

ORIGINAL ARTICLE

Structure, processes, and initial outcomes of The Ottawa Hospital Multi-Specialist Limb-Preservation Clinic and Programme: A unique-in-Canada quality improvement initiative

Derek J. Roberts^{1,2} | Christine Murphy¹ | Shira A. Strauss¹ |
 Timothy Brandys¹ | Vicente Corrales-Medina³ | Jing Zhang⁴ |
 Karl-André Lalonde⁵ | Bradley Meulenkamp⁵ | Alison Jennings² |
 Alan J. Forster^{2,6,7,8} | Daniel I. McIsaac^{2,6,8,9} | Sudhir K. Nagpal¹

¹Division of Vascular and Endovascular Surgery, Department of Surgery, University of Ottawa, Ottawa, Ontario, Canada

²Ottawa Hospital Research Institute, Ottawa, Ontario, Canada

³Division of Infectious Diseases, Department of Medicine, University of Ottawa, Ottawa, Ontario, Canada

⁴Division of Plastic and Reconstructive Surgery, Department of Surgery, University of Ottawa, Ottawa, Ontario, Canada

⁵Division of Orthopaedic Surgery, Department of Surgery, University of Ottawa, Ottawa, Ontario, Canada

⁶IC/ES, Toronto, Ontario, Canada

⁷Department of Medicine, University of Ottawa and The Ottawa Hospital, Ottawa, Ontario, Canada

⁸School of Epidemiology & Public Health, Faculty of Medicine, University of Ottawa, Ottawa, Ontario, Canada

⁹Departments of Anesthesiology and Pain Medicine, University of Ottawa and The Ottawa Hospital, Ottawa, Ontario, Canada

Correspondence

Derek J. Roberts, Assistant Professor,
 Division of Vascular and Endovascular
 Surgery, Department of Surgery,
 University of Ottawa and Associate
 Scientist, Clinical Epidemiology Program,
 Ottawa Hospital Research Institute, The
 Ottawa Hospital Civic Campus, Room
 A280, 1053 Carling Avenue, Ottawa,
 Ontario, Canada, K1Y 4E9.
 Email: derek.roberts01@gmail.com

Abstract

In 2017, The Ottawa Hospital initiated a unique-in-Canada quality improvement initiative by opening a novel, multi-specialist limb-preservation clinic. We sought to describe the structure, processes, and initial outcomes of the clinic and evaluate whether it is achieving its mandate of providing high-quality wound clinical care, education, and research. We conducted a descriptive prospective cohort study alongside a nested study of 162 clinic patients requiring serial assessments. There have been 1623 visits, mostly (72.2%) from outpatients. During 17.8% of visits, patients were evaluated by >1 specialist. Therapies provided most often included negative-pressure wound therapy (32.7%), biological wound dressings (21.6%), and total contact casting (18.5%). Furthermore, 1.2% underwent toe/ray amputations or skin grafting in clinic and 22.8% were initiated on antimicrobials. Mixed-effects models suggested that mean wound volumes for those requiring serial assessments decreased by

This work was conducted at The Ottawa Hospital in Ottawa, Ontario, Canada.

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1.6 (95% confidence interval = -0.86 to -2.27) cm^3 between visits. The clinic provided seven rotations to vascular surgery, infectious diseases, dermatology, and palliative care physicians; three nursing preceptorships; and two educational workshops. It also initiated provincial and national vascular health and wound care research initiatives. This study may be used to guide development of other limb-preservation clinics and programmes. Findings support that our programme is achieving its mandate.

KEYWORDS

arterial ulcer, diabetic foot ulcer, limb-preservation clinic, postsurgical wound, venous ulcer, wounds and injuries

Key Messages

- numerous organisations recommend a multi-specialist team approach to caring for patients at risk of limb loss
- in 2017, The Ottawa Hospital opened a novel, unique-in-Canada, multi-specialist limb-preservation clinic
- this study provides a detailed description of the structure and processes of the clinic and programme, which may be used to guide others' intent on developing similar programmes
- data reported by the study support that the programme is achieving its mandate of providing high-quality wound clinical care, education, and research

1 | INTRODUCTION

Hard-to-heal wounds are increasingly common, costly, and associated with a high risk of limb loss.¹⁻⁴ More than 25% of people aged ≥ 80 years have peripheral artery disease (PAD) and 5% to 10% of those with asymptomatic PAD or intermittent claudication progress to chronic-limb threatening ischaemia (CLTI) (rest pain, gangrene, or tissue loss) within 5 years.^{1,3} Patients with CLTI-related gangrene or tissue loss are 3 times more likely to be hospitalised, their inpatient care is 6 times more costly than the general inpatient population, and they have a $>10\%$ risk of amputation within 4 years.^{2,5,6} Furthermore, 5% of elderly patients develop a venous leg ulcer, a diagnosis which now accounts for 70% of all leg ulcers.^{7,8} The incidence of diabetes is also increasing; by 2030, approximately 8% of people will have diabetes and 15% of these individuals will develop a foot ulcer, the leading cause of direct medical costs and amputation in people with diabetes.^{4,9,10}

