The Correlation between Regional Health Care Services and Rates of Lower Extremity Amputation related to Diabetes and Peripheral Artery Disease

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ABSTRACT

Background: Integrated regional amputation prevention efforts may help save limbs for patients with diabetes and peripheral artery disease (PAD). This ecological study explores the correlation between regional health care services and rates of lower extremity amputation related to diabetes or PAD.

Methods: All diabetes or PAD-related major (above ankle) lower extremity amputations were identified among Ontario residents at least 40 years old, between April 1, 2007 and March 31, 2017. For each of fourteen administrative health regions, age- and sex-adjusted amputation rates were calculated as well as per capita counts of key health providers (podiatrists/chiropodists and surgeons) and, health care utilization among amputees in the year prior to first major amputation (physician visits, publicly-funded podiatry visits, emergency department visits, hospitalization, home care nursing, minor amputation, limb revascularization). The magnitude of correlation between health care services and amputation rates, at the region level, was quantified through linear regression.

Results: A total of 11,658 major amputation patients were identified (79% with diabetes, 97% with PAD). There was wide variation across regions in the adjusted rate of major amputation: 2.53-11.77 per 100,000 person-quarters. At a regional level, the proportion of amputees who received endovascular or open revascularization showed the strongest negative correlation with amputation rates. The regional proportion of amputees who saw a vascular surgeon showed the strongest negative correlation with amputation rates relative to other health provider visits. Other measures of regional health care utilization among amputees correlated poorly with regional amputation rates, as did the regional number of key providers per capita. The results were similar when restricting the analysis to amputations related to diabetes.

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Interpretation: Vascular surgeon assessment and access to revascularization are integral to regional amputation prevention efforts for patients with diabetes or PAD.

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INTRODUCTION

Diabetes and peripheral artery disease (PAD) are responsible for over 80% of lower extremity amputations in Canada.[1,2] Neuropathy and arterial atherosclerosis are frequently synergistic and cannot be reversed. However, many diabetic and PAD-related amputations are preventable with early recognition of a threatened limb and coordinated care by a range of health providers (podiatrists, chiropodists, primary care physicians, medical specialists, surgeons as well as nurses). Evidence-based guidelines outline best practice with respect to foot screening, wound care, the management of infection as well as the assessment and treatment of arterial insufficiency. [3-6] However, the care necessary to prevent and treat foot complications from diabetes and PAD remains disjointed in many jurisdictions.

Patients with cancer, traumatic injury or in need of organ transplantation benefit from regional care pathways and dedicated centers of excellence in Canada.[7-9] The same cannot be said for patients with diabetes or PAD at risk limb loss. Unfortunately, the frequency of amputations related to diabetes, PAD or both is increasing.[10] Integrated regional amputation prevention efforts can help save limbs for these patients. However, relative to other complications of diabetes and cardiovascular disease, there is limited health system-level insight into the clinical burden of lower extremity amputation and the effectiveness of prevention. In an effort to begin addressing this important knowledge gap, the objective of this study was to quantify the correlation between potentially limb-preserving health services and amputation rates, at a regional level, in Ontario, Canada.

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METHODS

Study design, setting and overview

This ecological study explores the correlation between regional health care services and rates of amputation related to diabetes or PAD in Ontario, Canada, between 2007 and 2017. Ontario has over 13 million residents living across over 1 million square kilometers. Most health services necessary to prevent amputation are covered under the single-payer public health care system, which was structured within fourteen administrative health regions during the study period. Publicly funded services contributing to amputation prevention include primary and specialist physician care, emergency room and hospital care, and in-home or in-community nursing care for wounds. However, outpatient foot care by non-physician foot specialists, podiatrists and chiropodists, is mostly paid out-of-pocket by patients or through private insurers in Ontario.

With a focus on learning from cases of failed limb salvage, a population-based cohort of all Ontarians at least 40 years old, who underwent major lower extremity amputation related to diabetes or PAD, was first defined. In these patients, the proportion who received potentially limb-preserving health services within up to 1 year prior to first major amputation was calculated. For each region, we then calculated age and sex-adjusted amputation rates as well as per capita counts of key health providers of foot care –podiatrists/ chiropodists and surgeons. The correlation at the regional level between these measures and amputation rates was then quantified.

Data sources

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The amputee cohort and their health care utilization prior to first major amputation were captured from linked administrative health records for the province of Ontario.[11] Eligible Ontario residents aged 40 or more were identified in the Registered Person's Database. Amputation was identified from hospitalizations records in the Canadian Institute for Health Information's Discharge Abstract Database. Other inpatient and outpatient health services received prior to amputation and their associated costs to the Ontario Ministry of Health were identified from the Discharge Abstract Database in addition to the National Ambulatory Care Reporting System Database (all same day surgery and emergency department encounters), the Ontario Health Insurance Plan Claims Database (all physician claims and any publicly-funded podiatry claims, which represent a small subset of podiatrist/chiropodist services), and the Home Care Database (all publicly-funded at-home or in-community nursing care). The datasets were linked using unique encoded identifiers and analyzed at ICES. Deterministic linkage of these datasets has been validated for a variety of diagnoses and procedures including diabetes and lower extremity major amputation.[12,13] Podiatrist/chiropodist counts by region were publicly reported by the College of Chiropodists of Ontario.[14] Physician provider counts per region were available from the ICES Physician Database.[11]

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Cohort of major amputation related to diabetes or peripheral artery disease

All Ontario residents with a hospitalization for major lower extremity amputation were identified based on specified Canadian Classification of Health Intervention Codes (CCI codes: 1VC93, 1VG93, 1VQ93 - below, through and above knee amputation). Patients with type 1 or 2 diabetes were identified according to a validated algorithm for prevalent cases of diabetes using physician billing claims[12] or the inclusion of an ICD-10-CA diagnosis code for diabetes (E10-

E14) on the index amputation hospitalization. Patients with PAD were identified based on specified ICD-10-CA diagnosis codes for symptomatic PAD from the index amputation encounter or any hospitalization, same day surgery or emergency room visit within the previous 3 years (See Appendix 1, Supplemental Table 1). Exclusions included patients under age 40 and those with a most-responsible diagnosis code on the index amputation hospitalization for traumatic injury, malignancy, congenital deformities, complications of an orthopedic prosthesis or other pathologies unrelated to diabetes or PAD (See Appendix 1, Supplemental Table 2). Certain patient characteristics were also captured including: age, sex, rural residence and income quintile and a comorbidity index based on weighted John Hopkins Aggregated Diagnosis Groups using a 3-year lookback.[15-17] A similar cohort of Ontario amputees and their characteristics has been previously described.[10]

Region-specific amputation rates

Given changes in the Ontario and region-specific populations over time, major amputation rates were first calculated for individual quarters from 2007 to 2017. The rate numerator was the number of major amputations within each region based on the region of residence of each amputee. Region of residence was selected rather than the region of hospitalization since inter-regional transfer is common for urgent vascular surgical care in Ontario. Given the long study period and the fact two legs may be at risk, multiple major amputations in the same patient may occur but a limit was set to one major amputation count per patient per quarter. The rate denominator included all Ontario residents at least 40 years old within a given region at the start of each quarter

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For each quarter, direct standardization of the regional rates was performed on age (40-70 years, ≥ 70 years) and sex (male, female). Previous analyses have suggested that the same regions have remained high and low outliers with respect to amputation rates for diabetes or PAD over the study period.[18-20] An average quarterly rate for the 10-year study period was therefore calculated for each region.

Health provider counts, Health Service Utilization, Health Care Costs

On the premise that access and use of potentially preventative health services may influence amputation rates in certain regions, we defined region-specific measures of potential access and, among amputees, realized use of health care services prior to amputation.

