, we anticipate that the number of patients presenting for primary amputation will increase over time, especially with a growing referral base and increased clinic visibility (Fig. 2).

Table 3. Evaluation Patterns for Revision or Adjunct Surgical Procedures

Variable	Total (%)
Evaluated for adjunct surgical procedure	10 (15.4)
Underwent therapeutic TMR	9 (90.0)
Underwent therapeutic RPNI	1 (10.0)
Evaluated for stump revision	15 (23.1)
Underwent multidisciplinary stump revision	11 (73.3)
Evaluated for local stump or wound care	30 (46.2)
Osseointegration	
Evaluated for osseointegration	5 (7.7)
Candidate for osseointegration	3 (4.6)
Underwent osseointegration	0 (0.0)

With regard to prosthetic-related complications that prompted initial ICAN clinic evaluation, neurogenic pain (neuroma formation or phantom limb pain) ($n = 30$, 46.1%) was more common than other postamputation reasons for evaluation. A total of 14 patients have received multidisciplinary TMR, RPNI, or other procedures for the management or prevention of chronic residual limb nerve pain (Table 3), of which 4 (28.6%) were performed prophylactically at the time of primary amputation, with no complications reported to date. Five (7.7%) patients have been evaluated for osseointegration, with 3 patients considered candidates for the procedure.

DISCUSSION

The management of amputations has begun to change over the past decade. Previous emphasis on expediency

has likely contributed to the high morbidity rate associated with amputation. Recent advances in neuroma management, residual limb contour and tissue coverage, myodesis, and osseointegration have sparked a renewed interest in refining limb removal to improve functional outcomes following amputation.¹⁸ To better leverage these novel techniques for the longitudinal care of amputees, we have developed and implemented a multi-specialty, team-based approach to amputation management. We believe that this approach provides an optimized model of comprehensive care delivery for amputee patient populations.

The benefit of interdisciplinary care for the management of traumatic or neurovascular limb compromise has been reported in the literature.^{31,32} In a recent systematic review, the authors concluded that the use of interdisciplinary wound care centers for the management of diabetic foot ulcers could confer a significant reduction in the rate of limb loss.³³ Several studies have similarly espoused the benefit of interdisciplinary wound care to avoid amputation.^{34,35} However, investigators have increasingly begun to advocate for the use of multi-specialty approaches to the management of patients with irreparable limb compromise.³⁶ In a recent retrospective study, Alexander et al described their interdisciplinary approach to confer TMR at the time of primary oncologic amputation, which resulted in a significant reduction in chronic residual limb pain.²⁴ The authors suggest that collaboration among orthopedic surgeons, surgical oncologists, plastic surgeons, and medical and rehabilitation services