Compared with primary major (i.e., above or below knee) amputation in patients with hard-to-heal wounds, limb preservation is associated with reduced healthcare costs and improved health-related quality of life.¹¹⁻¹⁴ However, evidence suggests that the structure, processes, and outcomes of care provided to those with arterial, venous, diabetic, and postsurgical wounds is suboptimal.⁹

Observational studies have reported that arterial-insufficient and diabetic foot ulcer care by a multi-specialist team with different clinical backgrounds, knowledge, and expertise is associated with improved wound healing and reduced major amputations.¹⁵⁻²⁰ Proposed mechanisms for this improvement include increased wound monitoring, revascularisation efforts, attention to structural foot problems, and education and research surrounding limb preservation.²¹ However, in most healthcare centres, these clinicians do not commonly work together to provide a cohesive team approach to complex wound care, nor are they commonly located in a similar physical hospital space.^{9,22}

The Society for Vascular Surgery, the American Podiatric Medical Association, and numerous other organisations recommend a multi-specialist team approach to caring for patients at risk of limb loss.²³ Despite this, a limited number of multi-specialist limb-preservation clinics or programmes exist in North America, and very few studies exist examining the structure, processes, and outcomes of care provided by these clinics or programmes to guide their creation.²⁴ In September 2017, based on clinical need and informed by published opinions,^{21,23,25-27} The Ottawa Hospital (TOH) Division of Vascular and Endovascular Surgery initiated a unique-in-Canada quality improvement initiative by opening a novel, university-affiliated limb-preservation clinic and

programme in collaboration with colleagues from nursing, infectious diseases, and orthopaedic and plastic surgery. In this study, we sought to describe the structure, processes, and initial outcomes of TOH multi-specialist limb-preservation clinic and programme to evaluate the quality of care it provides and inform others' intent on designing similar clinics and programmes.²⁸ We also sought to determine whether early data suggest that our programme is achieving its mandate of providing high-quality wound clinical care, education, and research.

2 | MATERIALS AND METHODS

2.1 | Study design and reporting

We conducted a descriptive prospective cohort study.²⁹ We first described the clinic and programme structure and processes. We then analysed the frequency of patient visits and wound clinical care, educational, and research activities during the study period, alongside a nested cohort study of a subsample of clinic patients requiring serial assessments. Because our study relied on anonymised data generated during clinical care to support quality improvement, it was exempt from research ethics review. Written informed patient consent was obtained for inclusion of wound photographs. Reporting followed recommended guidelines.³⁰⁻³²

2.2 | Setting

The study was set at TOH. TOH is a three campus, quaternary care, non-profit, public, teaching hospital in Ottawa, Ontario, Canada. Its Civic Campus is a vascular and endovascular surgery centre of excellence that serves eastern Ontario and western Quebec.

2.3 | Design of TOH Multi-Specialist Limb-Preservation Clinic and Programme

Prior to September 2017, outpatient clinics for the Divisions of Vascular and Endovascular Surgery, Infectious Diseases, Plastic and Reconstructive Surgery, and Orthopaedic Surgery were located in different physical locations within TOH Civic Campus. When these clinics were scheduled to be relocated to a new wing of the Civic Campus, Heads and members of the above Divisions and a specialty vascular wound care nurse met. They then engaged senior members of TOH administration and the Department of Surgery, who assisted in codesigning the structure and anticipated processes of the clinic and programme,

informed by published opinions on designing a limb-preservation programme.^{21,23,25-27} In the first 3 years, the clinic was funded largely by grant money. TOH provided the clinic infrastructure and is now funding the clinic. The clinic is affiliated with the University of Ottawa and was given the mandate of providing high-quality wound clinical care, education, and research.

2.4 | Data sources and participants

A specialty vascular wound care nurse prospectively collected data on clinic processes (patient visits, wound clinical care provided in the clinic, virtual patient visits, and other clinical activities), and outcomes (wound care education and research activities) between clinic opening and 1 July 2019.²⁸ After didactic and hands-on workshops were provided in the clinic, participants were administered a standardised evaluation form. On 1 June 2018, the specialty nurse also began entering detailed data into how2trak wound management software (Health Outcomes Worldwide, Toronto, Ontario, Canada) on patients that required serial clinic assessments. Patient data collection was limited before 1 June 2018 because in the first year after the clinic opened, staff were focused on ensuring clinic procedures were established, including implementation of how2trak. how2trak combines point-of-care diagnostics, longitudinal documentation of wound treatments and progression, suggestions for best practices, integration of multi-specialist assessments, formulation of individualised care plans, and two-way communication of wound status and treatment plan and execution between referral centres, specialists, and community providers.