Counts (per 100,000 residents at least 40 years old) of vascular surgeons, general surgeons, orthopedic surgeons and podiatrists/chiropodists were made for each region in fiscal year 2013. Health service utilization was measured among amputees as the proportion whom, within up to 1 year prior to the date of index amputation hospitalization had any of the following: physician visits, publicly-funded podiatry visits, emergency department visits, hospitalizations, outpatient nursing care, endovascular or open surgical revascularization (e.g. endovascular angioplasty/stenting, open surgery), minor (below ankle) amputations. Physician visits included those to a family physician, vascular surgeon, general surgeon, orthopedic surgeon or other specialist. Physician and podiatry visits within 30 days prior to index amputation admission were not counted since visits so close to amputation are more likely to reflect the assessment and determination of a non-salvageable limb, rather than an opportunity to avoid amputation. Minor amputation and revascularization, identified based on CCI codes (See Appendix 1, Supplemental Table 3), were captured within up to 1 year prior to major amputation but also on the index

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major amputation admission, since same-admission revascularization or toe amputation most likely reflects attempted limb salvage. Finally, as a broad measure of all publicly-funded health care services received prior to amputation, total health care costs to the Ontario Ministry of Health, within up to 1 year prior to the index amputation hospitalization, were also captured according to person-level costing based on Resource Intensity Weight of hospital encounters and unit costing.[21] These costs were standardized to 2017 Canadian dollars and included those attributable to hospital care (acute care, rehabilitation, chronic continuing care), physician services claims, publicly-funded podiatry claims, outpatient procedures, outpatient testing, outpatient nursing and allied health home care and, for those at least 65 years old, outpatient medications.

Analysis

The magnitude of correlation between regional amputation rates and health services was evaluated through linear regression and calculating the coefficient of determination (R-squared) that ranges from 0 – no correlation to 1 – perfect linear correlation. The direction of correlation (positive or negative) was quantified with the Pearson correlation coefficient. A secondary analysis was performed repeating the analysis based on amputations related to diabetes (i.e. excluding those amputees with PAD but not diabetes).

Ethics approval

The use of data in this project was authorized under section 45 of Ontario's Personal Health Information Protection Act, which does not require review by a Research Ethics Board.

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RESULTS

The province-wide rate of major amputation related to diabetes or PAD was 5.31 per 100,000 person-quarters. At the regional level, the age- and sex-adjusted rates of major amputation ranged widely from 2.53 to 11.77 per 100,000 person-quarters (Figure 1 and Appendix 2, Supplemental Table 1). Regions with the highest amputation rates had a larger proportion of their amputees living in rural areas and in the lowest provincial income quintile. There was no meaningful regional difference in overall comorbidity level of amputees, based on comorbidity index or in-hospital mortality associated with major amputation (Appendix 2, Supplemental Table 2).

The regional count of vascular surgeons and podiatrists/chiropodists per 100,000 residents was inversely related with amputation rates; however, there was low correlation between regional counts of all health providers and amputation rates (Table 1 and Appendix 2, Supplemental Table 3).

With respect to regional measures of health service utilization among amputees, the regional proportion of amputees who received endovascular or open revascularization showed the strongest negative correlation with regional amputation rates (Table 1). Among provider visits, a vascular surgeon visit showed the strongest negative correlation with regional amputation rates (Table 1). Previous hospitalization, emergency department visit, receipt of outpatient at-home or in-community nursing care and total publicly-funded health care costs all correlated poorly with regional amputations rates (Table 1 and Appendix 2, Supplemental Tables 4-6).

These afore-mentioned findings were similar when considering only amputations related to diabetes (Appendix 3, Supplemental Tables 1-7)

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DISCUSSION

This population-based study of major amputations related to diabetes or PAD sought to quantify the correlation between regional amputations rates and regional rates of health services across Ontario. There were two main findings. First, there was wide regional variation in amputation rates with the highest rates seen in more rural and northern regions. Second, vascular surgeon assessment and receipt of revascularization to address arterial insufficiency among amputees was strongly correlated, at a regional level, with lower amputations rates.

Previous analyses have consistently documented high amputation rates in residents of northern Ontario.[18-20] In Canadian provinces as well in the United States and Australia, residents of rural regions and indigenous communities have higher amputation rates related to diabetes.[22-26] Compared to amputees in low-rate regions, those in northern regions of Ontario had a similar comorbidity level and received primary care and many health services with similar frequency prior to amputation. However, potentially limb saving treatments were less commonly performed, most notably revascularization. As with myocardial infarction and stroke,[27] geography appears to influence the clinical outcome of patients with a threatened limb due to diabetes or PAD. Initiatives to improve foot care for patients living in vast rural regions of Canada must be tailored to their unique circumstances, as exemplified by Loewen and colleagues with the Sioux Lookout Diabetic Foot Ulcer Protocol.[25] There are however shared principles that apply to all contexts of practice: (i) patients with diabetes or PAD should check their feet daily for wounds, (ii) foot assessment should be completed at least annually by a trained health care provider who can also provide patient education, (iii) foot wounds or infection should be promptly evaluated by a knowledgeable care provider who works within or is supported by a multidisciplinary foot care team.

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Amputation prevention requires a range of expertise that no single health provider can offer alone. International and Canadian studies support multidisciplinary care to prevent and treat foot complications of diabetes and peripheral atherosclerosis.[28-31] Models of collaborative care must bring together key domains of expertise necessary to effectively treat a threatened limb. All patients require (i) tailored medical and/or surgical treatment of arterial atherosclerosis, (ii) medical and/or surgical management of any foot infection and (iii) wound care including assessment and/or treatment of contributory pathologic foot biomechanics. The toe and flow model structured around the close collaboration of podiatry and vascular surgery, with support from other specialists (e.g. endocrinology, infectious disease, general internal medicine, hematology, orthopedic surgery, plastic surgery, interventional radiologists and physiatrists), is a well-known example of foot care team structure.[32] More commonly seen in Canada, medical teams treating a broad range of wounds can also be supported by hospital-based surgical expertise to address infection, foot deformity and ischemia.[33-35] Regardless of foot care team structure, our analysis confirms the integral importance of assessing and treating arterial insufficiency to prevent limb loss. It also warrants emphasis that not all patients with diabetes or PAD can realistically be screened and surveyed by a multidisciplinary team. As the prevalence of diabetes increases, primary care physicians will increasingly need to triage their patients at highest risk for referral to foot care teams. Foot screening and referrals pathways for diabetic foot care have been implemented in Alberta, Nova Scotia, Prince Edward Island and Saskatchewan.[36-39] Other health systems internationally have implemented national foot screening programs (e.g. Scotland[40]) and defined a national foot care strategy (e.g. Australia[41]). However, over 80% of Canadians living in Ontario, Québec and other provinces and territories

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must rely on informal pathways of care that too often fail patients, particularly those who are marginalized or medically complex.

Certain limitations of our analysis should be made explicit. First, we did not have information on the extent of foot wound(s), infection or severity of foot ischemia prior to amputation. As a result, we cannot quantify how many amputations in high-rate regions could have been prevented if the same patients lived in low-rate regions. Second, the date of onset or recognition of a threatened limb by the patient or any doctor cannot be captured using existing provincial administrative data. As a result, a cohort of patients at risk of limb loss cannot be defined and the extent to which delayed presentation or diagnosis contributes to variation in regional amputation rates remains uncertain. Third, PAD was captured based on diagnosis coding from a previous hospitalization, same day surgery, emergency room visit or on the index amputation hospitalization. However, it is possible some patients with less symptomatic PAD were missed with this algorithm. Fourth, the correlation between the care delivered by podiatrists-chiropodists and regional amputation rates could not be well documented in our analysis. Assessment (foot exam, footwear evaluation) and intervention (e.g. debridement, prescription of offloading footwear) by a podiatrist or chiropodist is not publicly funded in Ontario outside of a few family health teams, wound care clinics and a minority podiatrists-chiropodists who can directly submit claims (maximum $135 per year) to the Ontario Health Insurance Plan. It is likely that the financial barrier to access private podiatry-chiropody services contributes to limited foot care and amputation prevention for many Ontarians with diabetes or PAD. Finally, given the ecological nature of this study, the effectiveness of specific health services in preventing amputation at the patient level in Ontario has not be directly demonstrated.