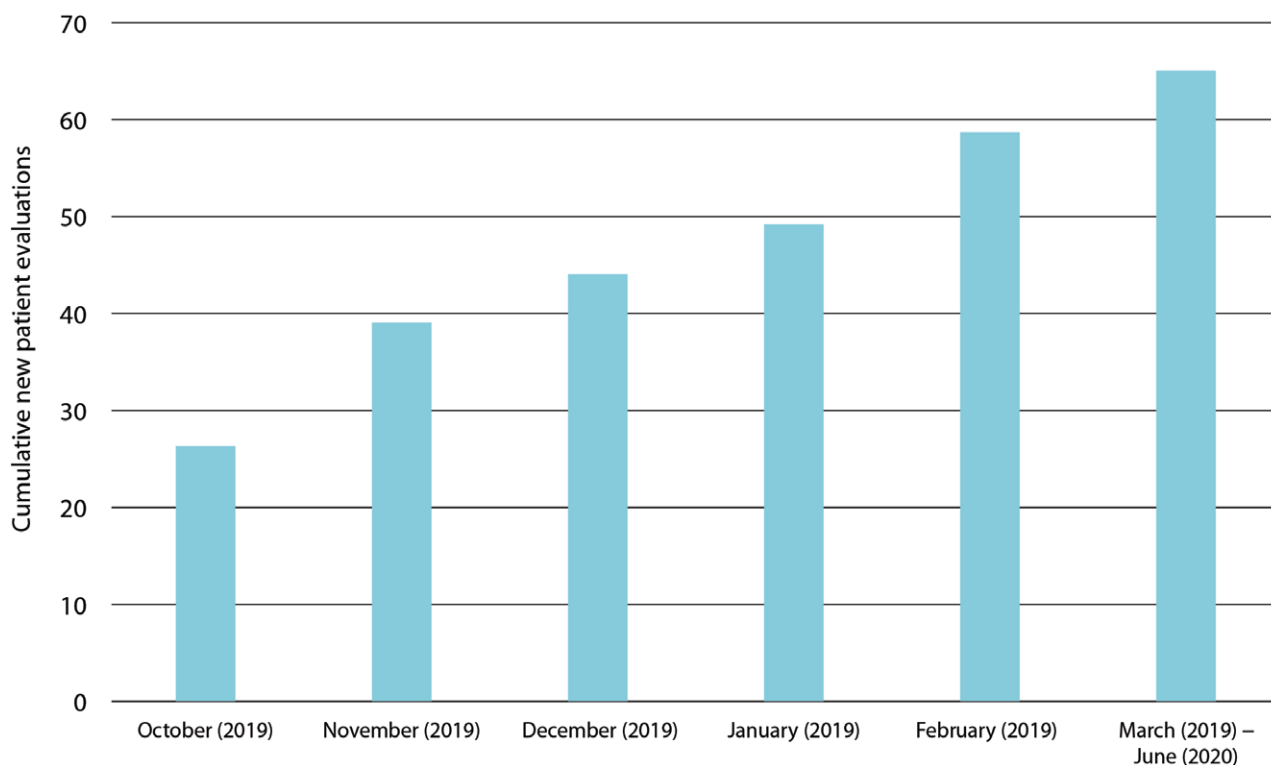


Fig. 2. New patient evaluations at the ICAN clinic during the interval of observation. Our patient census continues to grow monthly, with sharp increases in patient volume in the first month of observation (October, 2019) and early the following year (February, 2020). Note, due to the COVID-19 crisis, data for March 2020–June 2020 have been consolidated, given limitations in clinical evaluation and elective operation. The total number of clinic visits for these 3 months would typically equal 1 month under usual circumstances.

was a central driver in ensuring successful care for oncologic amputee populations. Other studies have demonstrated the efficacy of interdisciplinary care to improve patient outcome after amputation for those with traumatic wounds or chronic neurovascular conditions.^{37–39} Patients are often more motivated to comply with care plans when shared decision-making models are implemented and tend to appreciate the transparency and patient education that can be achieved through interdisciplinary networks.⁴⁰ However, despite the availability of studies that report superior patient outcome following introduction of multi-specialty care teams, there are few dedicated clinics with a focus on integrating operative and nonoperative services for amputees. Therefore, our combined orthoplastic amputation center serves as an evolution of the traditional operative paradigm, which can provide more consistent and comprehensive care to an otherwise challenging patient population (Fig. 3).

Lessons learned from the successful implementation of a combined orthoplastic clinic can be used to inform the development and operation of interdisciplinary framework for amputation management across institutions. We have found that early limitations in staffing and provider experience must be met with appropriate patient selection. Interdisciplinary clinics at large academic institutions are uniquely advantaged by pre-existing care infrastructures, such that primary care physicians, wound care providers, and other specialists already employed by the hospital can internally refer patients to the comprehensive care center. However, a growing proportion of our patient population is national and international, often hearing of our clinic through educational websites, social media, or scientific publications. Diversity in recruitment methodology is important because it not only contributes to the growing viability of a clinic, but also helps confer a cost-benefit to the institution. By negotiating an influx of new patients and consolidating existing amputation

services into a streamlined pathway, our combined orthoplastic clinic can provide an important service and remain fiscally viable. Moreover, our focus on efficiency and innovative patient care within a common setting serves as the foundation for a center of excellence that attracts patients who would otherwise rely on disparate care models. Given the tenable need for deliberate resource allocation, institutions should begin focusing on those services, such as the ICAN clinic, that confer optimal care to their patients while minimizing resource burden.

The transition to an interdisciplinary care model for amputees represents a necessary paradigm shift that most completely addresses the needs of a challenging patient population. Through extensive collaboration between specialties, an interdisciplinary approach may foster a collegiality among providers that can serve to improve workflow and enhance patient experience. Additionally, by incorporating services that may not otherwise be familiar with the cutting-edge of amputation management, we can begin to augment provider fund of knowledge across the multi-specialty framework to confer more comprehensive amputation support and improve long-term patient outcome. Furthermore, by closely collaborating with wound care services, including endocrinology, vascular surgery, and podiatry, we are also able to offer comprehensive amputation prevention. Patients who present to our clinic for elective amputation are evaluated to ensure that all feasible efforts for limb salvage have been exhausted. In fact, several patients have been advised against amputation at this time and have undergone limb reconstruction by our surgeons instead. As such, through the maximization of our interdisciplinary arsenal and capacity to provide a full range of services to patients with limb compromise, we are able to more routinely incorporate novel surgical techniques and offer individualized treatment options based on patient-specific needs. The ICAN clinic, therefore, serves as an