2.5 | Variables

Data collected in how2trak included patient demographics; wound measurements and treatment goals (healable, maintenance, non-healable); revised photographic wound assessment tool (revPWAT) and visual analogue pain scores; treatments provided in clinic; and wound measurements. Wound measurements were obtained by digitally tracing the wound with how2trak and a reference sticker. This software then computed the area and longest length and width of the wound. Wound depth was measured by positioning a reference stick at the deepest point within the wound.

The revPWAT is a valid and reliable tool to assess wounds of various aetiologies.³³ Scores from 0 to 4 are assigned to each of the revPWAT domains, including wound size and depth, necrotic tissue type and amount, type and amount of granulation tissue, wound edges, and

periwound skin viability.³³ Lower revPWAT scores indicate improved tissue appearance.³³

To capture more detailed information on those requiring serial clinic assessments, two investigators also independently examined all physician and allied health service consults, laboratory results, and pharmacy information recorded in our hospital electronic medical record during the last 3 years. They then independently recorded data on comorbidities; medications; previous amputations, lower limb revascularisation procedures, hospitalisations, and wound microbiology results, and then cross-referenced these with the data recorded in how2trak. Discrepancies during data collection were resolved via consensus.

2.6 | Statistical methods

We summarised categorical data using counts (percentages) and skewed data using medians [with interquartile ranges (IQRs)]. Wound volume was determined by multiplying wound area and depth. For the patients requiring serial clinic assessments, we calculated median wound volumes and compared these across wound types/locations using Kruskal-Wallis tests. We used linear mixed-effects models with a random intercept for each patient to calculate mean changes in wound volume [and its surrounding 95% confidence interval (CI)] for these patients between clinic visits. We considered *P*-values <.05 significant. Statistical analyses were performed using Stata/MP version 13.1 (StataCorp, Houston, Texas).

3 | RESULTS

3.1 | Description of the clinic and programme

3.1.1 | Structure

The clinic is located in the same hospital space as the outpatient vascular surgery, infectious diseases, and plastic surgery clinics (while that for the outpatient orthopaedic surgery clinic is located adjacent to it). The clinic space includes a large room in TOH Civic Campus that has three stretcher bays, one chiropody chair, a staff computer station, and an office equipped with telehealth technology (Figure 1). Equipment located in the clinic includes handheld continuous-wave Doppler machines; personal protective equipment; basic surgical supplies; an electrocautery machine; a 22.5-kHz contact ultrasound debridement generator; minor surgery procedure trays containing punch biopsy tools, scalpels, ronguers, and bone cutting instruments; and a bacterial fluorescence device.

The clinic is located on the main floor of TOH Civic Campus. The surrounding hallways are wide to support receipt of patients via wheelchairs and stretchers. The inpatient vascular surgery service, a pharmacy that fits patients with various compression garments, and a vascular diagnostic centre is located within the same building. The vascular diagnostic centre performs all types of non-invasive vascular investigations, including arterial and venous Duplex studies and toe pressure measurements. The programme is affiliated with a vascular health risk factors clinic staffed by internal medicine physicians specialised in primary and secondary cardiovascular prevention. Finally, the neighbouring University of Ottawa Heart Institute has a smoking cessation programme, TOH General Campus has an inpatient hyperbaric oxygen programme (which utilises both a single and a dual hyperbaric oxygen therapy chamber), and Ottawa has a number of different foot care programmes that provide preventive foot care and fit patients with orthotics and prosthetics.

Patients may be admitted to the inpatient vascular surgery ward directly from clinic, which is staffed by vascular surgery-dedicated nurses, physiotherapists, occupational therapists, dietitians, and social workers. A diabetes care nurse also consults on most of our patients with diabetes, and recommends endocrinology consults where appropriate.

3.1.2 | Referrals, specialist staffing, and patient assessments

Nearly all patients with arterial-insufficient, diabetic, chronic venous, and complex postoperative wounds who are initially referred to vascular surgery are subsequently referred to the clinic. All clinic referrals are received from vascular surgery faculty and housestaff. Prior to their initial clinic visit, a vascular surgeon (who is subsequently designated as the patient's most responsible physician) first assesses patients to diagnose wound type or pathology, determine need for revascularisation, and/or provide recommendations regarding indication for and safety of compression.

Eight to 10 outpatient referrals are seen on Mondays, Tuesdays, and Thursdays while inpatient consults are seen during the remainder of the week. Outpatient appointments are 30 to 60 minutes in duration. In February 2019, virtual video patient visits were initiated in collaboration with regional nursing clinics in Ontario. During virtual visits, the community nurse assesses the patient in their regional clinic and provides wound photographs and measurements within privacy protocols for entry into how2trak and the electronic medical record.