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In conclusion, diabetes and PAD-related major amputation rates differed considerably based on geographic region in Ontario. Regional rates of vascular surgeon assessment and receipt of revascularization were inversely correlated with regional rates of amputation. These data are important to justify and inform the integrated regional foot care efforts necessary to prevent amputations from diabetes and PAD.

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REFERENCES

1. Imam B, Miller WC, Finlayson HC, Eng JJ, Jarus T. Incidence of lower limb amputation in Canada. 2017;108:e374-e380.
2. Kayssi A, de Mestral C, Forbes TL, Roche-Nagle G. A Canadian population-based description of the indications for lower-extremity amputations and outcomes. Can J Surg. 2016;59:99-106.
3. Botros M, Kuhnke J, Embil J, Goettl K, Morin C, Parsons L, Scharfstein B, Somayaji R, Evans R. Best Practice Recommendations for the Prevention and Management of Diabetic Foot Ulcers. In: Foundations of Best Practice for Skin and Wound Management. A supplement of Wound Care Canada; 2017. 68p. Available from: https://www.woundscanada.ca/docman/public/health-care-professional/bpr-workshop/895-wc-bpr-prevention-and-management-of-diabetic-foot-ulcers-1573r1e-final/file
4. Embil JM, Albalawi Z, Bowering K, Trepman E. Diabetes Canada 2018 clinical practice guidelines for the prevention and management of diabetes in Canada: foot care. Can J Diabetes. 2018;42:S222-7.
5. Conte MS, Bradbury AW, Kolh P, White JV, Dick F, Fitridge R et al. Global vascular guidelines on the management of chronic limb-threatening ischemia. J Vasc Surg. 2019 Jun;69(6S):3S-125S.e40.
6. International Working Group on the Diabetic Foot. 2019 IWGDF Guidelines on the Prevention and Management of Diabetic Foot Disease. Available at: https://iwgdfguidelines.org/. Accessed August 1, 2019
7. MacKenzie EJ, Rivara FP, Jurkovich GJ, Nathens AB, Frey KP, Egleston BL, Salkever DS, Scharfstein DO. A national evaluation of the effect of trauma-center care on mortality. N Engl J Med. 2006 Jan 26;354(4):366-78.
8. Canadian Partnership Against Cancer. Approaches To High-Risk, Resource Intensive Cancer Surgical Care In Canada. Available at http://www.longwoods.com/articles/images/high-risk-resource-intensive-cancer-surgical.pdf. Accessed April 15, 2019.
9. Canadian Blood Services. Organ Donation and Transplantation in Canada. System Progress Report 2006-2015. Available at https://blood.ca/sites/default/files/ODT_Report.pdf. Accessed April 15, 2019.
10. Hussain MA, Al-Omran M, Salata K, Sivaswamy A, Forbes TL, Sattar N, Aljabri B, Kayssi A, Verma S, de Mestral C. Population-Based Secular Trends in Lower Extremity Amputation for Diabetes and Peripheral Artery Disease. CMAJ 2019: 191(35): E955-E961
11. ICES data Dictionary. Available at https://datadictionary.ices.on.ca/ Accessed April 15, 2019.
12. Hux JE, Ivis F, Flintoft V, Bica A. Diabetes in Ontario: determination of prevalence and incidence using a validated administrative data algorithm. Diabetes Care 2002; 25:512─516.
13. Juurlink D, Preyra C, Croxford R, Chong A, Austin P, Tu J et al. Canadian Institute for Health Information Discharge Abstract Database: A Validation Study. Toronto: Institute for Clinical Evaluative Sciences 2006.

Confidential

14. The College of Chiropodists of Ontario. Review of the Chiropody and Podiatry Professions. http://cocoo.on.ca/pdf/cocoo_hprac_submission_28nov2014.pdf. Accessed November 2018.
15. Wilkins R. Use of postal codes and addresses in the analysis of health data. Health Rep 1993; 5:157-177.
16. Kralj B. Measuring Rurality – RIO2008_BASIC: Methodology and Results, https://content.oma.org//wp-content/uploads/2008rio-fulltechnicalpaper.pdf. Accessed March 1, 2019.
17. Austin PC, Van Walraven C. The mortality risk score and the ADG score: two points-based scoring systems for the Johns Hopkins aggregated diagnosis groups to predict mortality in a general adult population cohort in Ontario, Canada. Med Care 2011;49:940e7.
18. Booth GL, Polsky JY, Gozdyra P, Cauch-Dudek K, Kiran T, Shah BR, Lipscombe LL, Glazier RH. Regional Measures of Diabetes Burden in Ontario. Toronto: Institute for Clinical Evaluative Sciences; 2012.
19. Cardiac Care Network of Ontario. A Vascular Services Quality Strategy for Ontario: Observations and Recommendations. Cardiac Care Network of Ontario 2012.
20. Hussain MA, Al-Omran M, Salata K, Sivaswamy A, Verma S, Forbes TL, Kayssi A, de Mestral C.A call for integrated foot care and amputation prevention pathways for patients with diabetes and peripheral arterial disease across Canada. Can J Public Health. 2019;110(2):253-255.
21. Wodchis WP, Bushmeneva K, Nikitovic M, McKillop I. Guidelines on Person-Level Costing Using Administrative Databases in Ontario. Working Paper Series. Vol 1. Toronto: Health System Performance Research Network; 2013.
22. Martens PJ, Martin BO, Neil J, et al. Diabetes and adverse outcomes in a First Nations population: association with healthcare access and socioeconomic and geographic factors. Can J Diabetes 2007;31:2
23. Skrepnek GH, Mills JL Sr, Armstrong DG. A Diabetic Emergency One Million Feet Long: Disparities and Burdens of Illness among Diabetic Foot Ulcer Cases within Emergency Departments in the United States, 2006-2010. PLoS One. 2015 Aug 6;10(8):e0134914.
24. Australian Institute of Health and Welfare 2017. Burden of lower limb amputations due to diabetes in Australia: Australian Burden of Disease Study 2011. Australian Burden of Disease Study series no. 10. BOD 11. Canberra: AIHW.
25. Loewen K, Vigliarolo J, Lance B. Rates of diabetes-related lower-limb amputation in northwestern Ontario: An incidence study and introduction of a standardized diabetic foot ulcer management protocol. Canadian Journal of Rural Medicine 2017;22(3):100-107.
26. Shah BR, Frymire E, Jacklin K, Jones CR, Khan S, Slater M, et al. Peripheral arterial disease in Ontario First Nations people with diabetes: a longitudinal population-based cohort study. CMAJ Open. 2019;7(4):E700-E705.
27. Tu JV, Chu A, Maclagan L, Austin PC, Johnston S, Ko DT, et al. Regional variations in ambulatory care and incidence of cardiovascular events. CMAJ 2017;189:E494-E501.
28. Rose G, Duerksen F, Trepman E, Cheang M, Simonsen JN, Koulack J, Fong H, Nicolle LE, Embil JM. Multidisciplinary treatment of diabetic foot ulcers in Canadian Aboriginal and non-Aboriginal people. Foot Ankle Surg. 2008;14(2):74-81.