Traditional		Interdisciplinary	
Siloed	Care model	Multi-specialty	
Individual	Clinic evaluation	Combined	
Expeditious	Amputation	Deliberate	
Local Stump Care + Neurectomy	Adjusted procedures	TMR vs. RPNI	
Opioid Analgesia	Analgesia	Multi-factorial Pain Management	
Static + Myoelectric Prostheses	Prosthesis	Bioprostheses + Osseointegration	
Limited	Follow-up	Longitudinal	

Fig. 3. Interdisciplinary amputee care model vs. traditional amputation pathway.

ideal care provision model that combines the best available medical and surgical practices to provide optimal care for amputee patient populations.

CONCLUSIONS

Although amputation has historically been fraught with complications and patient morbidity, recent operative advances have conferred significant improvement in post-amputation function. However, successful implementation of these novel techniques often requires the use of an interdisciplinary framework. As such, we successfully developed a combined orthoplastic clinic to provide longitudinal care to patients with limb-threatening conditions. It is our hope that this guide will serve as a foundation for the development of interdisciplinary, team-based approaches for the management of amputee patient populations at other institutions.

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REFERENCES

- Dillingham TR, Pezzin LE, Shore AD. Reamputation, mortality, and health care costs among persons with dysvascular lower-limb amputations. *Arch Phys Med Rehabil*. 2005;86:480–486.
- Ziegler-Graham K, MacKenzie EJ, Ephraim PL, et al. Estimating the prevalence of limb loss in the United States: 2005 to 2050. *Arch Phys Med Rehabil*. 2008;89:422–429.
- Driver VR, Fabbi M, Lavery LA, et al. The costs of diabetic foot: the economic case for the limb salvage team. *J Am Podiatr Med Assoc*. 2010;100:335–341.
- Flores AM, Mell MW, Dalman RL, et al. Benefit of multidisciplinary wound care center on the volume and outcomes of a vascular surgery practice. *J Vasc Surg*. 2019;70:1612–1619.
- Sachs M, Bojunga J, Encke A. Historical evolution of limb amputation. *World J Surg*. 1999;23:1088–1093.
- Markatos K, Karamanou M, Saranteas T, et al. Hallmarks of amputation surgery. *Int Orthop*. 2019;43:493–499.
- Robinson KP. Historical aspects of amputation. *Ann R Coll Surg Engl*. 1991;73:134–136.
- Iannuzzi JC, Chandra A, Rickles AS, et al. Resident involvement is associated with worse outcomes after major lower extremity amputation. *J Vasc Surg*. 2013;58:827–31.e1.
- Potter BK. Editorial comment: Symposium: recent advances in amputation surgery and rehabilitation. *Clin Orthop Relat Res*. 2014;472:2938–2941.
- Bowen RE, Struble SG, Setoguchi Y, et al. Outcomes of lengthening short lower-extremity amputation stumps with planar fixators. *J Pediatr Orthop*. 2005;25:543–547.
- Ducic I, Mesbahi AN, Attinger CE, et al. The role of peripheral nerve surgery in the treatment of chronic pain associated with amputation stumps. *Plast Reconstr Surg*. 2008;121:908–914.
- Gailey RS, Wenger MA, Raya M, et al. Energy expenditure of trans-tibial amputees during ambulation at self-selected pace. *Prosthet Orthot Int*. 1994;18:84–91.
- Guse DM, Moran SL. Outcomes of the surgical treatment of peripheral neuromas of the hand and forearm: a 25-year comparative outcome study. *Ann Plast Surg*. 2013;71:654–658.
- Bowen JB, Wee CE, Kalik J, et al. Targeted muscle reinnervation to improve pain, prosthetic tolerance, and bioprosthetic outcomes in the amputee. *Adv Wound Care (New Rochelle)*. 2017;6:261–267.
- Dumanian GA, Ko JH, O'Shaughnessy KD, et al. Targeted reinnervation for transhumeral amputees: current surgical technique and update on results. *Plast Reconstr Surg*. 2009;124:863–869.
- Kuiken TA, Barlow AK, Hargrove L, et al. Targeted muscle reinnervation for the upper and lower extremity. *Tech Orthop*. 2017;32:109–116.
- Souza JM, Cheesborough JE, Ko JH, et al. Targeted muscle reinnervation: a novel approach to postamputation neuroma pain. *Clin Orthop Relat Res*. 2014;472:2984–2990.