FIGURE 1 Structure of The Ottawa Hospital Limb-Preservation Clinic. The clinic is located in the same hallway as outpatient clinics for the Divisions of Vascular and Endovascular Surgery, Infectious Diseases, and Plastic and Reconstructive Surgery. The outpatient clinic for the Division of Orthopaedic Surgery is located just adjacent to it. The clinic space includes a large room that has three stretcher bays, one chiropody chair, a staff computer station, and an office equipped with telehealth technology (located between the chiropody chair and the interprofessional staff computer station to the left of the clinic)

A full-time specialty vascular wound care nurse and a number of part-time consulting surgeons staff the clinic. The surgeons affiliated with the clinic have expertise in open and endovascular lower limb revascularisation, soft tissue coverage and reconstruction, correction of structural foot deformities and biomechanical orthopaedic problems, minor and major lower limb amputations, and simple and complex debridement procedures. All patients with signs or suspicion of infection are seen by the infectious diseases service while most of those with suspicion for structural foot deformities are seen by foot and ankle orthopaedic surgeons or referred for orthotics.

During clinic visits, the specialty nurse assesses, measures, and photographs patients' wounds. Wound microbiology

swabs are taken from wounds with signs of infection. She then uses how2trak to create a one-page summary that is immediately uploaded to the hospital electronic medical record and sent to the most responsible vascular surgeon and relevant consultants. This process allows continuous, ongoing documentation of wound progress or deterioration, including acute-on-chronic complications that may occur during outpatient wound care. It also ensures all the necessary clinicians follow the wound without duplicating work. After their initial consult, outpatients are re-evaluated every 2 to 3 weeks in-person or through virtual patient visits or telehealth in collaboration with community nurses until their wounds are healed. Inpatient referrals are followed daily until stabilised and then less frequently thereafter.

TABLE 1 Baseline characteristics of the 162 patients evaluated in The Ottawa Hospital Multi-Specialist Limb-Preservation Clinic that required serial clinic assessments

Characteristic	No. (%) (n = 162)
Personal characteristics	
Age, years—median (IQR)	70 (62-78)
Male	96 (59.3)
Rural residence	67 (41.4)
Long-term care facility resident	5 (3.1)
Current cigarette smoker	38 (23.4)
Past cigarette smoker	62 (38.3)
Comorbidities recorded in the 3 years before clinic visit	
Acute coronary syndrome	60 (37.0)
Cerebrovascular event (stroke or transient ischaemic attack)	22 (13.6)
Chronic kidney disease	37 (22.8)
Chronic obstructive pulmonary disease	21 (13.0)
Coronary artery disease	69 (42.6)
Diabetes mellitus	93 (57.4)
Dialysis	14 (8.6)
Dyslipidaemia	99 (61.1)
Heart failure	35 (21.6)
Hypertension	126 (77.8)
Current medications	
Antihypertensive	125 (77.2)
Antiplatelet agent	120 (74.1)
Warfarin	18 (11.1)
Novel oral anticoagulant	28 (17.3)
Statin	106 (65.4)
Oral antihyperglycaemic agent	59 (36.4)
Insulin	56 (34.6)
Prior ipsilateral or contralateral lower limb amputation	
Contralateral above- or below-knee amputation	10 (6.2)
Ipsilateral toe or ray (i.e., toe and partial metatarsal) amputation	42 (25.9)
Ipsilateral transmetatarsal amputation	11 (6.8)
No. of ipsilateral lower limb revascularisation procedures performed before clinic visit	
0	58 (35.8)
1	6 (3.7)
2	74 (45.7)
3	24 (14.8)

(Continues)

TABLE 1 (Continued)

Characteristic	No. (%) (n = 162)
Ipsilateral lower limb revascularisation procedures performed before clinic visit	
Iliac artery angioplasty and/or stenting	23 (14.2)
Femoral and/or popliteal artery angioplasty and/or stenting	52 (32.1)
Tibial and/or peroneal artery angioplasty	50 (30.9)
Aortofemoral or aortobifemoral bypass	1 (0.6)
Axillofemoral or axillobifemoral bypass	10 (6.2)
Iliofemoral or femoral endarterectomy	27 (16.7)
Femoral-popliteal bypass	12 (7.4)
Femoral-tibial or -peroneal bypass	10 (6.2)
Other revascularisation procedure	21 (13.0)

Abbreviation: IQR, interquartile range.

3.1.3 | Continuing wound clinical care and clinic-community collaborations

When clinic patients with a newly diagnosed lower limb wound infection are admitted to any hospital service, they are followed by the specialty vascular wound care nurse, vascular surgery, and infectious diseases. The nurse participates in weekly infectious disease rounds and weekly rounds with our regional community wound care nursing lead regarding shared outpatients receiving advanced wound care therapies. During the latter sessions, she works with community nurses and ensures that outpatients have a clear wound care plan, tracks wound healing trajectories, and proactively plans timing of clinic surgical procedures such as wound debridements, toe/ray amputations, and skin grafts with community nurses and consultant surgeons affiliated with the clinic. She also performs virtual wound reviews with individual community nurses every 3 weeks and provides updated wound dressing orders after discussion with these nurses and the most responsible vascular surgeon where needed. During these reviews, photographs of the patients' wounds are provided and included in the one-page summary uploaded to the hospital medical record. The specialty nurse and a plastic surgeon simultaneously assess those patients with wounds that may benefit from skin graft closure in clinic. When clinic patients are discharged, an outpatient clinic referral is sent to ensure follow-up. All patients with wounds being managed with negative-pressure wound therapy are also referred.