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29. Chiu CC1, Huang CL, Weng SF, Sun LM, Chang YL, Tsai FC. A multidisciplinary diabetic foot ulcer treatment programme significantly improved the outcome in patients with infected diabetic foot ulcers. J Plast Reconstr Aesthet Surg. 2011;64(7):867-72.
30. Morbach S, Kersken J, Lobmann R, Nobels F, Doggen K, Van Acker K. The German and Belgian accreditation models for diabetic foot services. Diabetes Metab Res Rev 2016; 32: Suppl 1: 318-25.
31. Joret MO, Osman K, Dean A, Cao C, van der Werf B, Bhamidipaty V. Multidisciplinary clinics reduce treatment costs and improve patient outcomes in diabetic foot disease. J Vasc Surg 2019;70(3):806-814.
32. Rogers LC, Andros G, Caporusso J, Harkless LB, Mills JL Sr, Armstrong DG. Toe and flow: essential components and structure of the amputation prevention team. J Am Podiatr Med Assoc. 2010;100(5):342-8.
33. Ogrin R, Houghton PE, Thompson GW. Effective management of patients with diabetes foot ulcers: outcomes of an Interprofessional Diabetes Foot Ulcer Team. Int Wound J. 2015;12(4):377-86.
34. Roth-Albin I, Mai SHC, Ahmed Z, Cheng J, Choong K, Mayer PV. Outcomes Following Advanced Wound Care for Diabetic Foot Ulcers: A Canadian Study. Can J Diabetes. 2017;41(1):26-32.
35. Somayaji R, Elliott JA, Persaud R, Lim M, Goodman L, Sibbald RG. The impact of team based interprofessional comprehensive assessments on the diagnosis and management of diabetic foot ulcers: A retrospective cohort study. PLoS One. 2017;12(9):e0185251.
36. Alberta Heath Services. Diabetes Foot Care Clinical Pathway July 2017. Available at: https://www.albertahealthservices.ca/scns/Page10321.aspx. Accessed August 1, 2019
37. Saskatchewan Health Authority. Lower Extremity Wound Pathway. Available at http://www.sasksurgery.ca/provider/lowerextremitywound.html. Accessed August 1, 2019
38. Diabetes Care Program of Nova Scotia. Foot Resources. Available at https://diabetescare.nshealth.ca/guidelines-resources/professionals-and-patients/professionals/foot-resources. Accessed August 1, 2019
39. Mutch K, Dewar D. Implementing a Provincial Diabetic Foot Screening Program. J Wound Ostomy Continence Nurs 2015;42(5):439-42.
40. Stang D, Leese GP. The Scottish Diabetes Foot Action Group 2016 update of the Diabetic Foot Risk Stratification and Triage System. The Diabetic Foot Journal 2016. 19: 182–6
41. Van Netten JJ, Lazzarini PA, Fitridge R, Kinnear E, Griffiths I, Malone M, Perrin BM, Prentice J, Sethi S, Wraight PR. Australian diabetes-related foot disease strategy 2018-2022: The first step towards ending avoidable amputations within a generation. Brisbane: Diabetic Foot Australia, Wound Management CRC; 2017.

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FIGURES and TABLES

Figure 1 – Age- and sex- standardized rates of major amputations related to diabetes or peripheral artery disease among resident ≥40 years old across Ontario, 2007-2017.

Table 1 – Correlation of Regional Health Provider Counts and Health Care Utilization Among Amputees with Regional Major Amputation Rates

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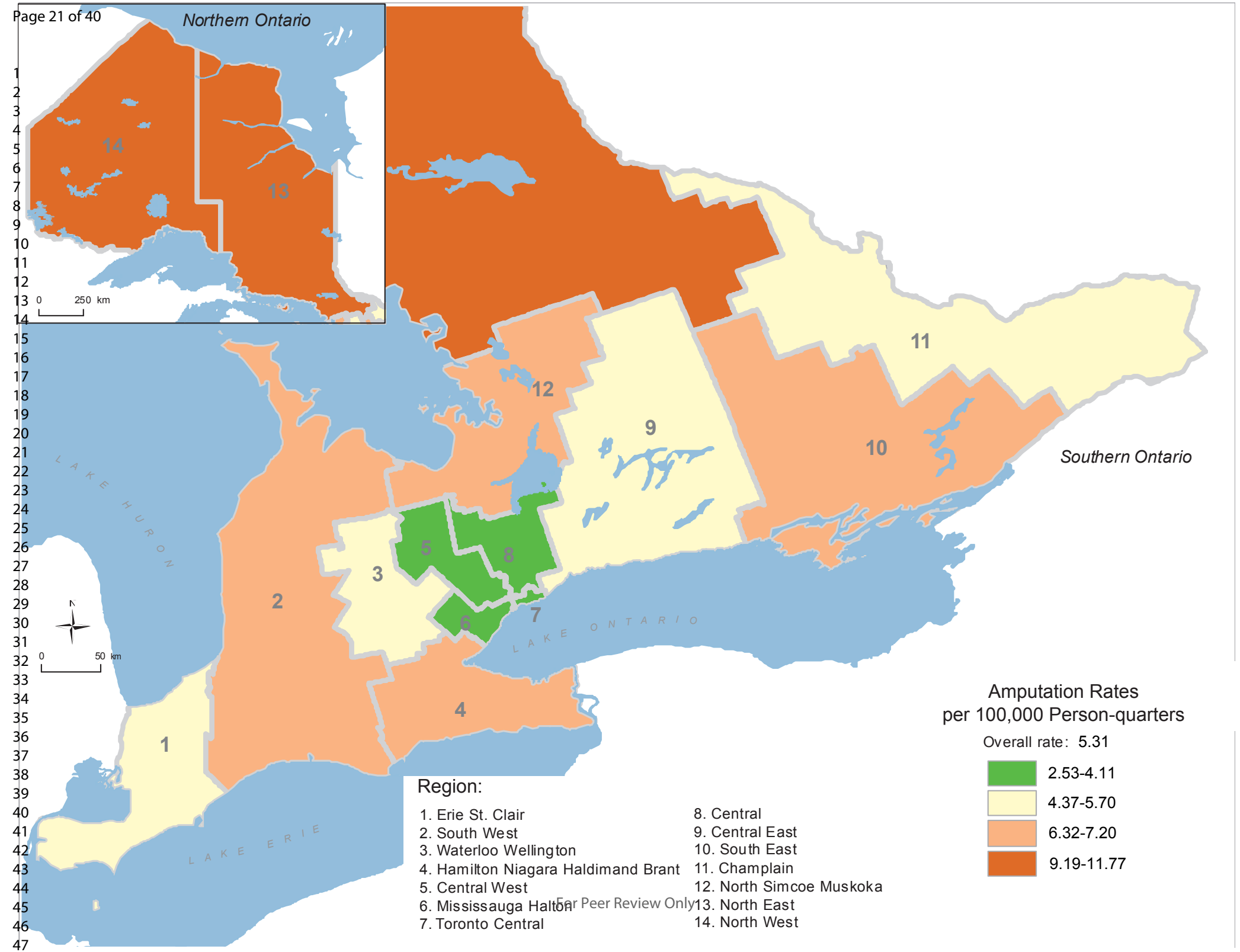

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Table 1. Correlation of Regional Health Provider Counts and Health Care Utilization Among Amputees with Regional Major Amputation Rates