- Eberlin KR, Ducic I. Surgical algorithm for neuroma management: a changing treatment paradigm. *Plast Reconstr Surg Glob Open*. 2018;6:e1952.
- Woo SL, Kung TA, Brown DL, et al. Regenerative peripheral nerve interfaces for the treatment of postamputation neuroma pain: a pilot study. *Plast Reconstr Surg Glob Open*. 2016;4:e1038.
- Hagberg K, Brånemark R, Gunterberg B, et al. Osseointegrated trans-femoral amputation prostheses: prospective results of general and condition-specific quality of life in 18 patients at 2-year follow-up. *Prosthet Orthot Int*. 2008;32:29–41.
- Lee WC, Frossard LA, Hagberg K, et al. Magnitude and variability of loading on the osseointegrated implant of transfemoral amputees during walking. *Med Eng Phys*. 2008;30:825–833.
- Hagberg K, Hansson E, Brånemark R. Outcome of percutaneous osseointegrated prostheses for patients with unilateral transfemoral amputation at two-year follow-up. *Arch Phys Med Rehabil*. 2014;95:2120–2127.
- Kang N, Woollard ACS. Targeted muscle reinnervation: advances and opportunities. *J Plast Reconstr Aesthet Surg*. 2018;71:920–921.
- Alexander JH, Jordan SW, West JM, et al. Targeted muscle reinnervation in oncologic amputees: early experience of a novel institutional protocol. *J Surg Oncol*. 2019;120:348–358.
- Fillon M. Multidisciplinary care coupled with targeted muscle reinnervation may reduce pain for amputees. *CA Cancer J Clin*. 2019;69:433–434.
- Frölke JP, Leijendekkers RA, van de Meent H. Osseointegrated prosthesis for patients with an amputation: multidisciplinary team approach in the Netherlands. *Unfallchirurg*. 2017;120:293–299.
- Gfrerer L, Mattos D, Mastroianni M, et al. Assessment of patient factors, surgeons, and surgeon teams in immediate implant-based breast reconstruction outcomes. *Plast Reconstr Surg*. 2015;135:245e–252e.
- Gajewski D, Granville R. The United States armed forces amputee patient care program. *J Am Acad Orthop Surg*. 2006;14(10 Spec No.):S183–S187.
- Granville R, Menetrez J. Rehabilitation of the lower-extremity war-injured at the center for the intrepid. *Foot Ankle Clin*. 2010;15:187–199.
- Sahu A, Sagar R, Sarkar S, et al. Psychological effects of amputation: A review of studies from India. *Ind Psychiatry J*. 2016;25:4–10.
- Vartanian SM, Robinson KD, Ofili K, et al. Outcomes of neuroischemic wounds treated by a multidisciplinary amputation prevention service. *Ann Vasc Surg*. 2015;29:534–542.
- Krishnan S, Nash F, Baker N, et al. Reduction in diabetic amputations over 11 years in a defined U.K. population: benefits of multidisciplinary team work and continuous prospective audit. *Diabetes Care*. 2008;31:99–101.
- Musuuzi J, Sutherland BL, Kurter S, et al. A systematic review of multidisciplinary teams to reduce major amputations for patients with diabetic foot ulcers. *J Vasc Surg*. 2020;71:1433–1446.e3.
- Buggy A, Moore Z. The impact of the multidisciplinary team in the management of individuals with diabetic foot ulcers: a systematic review. *J Wound Care*. 2017;26:324–339.
- Fitzgerald RH, Mills JL, Joseph W, et al. The diabetic rapid response acute foot team: 7 essential skills for targeted limb salvage. *Eplasty*. 2009;9:e15.

36. Beckett A, Pelletier P, Mamczak C, et al. Multidisciplinary trauma team care in Kandahar, Afghanistan: current injury patterns and care practices. *Injury*. 2012;43:2072–2077.
37. Hebert JS, Payne MW, Wolfe DL, et al. Comorbidities in amputation: a systematic review of hemiplegia and lower limb amputation. *Disabil Rehabil*. 2012;34:1943–1949.
38. Meier RH III, Choppa AJ, Johnson CB. The person with amputation and their life care plan. *Phys Med Rehabil Clin N Am*. 2013;24:467–489.
39. Messinger S, Bozorghadad S, Pasquina P. Social relationships in rehabilitation and their impact on positive outcomes among amputees with lower limb loss at Walter Reed National Military Medical Center. *J Rehabil Med*. 2018;50:86–93.
40. Quigley M, Dillon MP, Fatone S. Development of shared decision-making resources to help inform difficult health-care decisions: an example focused on dysvascular partial foot and transtibial amputations. *Prosthet Orthot Int*. 2018;42:378–386.