3.2 | Clinic and programme process and outcome data during the study period

3.2.1 | Clinic visits

Between 1 April 2018 and 1 July 2019, there were 1623 total patient visits to the clinic, the majority (72.2%) of which were from outpatients. In 17.8% of visits, patients were evaluated by >1 specialist. Furthermore, 15 virtual video patient visits were provided between 1 April 2018 and 1 July 2019. The clinic also performed two intraoperative consults for difficult wound care management.

In total, 162 patients between 1 June 2018 and 1 July 2019 assessed in the clinic required serial assessments (Table 1). These patients had a median age of 70 (IQR = 62-78) years and multiple comorbidities, and nearly half (41.4%) lived in a rural area. Furthermore, 64.6% had previously undergone an ipsilateral lower limb revascularisation procedure (and 60.5% two or more of these procedures), 6.2% a contralateral major amputation, and 25.9% an ipsilateral toe or ray (i.e., toe and partial metatarsal) amputation before their visit. Most had visited the emergency department (68%) or been hospitalised (78%) at least once within the last year, and 24% had been hospitalised more than once.

Table 2 shows characteristics of the wounds of the 162 patients. Common types included arterial-insufficient ulcers (37.4%), postoperative wounds after vascular surgery (25.9%), and mixed aetiology (e.g., arterial-insufficient and diabetic or chronic venous) wounds (10.8%). Most were assessed to be healable (92.1%) and located on the foot or ankle (61.2%). They had a median width of 2 cm (IQR = 1-4 cm; range 1-11 cm) and a volume of 2.5 (IQR = 0.54-11.1; range 0.10-126.6) cm³. Nearly half (43.8%) also had an associated diagnosed wound infection. Of the 85 wounds on the foot or ankle, many were confined to the toes (25.9%), heel (23.5%), or medial or lateral malleolus (10.6%). Median patient wound volumes did not vary by wound type ($P = .55$) or location ($P = .34$). revPWAT scores are described in Table 3.

3.2.2 | Wound clinical care

The types and frequencies of wound therapies provided to patients in the clinic during the 1623 visits during the study period are summarised in Figure 2. These most often included negative-pressure wound therapy, application of biological wound dressings (e.g., wound balancing dressings or extracellular matrices), and total contact casting. Others included the provision of

TABLE 2 Characteristics of the wounds possessed by the 162 patients evaluated in The Ottawa Hospital Multi-Specialist Limb-Preservation Clinic that required serial clinic assessments

Characteristic	No. (%) (n = 162)
Wound type (n = 139 with a documented aetiology)	
Arterial	52 (37.4)
Venous	13 (9.4)
Diabetic	10 (7.2)
Mixed	15 (10.8)
Postoperative	36 (25.9)
Other	13 (9.4)
Wound location (n = 139 with a documented location)	
Groin	3 (2.2)
Thigh	9 (6.5)
Leg	39 (28.1)
Foot or ankle	85 (61.2)
Other	3 (2.2)
Wound size, cm—median (IQR)	
Width	2.0 (1.0-4.0)
Length	3.5 (1.7-6.0)
Depth	0.40 (0.20-0.50)
Area, cm ²	7.5 (1.8-22.0)
Volume, cm ³	2.5 (0.54-11.1)
Wound treatment goal after assessment (n = 139 with a documented goal)	
Healable	128 (92.1)
Maintenance	10 (7.2)
Not healable	1 (0.7)
Visual analogue scale pain score—median (out of 10)	1 (0-3)
Associated wound infection at presentation	
Organisms cultured from wound	
Coagulase-negative Staphylococcal species	4/71 (5.6)
Methicillin-sensitive or -resistant <i>Staphylococcus aureus</i>	50/71 (70.4)
Methicillin-resistant <i>S. aureus</i>	13/71 (18.3)
Enterococcus species	5/71 (7.0)
Vancomycin-resistant Enterococcus	2/71 (2.8)
<i>Streptococcus</i> species	4/71 (5.6)
<i>Corynebacterium</i> species	6/71 (8.5)
Enterobacteriaceae	34/71 (47.9)
<i>Pseudomonas</i> species	17/71 (23.9)

Abbreviation: IQR, interquartile range.