	Range of Values Across 14 Regions	**Magnitude of Correlation** - R-squared	**Direction of Correlation** (Pearson Correlation Coefficient)
Health Providers Per Capita within Each Region [1]			
Count of Vascular Surgeons	0 – 1.9	0.19	Negative (-0.44)
Count of Chiropodists-Podiatrists	3.7 – 36.6	0.14	Negative (-0.38)
Count of Orthopedic Surgeons	5.5 – 15.0	0.03	Positive (0.17)
Count of Vascular, General and Orthopedic Surgeons	14.1 – 33.4	0.07	Positive (0.38)
Count of General Surgeons	8.3 – 16.5	0.19	Positive (0.42)
Health Provider Visit Among Amputees – At least 1 Visit Within 1 Year Prior to Index Amputation Hospitalization [2]			
Vascular Surgeon Visit	5.5% – 58.8%	0.43	Negative (-0.66)
Publicly-Funded Podiatry Visit [3]	0.0% – 8.4%	0.11	Negative (-0.34)
Vascular, General or Orthopedic Surgeon Visit	57.4% – 81.9%	0.09	Negative (-0.29)
General Practitioner Physician Visit	90.4% – 97.1%	0.002	Positive (0.05)
Orthopedic Surgeon Visit	16.4% – 33.2%	0.06	Positive (0.25)
Specialist Physician Visit	91.0% – 95.4%	0.18	Positive (0.43)
General Surgeon Visit	10.1% – 43.1%	0.29	Positive (0.54)
Health Services and Interventions Among Amputees - Within 1 Year Prior to Index Amputation Hospitalization			
Endovascular or Open Vascular Intervention	5.7% – 27.5%	0.71	Negative (-0.84)
Endovascular Intervention	2.7% – 18.5%	0.67	Negative (-0.82)
Open Vascular Intervention	4.4% – 19.5%	0.26	Negative (-0.51)
Outpatient Nursing Care	48.7% – 79.6%	0.22	Negative (-0.47)
Total Health Care Costs	$45,103 – $69,483	0.15	Negative (-0.39)
Hospitalization (at least one)	58.2% – 70.8%	0.01	Negative (-0.10)
Minor Amputation	8.2% – 20.4%	0.11	Positive (0.34)
Emergency Department visit (at least one)	83.6% – 91.2%	0.25	Positive (0.50)
Intervention - Index Amputation Hospitalization			
Endovascular or Open Vascular Intervention	4.2% – 21.0%	0.65	Negative (-0.81)
Open Vascular Intervention	1.8% – 13.7%	0.55	Negative (-0.74)
Endovascular Intervention	3.0% – 13.4%	0.43	Negative (-0.65)

[1] Counts of providers per 100,000 residents ≥40 years of age

[2] Excluding 30 days prior to amputation

[3] The majority of podiatry and chiropody services are not publicly funded in Ontario.

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Appendix 1

Supplemental Table I - Diagnosis Codes Used to Identify Peripheral Artery Disease.

Peripheral Artery Disease – ICD-10-CA Codes
• I70.0 - Atherosclerosis of aorta
• I70.2 - Atherosclerosis of arteries of extremities
• I70.20 - Atherosclerosis of arteries of extremities without gangrene
• I70.21 - Atherosclerosis of arteries of extremities with gangrene
• I70.8 - Atherosclerosis of other arteries
• I70.9 - Generalized and unspecified atherosclerosis
• I73.9 - Peripheral vascular disease, unspecified (includes intermittent claudication)
• I74.0 - Embolism and thrombosis of abdominal aorta
• I74.3 - Embolism and thrombosis of arteries of lower extremities
• I74.4 - Embolism and thrombosis of arteries of extremities, unspecified (Peripheral arterial embolism)
• I74.5 - Embolism and thrombosis of iliac artery
• I74.8 - Embolism and thrombosis of other arteries
• I74.9 - Embolism and thrombosis of unspecified artery
• I79.2 Peripheral angiopathy in diseases classified elsewhere
• E10.50x - Type 1 diabetes mellitus with peripheral angiopathy
• E10.51x - Type 1 diabetes mellitus with peripheral angiopathy with gangrene
• E10.70x - Type 1 diabetes mellitus with peripheral angiopathy foot ulcer (angiopathic) (neuropathic)
• E10.71x - Type 1 diabetes mellitus with foot ulcer (angiopathic) (neuropathic) with gangrene
• E11.50x - Type 2 diabetes mellitus with peripheral angiopathy
• E11.51x - Type 2 diabetes mellitus with peripheral angiopathy with gangrene
• E11.70x - Type 2 diabetes mellitus with foot ulcer (angiopathic)(neuropathic)
• E11.71x - Type 2 diabetes mellitus with foot ulcer (angiopathic) (neuropathic) with gangrene
• E13.50x – Other specified diabetes mellitus with peripheral angiopathy
• E13.51x - Other specified diabetes mellitus with peripheral angiopathy with gangrene
• E13.70x - Other specified diabetes mellitus with foot ulcer (angiopathic) (neuropathic)
• E13.71x - Other specified diabetes mellitus with foot ulcer (angiopathic) (neuropathic) with gangrene
• E14.50x - Unspecified diabetes mellitus with peripheral angiopathy
• E14.51x - Unspecified diabetes mellitus with peripheral angiopathy with gangrene
• E14.70x - Unspecified diabetes mellitus with foot ulcer (angiopathic) (neuropathic)
• E14.71x - Unspecified diabetes mellitus with foot ulcer (angiopathic) (neuropathic) with gangrene

[a] ICD-10-CA, *International Statistical Classification of Diseases, Tenth Revision, Canadian Version.*

Supplemental Table II - Most Responsible Diagnosis Codes Used to Exclude Patients with Amputation Related to Trauma/injury, Limb Malignancy or Other Limb Complications.

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Malignancy – ICD-10-CA Codes [a]

- C40.2 Malignant neoplasm of long bones of lower limb
- C40.3 Malignant neoplasm short bones of lower limb
- C41.8 Overlapping malignant lesion of bone and articular cartilage
- C41.9 Malignant neoplasm bone and articular cartilage, unspecified
- C43.7 Malignant melanoma of lower limb, including hip
- C47.2 Malignant neoplasm of peripheral nerves of lower limb, including hip
- C49.2 Malignant neoplasm of connective and soft tissue of lower limb, including hip
- C76.5 Malignant neoplasm of lower limb
- C79.5 Secondary malignant neoplasm of bone and bone marrow
- C90.0 Multiple myeloma
- C90.20 Plasmacytoma of bone
- D16.2 Benign neoplasm of long bones of lower limb
- D16.3 Benign neoplasm of short bones of lower limb
- D21.2 Other benign neoplasm of connective and other soft tissue of lower limb, including hip
- C44.7 Malignant neoplasm skin of lower limb, including hip
- C46.^ Kaposi's sarcoma
- C47.^ Malignant neoplasm of peripheral nerves and autonomic nervous system
- D36.1^ Benign neoplasm of peripheral nerves and autonomic nervous system

Trauma/Injury – ICD-10-CA Codes [a]

- S70-79, S80-89, S90-99: lower extremity trauma
- T01.3^ Open wounds of multiple regions of lower limb(s)
- T02.3^ Fractures involving multiple regions of one lower limb
- T02.5^ Fractures involving multiple regions of both lower limbs
- T04.3-T04.9 Crush injury including lower limbs
- T05.3-T05.9 Traumatic amputation including foot or lower limb
- T12.0 Fracture of lower limb, level unspecified, closed
- T12.00 Fracture of lower limb, level unspecified, closed
- T13.0 Superficial injury of lower limb, level unspecified
- T13.1 Open wound of lower limb, level unspecified
- T13.2 Dislocation, sprain and strain of unspecified joint and ligament of lower limb, level unspecified
- T13.3 Injury of unspecified nerve of lower limb, level unspecified
- T13.4 Injury of unspecified blood vessel of lower limb, level unspecified
- T13.5 Injury of unspecified muscle and tendon of lower limb, level unspecified
- T13.6 Traumatic amputation of lower limb, level unspecified
- T13.8 Other specified injuries of lower limb, level unspecified
- T13.9 Unspecified injury of lower limb, level unspecified
- T24.0 Burn of unspecified degree of hip and lower limb, except ankle and foot
- T24.1 Burn of first degree of hip and lower limb, except ankle and foot
- T24.2 Burn of second degree of hip and lower limb, except ankle and foot
- T24.3 Burn of third degree of hip and lower limb, except ankle and foot
- T24.4 Corrosion of unspecified degree of hip and lower limb, except ankle and foot
- T24.5 Corrosion of first degree of hip and lower limb, except ankle and foot
- T24.6 Corrosion of second degree of hip and lower limb, except ankle and foot
- T24.7 Corrosion of third degree of hip and lower limb, except ankle and foot
- T25.0 Burn of unspecified degree of ankle and foot
- T25.1 Burn of first degree of ankle and foot
- T25.2 Burn of second degree of ankle and foot
- T25.3 Burn of third degree of ankle and foot
- T25.4 Corrosion of unspecified degree of ankle and foot
- T25.6 Corrosion of second degree of ankle and foot
- T25.7 Corrosion of third degree of ankle and foot