TABLE 3 Revised Photographic Wound Assessment Tool Scores for the patients that required serial clinic assessments

Wound domain, No. (%)	Overall (n = 127 with revPWAT scored wounds)
Size	
0 = Wound is closed (skin intact) or nearly closed (<0.3 cm ²)	100 (78.7)
1 = 0.5-2.0 cm ²	6 (4.7)
2 = 2.0-10.0 cm ²	5 (3.9)
3 = 10.0-20.0 cm ²	2 (1.6)
4 = >20.0 cm ²	14 (11.0)
Depth	
0 = Wound is closed (skin intact) or nearly closed (<0.3 cm ²)	99 (78.0)
1 = Full thickness	9 (7.1)
2 = Unable to judge (majority of wound base covered by yellow/black eschar)	3 (2.4)
3 = Full thickness involving underlying tissue layers	12 (9.5)
4 = Tendon, joint capsule, bone visible/present in wound base	4 (3.2)
Necrotic tissue type	
0 = None visible or wound is closed (skin intact) or nearly closed (<0.3 cm ²)	105 (82.7)
1 = Majority of necrotic tissue is thin, white/grey, or yellow slough	7 (5.5)
2 = Majority of necrotic tissue is thick, adherent white yellow slough, or fibrin	8 (6.3)
3 = Majority of necrotic tissue is white/grey devitalised tissue or eschar	5 (3.9)
4 = Majority of necrotic tissue is hard grey to black eschar	2 (1.6)
Amount of necrotic tissue	
0 = None visible or wound is closed (skin intact) or nearly closed (<0.3 cm ²)	105 (82.7)
1 = <25% of wound bed covered	8 (6.3)
2 = 25%-50% of wound bed covered	7 (5.5)
3 = 50%-75% of wound bed covered	0 (0)
4 = 75%-100% of wound bed covered	7 (5.5)
Granulation tissue type	
0 = Wound is closed (skin intact) or nearly closed (<0.3 cm ²)	100 (78.7)
1 = Majority of granulation tissue is healthy looking (even bright red appearance)	3 (2.4)
2 = Majority of granulation tissue is unhealthy (pale, dull, dusky, hypergranulation)	13 (10.2)
3 = Majority of granulation tissue is damaged, friable, degrading	8 (6.3)
4 = There is no granulation tissue present at the base of the open wound	3 (2.4)
Amount of granulation tissue	
0 = Wound is closed (skin intact) or nearly closed (<0.3 cm ²)	101 (79.5)
1 = 75%-100% of open wound is covered with granulation tissue	7 (5.5)
2 = 50%-75% of open wound is covered with granulation tissue	7 (5.5)
3 = 25%-50% of open wound is covered with granulation tissue	2 (1.6)
4 = <25% of wound bed is covered with granulation tissue	10 (7.9)
Wound edges	
0 = Wound is closed (skin intact) or nearly closed (<0.3 cm ²) or edges are indistinct, diffuse, not clearly visible because of re-epithelialisation	101 (79.5)
1 = Majority of edges are attached with an advancing border of epithelium	0 (0)
2 = Majority of edges are attached even with wound base (not advancing)	12 (9.5)
3 = Majority of edges are unattached and/or undermined	6 (4.7)
4 = Majority of edges are rolled, thickened, or fibrotic	8 (6.3)

(Continues)

TABLE 3 (Continued)

Wound domain, No. (%)	Overall (n = 127 with revPWAT scored wounds)
Periulcer skin viability	
0 = None	101 (79.5)
1 = One only	2 (1.6)
2 = Two or three	14 (11.0)
3 = Four or five	8 (6.3)
4 = Six or more	2 (1.6)

Note: Majority indicates >50%.

Abbreviation: revPWAT, revised photographic wound assessment tool.

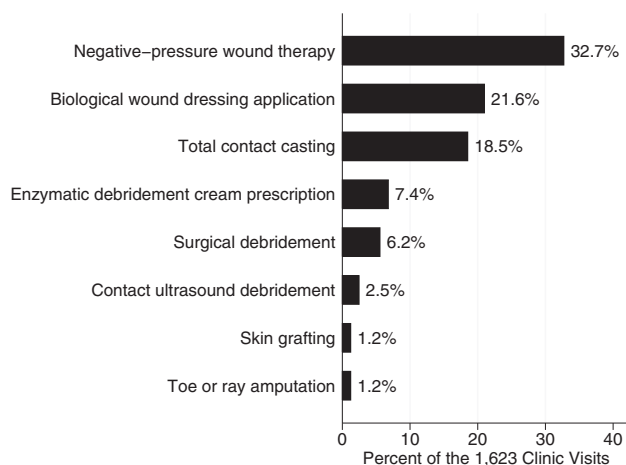


FIGURE 2 Types and frequencies of wound therapies provided to patients during the 1623 clinic visits during the study period

prescriptions for enzymatic wound debridement cream, surgical or contact ultrasound debridement, toe or ray foot amputations, and skin grafting of granulated arterial-insufficient or diabetic foot wounds (Figure 3). Furthermore, 22.8% of the patients were initiated on an antimicrobial or antimicrobials during their clinic visit. For the 162 patients that required serial clinic assessments, mixed-effects models accounting for clustering of data within patients suggested that mean wound volume decreased by more than half [-1.6 (95% CI = -0.86 to -2.27) cm^3] per clinic visit ($P < .001$).