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- T33. ^ Frostbite
- T34. ^ Frostbite with necrosis
- T35. ^ Frostbite unpsecified
- T79.6 Traumatic ischaemia of muscle
- M12.55 Traumatic arthropathy, pelvic region and thigh
- M12.56 Traumatic arthropathy, lower leg
- M12.57 Traumatic arthropathy, ankle and foot
- M12.58 Traumatic arthropathy, other site
- M12.59 Traumatic arthropathy, unspecified site

Other – ICD-10-CA Codes [a]

- T84.54 Infection and inflammatory reaction due to knee prosthesis
- T84.^ Complications of internal orthopaedic prosthetic devices, implants and grafts
- T84.^ Complications of internal orthopaedic prosthetic devices, implants and grafts (hip prosthesis, knee prosthesis, internal fixation device of bones of limb, Infection and inflammatory reaction due to internal joint prosthesis, Infection and inflammatory reaction due to internal fixation device [any site]
- L08.0 Pyoderma
- L51.2 Toxic epidermal necrolysis
- L88.^ Pyoderma gangrenosum
- L89.^ decubitus ulcer'
- L97.^ Lower limb ulcer not otherwise classified
- M00.^ Pyogenic arthritis
- M01.^ Direct infections of joint in infectious and parasitic diseases classified elsewhere
- M84.^ Disorders of continuity of bone (malunion, nonunion, delayed union) of fracture
- M89.0^ - Complex regional pain syndrome
- M96.6^ Fracture of bone following insertion of orthopaedic implant, joint prosthesis, or bone plate
- Q27.31 Peripheral arteriovenous malformation of lower limb
- Q27.38 Peripheral arteriovenous malformation of other site
- Q27.8 Other specified congenital malformations of peripheral vascular system
- Q27.9 Congenital malformation of peripheral vascular system, unspecified - Anomaly of artery or vein not otherwise specified
- Q65.^ Congenital deformities of hip
- Q66.^ Congenital deformities of feet
- Q68.2 Congenital deformity of knee
- Q68.3 Congenital bowing of femur
- Q68.4 Congenital bowing of tibia and fibula
- Q68.5 Congenital bowing of long bones of leg, unspecified
- I80.^ Phlebitis and thrombophlebitis
- I83.^ Venous ulcer
- I87.0^ Postthrombotic syndrome
- I87.1 Compression of vein
- I87.2 Venous insufficiency (chronic)(peripheral)
- I89.0 Lymphoedema, not elsewhere classified

[a] ICD-10-CA, *International Statistical Classification of Diseases, Tenth Revision, Canadian Version*

Supplemental Table III – Canadian Classification of Health Interventions (CCI) Codes for Lower Extremity Revascularization and Amputation

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Lower Extremity Revascularization and Amputation Codes

- **Open Surgery:** 1KA57LA, 1KA76MZ, 1KE57LA, 1KE76MZ, 1KG57LA, 1KG76MI, 1KT57LA, 1KT76MZ, 1JM76MI
- **Endovascular – angioplasty or stenting:** 1KA50GQ, 1KA57GQ, 1KE35, 1KE50, 1KE57GQ, 1KG35, 1KG50, 1KG57GQ, 1KT50, 1KT57GQ
- **Major amputation:** 1VC93, 1VG93, 1VQ93
- **Minor amputation:** 1WA93, 1WE93, 1WI93, 1WJ93, 1WK93, 1WL93, 1WM93, 1WN93

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Appendix 2

Supplemental Table 1. Rates of Major Amputation related to Diabetes or Peripheral Artery Disease

Region [a]	Major Amputations related to Diabetes or Peripheral Artery Disease per 100,000 person-quarters [a] (95% Confidence Interval)[b]
6- MISSISSAUGA HALTON	**2.53** (2.30-2.75)
8- CENTRAL	**3.23** (3.02-3.44)
5- CENTRAL WEST	**4.01** (3.67-4.35)
7- TORONTO CENTRAL	**4.11** (3.81-4.42)
11- CHAMPLAIN	**4.37** (4.08-4.66)
9- CENTRAL EAST	**5.37** (5.07-5.67)
1- ERIE ST. CLAIR	**5.40** (4.93-5.88)
3- WATERLOO WELLINGTON	**5.70** (5.24-6.16)
12- NORTH SIMCOE MUSKOKA	**6.32** (5.72-6.92)
2- SOUTH WEST	**6.58** (6.14-7.02)
10- SOUTH EAST	**6.93** (6.33-7.53)
4- HAMILTON NIAGARA	**7.20** (6.83-7.57)
13- NORTH-EAST	**9.19** (8.55-9.83)
14- NORTH-WEST	**11.77** (10.62-12.92)

[a] Rate reflects average over 2007-2017 study period and among residents ≥ 40 years old

[b] Ninety-five percent confidence intervals around the amputation rates were calculated assuming a negative binomial distribution accounting for recurrent events (i.e. repeat amputations in distinct quarters) over the study period (Glynn RJ, et al. Am J Epidemiol. 1993 Apr 1;137(7):776-86).

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Appendix 2

Supplemental Table 2. Major Amputee Cohort Characteristics by Region

Region [a]	No. of major amputees	Lowest income quintile - N (%)	Rural residence - N (%)	Comorbidity index [b] - Median (interquartile range)	Death on index amputation admission - N (%)
6- MISSISSAUGA HALTON	448	77 (17.2%)	<=5 (<=1.1%)	13 (6-24)	53 (11.8%)
8- CENTRAL	884	219 (24.8%)	11 (1.2%)	12 (6-21)	118 (13.3%)
5- CENTRAL WEST	471	97 (20.6%)	19 (4.0%)	13 (5-21)	63 (13.4%)
7- TORONTO CENTRAL	785	269 (34.9%)	0 (0.0%)	14 (6-23)	82 (10.4%)
11- CHAMPLAIN	925	232 (25.3%)	183 (19.8%)	13 (5-21)	116 (12.5%)
9- CENTRAL EAST	1,424	438 (30.8%)	120 (8.4%)	13 (4-21)	166 (11.7%)
1- ERIE ST. CLAIR	597	172 (29.3%)	77 (12.9%)	11 (4-18)	65 (10.9%)
3- WATERLOO WELLINGTON	642	165 (25.7%)	75 (11.7%)	12 (4-20)	63 (9.8%)
12- NORTH SIMCOE MUSKOKA	510	118 (23.4%)	198 (38.9%)	12 (3-22)	48 (9.4%)
2- SOUTH WEST	1,075	295 (28.0%)	374 (34.8%)	13 (4-22)	107 (10.0%)
10- SOUTH EAST	641	205 (32.2%)	277 (43.2%)	12 (4-21)	60 (9.4%)
4- HAMILTON NIAGARA	1,794	567 (32.0%)	103 (5.7%)	12 (5-20)	200 (11.1%)
13- NORTH-EAST	988	323 (33.9%)	390 (39.5%)	11 (3-19)	120 (12.1%)
14- NORTH-WEST	474	160 (34.3%)	192 (40.5%)	11 (3-18)	55 (11.6%)

[a] Regions are ordered from lowest to highest major amputation rate

[b] Aggregated Diagnosis Group Comorbidity Index

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Appendix 2

Supplemental Table 3. Regional provider counts, per 100,000 residents at least 40 years old, in 2013

Region [a]	Vascular Surgeons	Orthopedic Surgeons	General Surgeons	Vascular, Orthopedic or General Surgeons	Podiatrists-Chiropodists
6- MISSISSAUGA HALTON	0.70	5.61	9.63	15.94	20.49
8- CENTRAL	0.56	8.31	11.90	20.77	14.82
5- CENTRAL WEST	0.00	5.78	8.29	14.07	18.59
7- TORONTO CENTRAL	1.86	15.02	16.54	33.42	36.63
11- CHAMPLAIN	1.23	10.89	14.27	26.39	3.68
9- CENTRAL EAST	0.50	7.77	9.39	17.66	14.40
1- ERIE ST. CLAIR	0.30	6.53	12.17	18.99	12.76
3- WATERLOO WELLINGTON	0.83	6.64	9.96	17.44	12.73
12- NORTH SIMCOE MUSKOKA	0.40	5.53	11.46	17.38	14.22
2- SOUTH WEST	0.80	12.44	14.25	27.49	9.63
10- SOUTH EAST	0.72	12.56	9.69	22.97	25.12
4- HAMILTON NIAGARA	0.93	9.21	13.75	23.89	14.15
13- NORTH-EAST	0.00	8.50	14.80	23.30	11.02
14- NORTH-WEST	0.00	9.73	15.40	25.13	7.30

[a] Regions are ordered from lowest to highest major amputation rate

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Appendix 2

Supplemental Table 4. Physician and Publicly-Funded Podiatry Visits within 30-365 days prior to Index Amputation Admission

Region [a]	No. of Amputees	GP [b]	Vascular Surgeon	Orthopedic Surgeon	General Surgeon	Vascular, Orthopedic or General Surgeon	Other Specialist Physician	Publicly-Funded Podiatry [c]
		At least 1 Visit - N (%)						
6- MISSISSAUGA HALTON	448	418 (93.3%)	258 (57.6%)	103 (23.0%)	79 (17.6%)	328 (73.2%)	419 (93.5%)	6 (1.3%)
8- CENTRAL	884	843 (95.4%)	451 (51.0%)	222 (25.1%)	231 (26.1%)	630 (71.3%)	833 (94.2%)	74 (8.4%)
5- CENTRAL WEST	471	440 (93.4%)	204 (43.3%)	102 (21.7%)	187 (39.7%)	325 (69.0%)	437 (92.8%)	15 (3.2%)
7- TORONTO CENTRAL	785	710 (90.4%)	445 (56.7%)	182 (23.2%)	79 (10.1%)	539 (68.7%)	726 (92.5%)	52 (6.6%)
11- CHAMPLAIN	925	868 (93.8%)	456 (49.3%)	178 (19.2%)	209 (22.6%)	621 (67.1%)	853 (92.2%)	7 (0.8%)
9- CENTRAL EAST	1,424	1,365 (95.9%)	775 (54.4%)	280 (19.7%)	221 (15.5%)	965 (67.8%)	1,320 (92.7%)	49 (3.4%)
1- ERIE ST. CLAIR	597	557 (93.3%)	267 (44.7%)	133 (22.3%)	163 (27.3%)	416 (69.7%)	556 (93.1%)	9 (1.5%)
3- WATERLOO WELLINGTON	642	623 (97.0%)	325 (50.6%)	161 (25.1%)	158 (24.6%)	448 (69.8%)	610 (95.0%)	44 (6.9%)
12- NORTH SIMCOE MUSKOKA	510	495 (97.1%)	148 (29.0%)	145 (28.4%)	170 (33.3%)	330 (64.7%)	484 (94.9%)	8 (1.6%)
2- SOUTH WEST	1,075	1,022 (95.1%)	426 (39.6%)	197 (18.3%)	335 (31.2%)	722 (67.2%)	1,003 (93.3%)	17 (1.6%)
10- SOUTH EAST	641	591 (92.2%)	267 (41.7%)	164 (25.6%)	100 (15.6%)	402 (62.7%)	583 (91.0%)	10 (1.6%)
4- HAMILTON NIAGARA	1,794	1,703 (94.9%)	792 (44.1%)	595 (33.2%)	511 (28.5%)	1,255 (70.0%)	1,687 (94.0%)	61 (3.4%)
13- NORTH-EAST	988	949 (96.1%)	581 (58.8%)	162 (16.4%)	426 (43.1%)	809 (81.9%)	935 (94.6%)	21 (2.1%)
14- NORTH-WEST	474	437 (92.2%)	26 (5.5%)	141 (29.7%)	180 (38.0%)	272 (57.4%)	452 (95.4%)	0 (0.0%)

[a] Regions are ordered from lowest to highest major amputation rate
[b] General Practitioner
[c] The majority of podiatry and chiropody services are not publicly funded in Ontario

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Appendix 2

Supplemental Table 5. Health Services within 365 Days Prior to Index Amputation Admission

Region [a]	No. of Amputees	At least one Hospitalization - N (%)	At least one ED [b] visit - N (%)	Home care nursing - N (%)	Revascularization - N (%)			Minor [c] Amputation - N (%)	Total Health Care Costs [d] - Mean
					Open surgery	Endovascular	Open or endovascular		
6- MISSISSAUGA HALTON	448	317 (70.8%)	378 (84.4%)	310 (69.2%)	82 (18.3%)	73 (16.3%)	123 (27.5%)	44 (9.8%)	$66,711
8- CENTRAL	884	619 (70.0%)	763 (86.3%)	631 (71.4%)	134 (15.2%)	119 (13.5%)	213 (24.1%)	91 (10.3%)	$64,186
5- CENTRAL WEST	471	321 (68.2%)	398 (84.5%)	303 (64.3%)	58 (12.3%)	87 (18.5%)	113 (24.0%)	49 (10.4%)	$64,183
7- TORONTO CENTRAL	785	521 (66.4%)	685 (87.3%)	532 (67.8%)	80 (10.2%)	118 (15.0%)	169 (21.5%)	64 (8.2%)	$69,483
11- CHAMPLAIN	925	574 (62.1%)	793 (85.7%)	579 (62.6%)	102 (11.0%)	157 (17.0%)	209 (22.6%)	112 (12.1%)	$69,310
9- CENTRAL EAST	1,424	866 (60.8%)	1,243 (87.3%)	980 (68.8%)	150 (10.5%)	116 (8.1%)	229 (16.1%)	167 (11.7%)	$54,251
1- ERIE ST. CLAIR	597	398 (66.7%)	514 (86.1%)	475 (79.6%)	89 (14.9%)	46 (7.7%)	116 (19.4%)	122 (20.4%)	$68,481
3- WATERLOO WELLINGTON	642	425 (66.2%)	537 (83.6%)	471 (73.4%)	88 (13.7%)	106 (16.5%)	157 (24.5%)	80 (12.5%)	$53,128
12- NORTH SIMCOE MUSKOKA	510	340 (66.7%)	465 (91.2%)	392 (76.9%)	90 (17.6%)	41 (8.0%)	113 (22.2%)	61 (12.0%)	$51,334
2- SOUTH WEST	1,075	724 (67.3%)	919 (85.5%)	800 (74.4%)	137 (12.7%)	80 (7.4%)	179 (16.7%)	194 (18.0%)	$56,587
10- SOUTH EAST	641	373 (58.2%)	539 (84.1%)	427 (66.6%)	53 (8.3%)	46 (7.2%)	90 (14.0%)	98 (15.3%)	$45,103
4- HAMILTON NIAGARA	1,794	1,196 (66.7%)	1,550 (86.4%)	1,326 (73.9%)	349 (19.5%)	179 (10.0%)	437 (24.4%)	165 (9.2%)	$56,510
13- NORTH-EAST	988	683 (69.1%)	856 (86.6%)	645 (65.3%)	110 (11.1%)	33 (3.3%)	127 (12.9%)	201 (20.3%)	$57,686
14- NORTH-WEST	474	319 (67.3%)	430 (90.7%)	231 (48.7%)	21 (4.4%)	13 (2.7%)	27 (5.7%)	52 (11.0%)	$62,213

[a] Regions are ordered from lowest to highest major amputation rate
[b] ED – Emergency Department
[c] Minor amputation – below ankle
[d] Costs in 2017 Canadian dollars from the perspective of Ontario Ministry of Health & Long Term Care