3.2.3 | Wound care education

During the study period, the clinic provided elective rotations to five physicians from infectious diseases, dermatology, and palliative care as well as three preceptorships to nurses enrolled in a Masters of Clinical Science of Wound Healing programme or who were already

specialised in Wound Ostomy Continence. Two vascular surgery residents also rotated through the clinic. During clinic rotations, clinicians accompanied the specialty vascular wound care nurse and developed treatment plans for complex wounds, became familiar with dressings and advanced wound treatments, and assisted in determining surgical treatment options.

The clinic also provided mixed didactic and hands-on workshops on complex lower limb wound care to clinicians from across Canada. Prior to the hands-on component, participants attended presentations prepared by vascular surgeons, infectious disease specialists, plastic surgeons, foot and ankle surgeons, and wound care nurses on the epidemiology, diagnosis, and management of arterial-insufficient, venous, diabetic, and postsurgical wounds. They then received hands-on instruction on how to perform a peripheral vascular examination (including measurement of ankle-brachial indices), debride and dress a lower limb wound, and apply various types of negative-pressure wound therapy.

The 20 community wound care nurses and one family medicine physician who participated in the above workshops had been in practice for a median of 15 (IQR = 7-22) years, and had a median of 10 (IQR = 6-15) years of wound-related experience. After the workshop, most participants strongly agreed that the content was understandable, well organised, and applicable to their practice; the instructors were knowledgeable, communicated well, and were approachable; and that they would recommend the workshop to others and were interested in a more advanced workshop on the same subject (Figure 4). Furthermore, most felt that the workshop provided intermediate- (66.7%) or advanced- (23.8%) rather than introductory-level (9.5%) knowledge.

Finally, one clinic member recently assisted in developing a province-wide pathway for preventing and managing vascular wounds.

3.2.4 | Wound care research

During the study period, we enrolled 78 patients into two investigator-initiated, published randomised controlled trials. We also initiated a research programme on patient-reported outcomes among those at risk of limb loss and have completed two studies thus far. Furthermore, we



are conducting studies on use of skin grafts for granulating foot and leg wounds. Finally, clinic members recently contributed to the creation of both vascular health and lower limb wound research groups, which are each comprised of vascular surgeons, internal medicine and infectious disease specialists, family physicians, wound care nurses, epidemiologists, and health economists. These groups are now conducting a series of provincial and national vascular health and wound care studies.

4 | DISCUSSION

This study is one of the first to provide a detailed description of the structure and processes of a multi-specialist,



FIGURE 4 Violin plot of participants' ($n = 20$ nurses and $n = 1$ family medicine physician) evaluation of the workshops on complex lower limb wound care provided by the clinic. Violin plots are modified box plots that add estimated kernel density plots to the summary statistics displayed by box plots. Responses were rated on a 5-point Likert scale ranging from 1 = strongly disagree to 5 = strongly agree

FIGURE 3 Skin grafting of granulated mixed arterial-insufficient and diabetic foot wound after revascularisation, modified transmetatarsal amputation, and negative-pressure wound therapy in the clinic. This 59-year-old male presented with infected gangrene of the right 1st through 4th toes and a large plantar abscess. The patient underwent superficial femoral and tibial artery angioplasties and a modified transmetatarsal amputation by a vascular surgeon. The wound was left open to heal by secondary intention because of infection and an insufficient soft tissue plantar flap for closure. After two-and-a-half months of negative-pressure wound therapy monitored by a vascular surgeon and our specialty vascular wound care nurse, a plastic surgeon covered the granulated wound in the clinic with a partial-thickness skin graft taken from the right forearm. There was excellent skin graft take and the wound healed well

limb-preservation clinic and programme. The data reported support that our limb-preservation programme is achieving its mandate of providing high-quality wound clinical care, education, and research for several reasons. First, the clinic regularly provides a number of advanced wound therapies. Second, despite the fact that most of the patients that required serial clinic assessments had multiple high-risk comorbidities, nearly half lived in a rural area, and approximately a quarter had previously undergone a minor amputation, patients' wound sizes decreased significantly between visits. Third, to date and during the study period, the clinic has provided both informal and formal education on the peripheral vascular examination and complex wound care to a variety of different clinicians locally, regionally, and nationally. Finally, perhaps because the clinic is housed in an academic institution staffed by clinician-scientists, it has fostered an interest in conducting research on improving wound care patient-important outcomes.

Clinical practice guidelines²³ and opinion leaders^{19,20,22-24} recommend that limb-preservation clinics and programmes be structured in a way that improves revascularisation efforts, specialist collaboration, and limb preservation education and research. In our programme, likely because all patients are first evaluated by a vascular surgeon, nearly two-thirds had already undergone a revascularisation procedure by the time they were seen in clinic. This included many who were more challenging to revascularise because of infrapopliteal disease and that received a tibial or peroneal artery angioplasty or femoral-tibial bypass. In this study, colocalisation of wound care specialists in one physical hospital space also appeared to improve collaboration between them as nearly one-fifth of the patients seen in the clinic were evaluated by more than one specialist during their visit. Furthermore, some patients' wounds were managed in a way that would not have been possible without close multi-specialist collaboration. This includes those that received a revascularisation procedure followed by a minor amputation treated with negative-pressure wound therapy that was ultimately closed with a skin graft.

Although we know of no studies that detailed the structure and processes of a multi-specialist limb-preservation clinic, several have examined the ideal composition and function of multidisciplinary teams formed to reduce major amputations.³⁴ However, the majority of these studies focused exclusively on people with diabetes.³⁴ A systematic review of 33 of these studies reported that the most common people included on diabetes amputation prevention teams included endocrinologists (82%), vascular surgeons (74%), and orthopaedic surgeons (67%), and less often nurses (56%), allied health

professionals (54%), podiatrists (52%), plastic surgeons (44%), and infectious disease specialists (37%).³⁴ The most common non-glycaemic control tasks performed by these teams included local wound management and treatment of vascular disease and infection.³⁴ Only 11 (33%) of the studies reported addressing education and most teams used basic tools to assist with communication and coordination rather than advanced wound care technologies like how2trak.³⁴ Finally, only 55% of the teams studied functioned in both the inpatient and outpatient settings.³⁴

An increasing number of small studies have reported that a multidisciplinary team approach to patients with CLTI or diabetic foot wounds is associated with a reduction in the risk of major amputations.^{15,34,35} In a retrospective cohort study of 146 patients with CLTI (85 of which had tissue loss), multidisciplinary care by a team of vascular, plastic, and podiatric surgeons was associated with a more than twofold improvement in major amputation-free survival.¹⁵ Another study of 72 patients with CLTI (only 11 of which had tissue loss) reported a similar improvement.³⁵ Finally, a systematic review that included mostly studies of people with diabetic foot ulcers reported that 31 (94%) of the 33 included studies reported a reduction in major amputations after institution of a multidisciplinary care team.³⁴ However, as most of these studies utilised an observational design, they may be limited by confounding or treatment selection bias.

Our study may be used as a detailed guide to inform others' intent on designing similar limb-preservation clinics and programmes. To develop a similar programme, centres would need to design their clinics with a patient-centred team approach in mind. Ideally, the limb-preservation clinic should be a multi-specialist space, allowing for seamless collaboration between key specialists, including vascular, orthopaedic, and plastic surgeons; nurses and nurse specialists; infectious disease physicians; and chiropodists. An office equipped with telehealth technology for virtual patient visits also allows for care to be expanded beyond the physical boundaries of the clinic. The clinic also requires access to a non-invasive vascular diagnostic centre; primary and secondary cardiovascular risk factors prevention clinic; smoking cessation and diabetes management programmes; an inpatient limb-preservation service for acute care needs; and, where possible, a hyperbaric oxygen programme. Most importantly, the clinic should designate one clinician (such as our nurse specialist) who can quarterback the care of clinic patients by continuously communicating about their progress with the most responsible vascular surgeon, other surgical specialists, and community nurses. Finally, having a shared electronic medical record that permits continuous,

collaborative documentation of wound progress and deterioration is important as it allows the involved clinicians to detect or prevent wound complications that occur during outpatient care.

This study's findings should be considered in the context of its strengths and limitations. First, although our study provided a detailed description of our limb-preservation clinic and programme, we did not examine whether improvements in patient outcomes or health system costs were associated with programme implementation. This is because we felt it necessary to first describe the structure and processes of our clinic and programme before conducting any before and after studies of patient clinical outcomes associated with clinic and programme implementation. We also did not consistently capture clinical data on patients at risk of limb loss before the clinic opened. However, our results do suggest that the clinic provides high-quality wound clinical care, education, and research at TOH. Data from the Vascular Volumes and Outcomes Report from CorHealth Ontario also suggest that patients who underwent lower limb revascularisation at TOH during the study time period had a lower 90-day adjusted risk of major amputation than the provincial average.³⁶ Second, while our limb-preservation programme consults with various chiropractors across the city, podiatric surgeons are an obvious missing component of our multidisciplinary team. Therefore, the majority of minor foot amputations and debridements are performed at TOH by our vascular and orthopaedic surgeons. Furthermore, because we had not yet transitioned to doing more minor amputation operations in the clinic during the study period, many were performed in the operating room, explaining the relatively low rate of use of these procedures in the clinic. Finally, we only collected detailed data on a subset of the patients evaluated in the clinic who required serial assessments, and therefore these patients may represent a higher risk cohort when compared to all of the patients seen.

5 | CONCLUSIONS

This study provides a detailed description of the structure and processes of a unique-in-Canada, multi-specialist, limb-preservation clinic and programme. Results may be used to guide others' intent on developing similar programmes. Data reported by the study support that our limb-preservation programme is achieving its mandate of providing high-quality wound clinical care, education, and research. Future research will focus on determining whether implementation of our programme was associated with improvements in patient-important outcomes and health system resources and costs.

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CONFLICT OF INTEREST

The authors have no conflict of interest to declare.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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