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Appendix 2

Supplemental Table 6. Revascularization on Index Hospitalization

Region [a]	No. of amputees	Revascularization – N (%)		
		Open surgery	Endovascular	Open or endovascular
6- MISSISSAUGA HALTON	448	55 (12.3%)	60 (13.4%)	94 (21.0%)
8- CENTRAL	884	61 (6.9%)	80 (9.0%)	129 (14.6%)
5- CENTRAL WEST	471	56 (11.9%)	43 (9.1%)	88 (18.7%)
7- TORONTO CENTRAL	785	57 (7.3%)	46 (5.9%)	88 (11.2%)
11- CHAMPLAIN	925	127 (13.7%)	87 (9.4%)	189 (20.4%)
9- CENTRAL EAST	1,424	78 (5.5%)	92 (6.5%)	150 (10.5%)
1- ERIE ST. CLAIR	597	26 (4.4%)	54 (9.0%)	72 (12.1%)
3- WATERLOO WELLINGTON	642	38 (5.9%)	54 (8.4%)	78 (12.1%)
12- NORTH SIMCOE MUSKOKA	510	32 (6.3%)	38 (7.5%)	62 (12.2%)
2- SOUTH WEST	1,075	33 (3.1%)	77 (7.2%)	96 (8.9%)
10- SOUTH EAST	641	39 (6.1%)	37 (5.8%)	68 (10.6%)
4- HAMILTON NIAGARA	1,794	84 (4.7%)	211 (11.8%)	254 (14.2%)
13- NORTH-EAST	988	18 (1.8%)	62 (6.3%)	77 (7.8%)
14- NORTH-WEST	474	12 (2.5%)	14 (3.0%)	20 (4.2%)

[a] Regions are ordered from lowest to highest major amputation rate

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Appendix 3

Supplemental Table 1. Rates of Major Amputation related to Diabetes

Region [a]	Major Amputations related to Diabetes per 100,000 person-quarters [a] (95% Confidence Interval)[b]
6- MISSISSAUGA HALTON	**1.95** (1.75-2.15)
8- CENTRAL	**2.65** (2.46-2.84)
5- CENTRAL WEST	**3.34** (3.02-3.66)
11- CHAMPLAIN	**3.38** (3.12-3.64)
7- TORONTO CENTRAL	**3.43** (3.16-3.71)
9- CENTRAL EAST	**4.34** (4.08-4.61)
3- WATERLOO WELLINGTON	**4.35** (3.95-4.76)
1- ERIE ST. CLAIR	**4.36** (3.94-4.78)
12- NORTH SIMCOE MUSKOKA	**5.00** (4.47-5.53)
2- SOUTH WEST	**5.20** (4.81-5.59)
10- SOUTH EAST	**5.33** (4.80-5.86)
4- HAMILTON NIAGARA	**5.72** (5.39-6.04)
13- NORTH-EAST	**7.21** (6.64-7.79)
14- NORTH-WEST	**10.45** (9.37-11.52)

[a] Rate reflects average over 2007-2017 study period and among residents ≥ 40 years old

[b] Ninety-five percent confidence intervals around the amputation rates were calculated assuming a negative binomial distribution accounting for recurrent events (i.e. repeat amputations in distinct quarters) over the study period (Glynn RJ, et al. Am J Epidemiol. 1993 Apr 1;137(7):776-86).

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Appendix 3- Secondary Analysis Limited to Amputations Related to Diabetes

Supplemental Table 2. Major Diabetic Amputee Cohort Characteristics by Region

Region [a]	No. of major amputees	Lowest income quintile - N (%)	Rural residence - N (%)	Comorbidity index[b] - Median (interquartile range)	Death on index amputation admission - N (%)
6- MISSISSAUGA HALTON	350	58 (16.6%)	≤5 (≤1.1%)	13 (7-24)	41 (11.7%)
8- CENTRAL	722	190 (26.4%)	10 (1.4%)	13 (6-21)	96 (13.3%)
5- CENTRAL WEST	389	85 (21.9%)	10 (2.6%)	13 (5-22)	48 (12.3%)
7- TORONTO CENTRAL	709	176 (25.1%)	137 (19.3%)	14 (7-21)	80 (11.3%)
11- CHAMPLAIN	649	230 (35.9%)	0 (0.0%)	15 (7-23)	72 (11.1%)
9- CENTRAL EAST	1,146	370 (32.3%)	95 (8.3%)	13 (5-21)	129 (11.3%)
1- ERIE ST. CLAIR	482	129 (26.8%)	51 (10.6%)	13 (6-21)	37 (7.7%)
3- WATERLOO WELLINGTON	483	140 (29.4%)	63 (13.0%)	11 (4-18)	46 (9.5%)
12- NORTH SIMCOE MUSKOKA	398	94 (23.7%)	150 (37.8%)	13 (4-23)	39 (9.8%)
2- SOUTH WEST	834	234 (28.8%)	293 (35.1%)	12 (4-22)	78 (9.4%)
10- SOUTH EAST	487	160 (33.1%)	209 (42.9%)	12 (4-21)	45 (9.2%)
4- HAMILTON NIAGARA	1,399	450 (32.6%)	84 (6.0%)	12 (5-20)	159 (11.4%)
13- NORTH-EAST	769	248 (33.7%)	318 (41.4%)	11 (3-20)	86 (11.2%)
14- NORTH-WEST	415	142 (34.8%)	178 (42.9%)	11 (4-19)	49 (11.8%)

[a] Regions are ordered from lowest to highest major amputation rate

[b] Aggregated Diagnosis Group Comorbidity Index

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Appendix 3- Secondary Analysis Limited to Amputations Related to Diabetes

Supplemental Table 3. Regional provider counts, per 100,000 residents at least 40 years old, in 2013

Region [a]	Vascular Surgeons	Orthopedic Surgeons	General Surgeons	Vascular, Orthopedic or General Surgeons	Podiatrists-Chiropodists
6- MISSISSAUGA HALTON	0.70	5.61	9.63	15.94	20.49
8- CENTRAL	0.56	8.31	11.90	20.77	14.82
5- CENTRAL WEST	0.00	5.78	8.29	14.07	18.59
7- TORONTO CENTRAL	1.86	15.02	16.54	33.42	36.63
11- CHAMPLAIN	1.23	10.89	14.27	26.39	3.68
9- CENTRAL EAST	0.50	7.77	9.39	17.66	14.40
1- ERIE ST. CLAIR	0.30	6.53	12.17	18.99	12.76
3- WATERLOO WELLINGTON	0.83	6.64	9.96	17.44	12.73
12- NORTH SIMCOE MUSKOKA	0.40	5.53	11.46	17.38	14.22
2- SOUTH WEST	0.80	12.44	14.25	27.49	9.63
10- SOUTH EAST	0.72	12.56	9.69	22.97	25.12
4- HAMILTON NIAGARA	0.93	9.21	13.75	23.89	14.15
13- NORTH-EAST	0.00	8.50	14.80	23.30	11.02
14- NORTH-WEST	0.00	9.73	15.40	25.13	7.30

[a] Regions are ordered from lowest to highest major amputation rate

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Appendix 3- Secondary Analysis Limited to Amputations Related to Diabetes

Supplemental Table 4. Physician and Publicly-Funded Podiatry Visits within 30-365 days prior to Index Diabetic Amputation Admission

Region [a]	No. of Amputees	GP [b]	Vascular Surgeon	Orthopedic Surgeon	General Surgeon	Vascular, Orthopedic or General Surgeon	Other Specialist Physician	Publicly-Funded Podiatry [c]
		At least 1 Visit - N (%)						
6- MISSISSAUGA HALTON	350	326 (93.1%)	215 (61.4%)	87 (24.9%)	57 (16.3%)	269 (76.9%)	332 (94.9%)	≤5 (≤1.4%)
8- CENTRAL	722	687 (95.2%)	367 (50.8%)	190 (26.3%)	184 (25.5%)	516 (71.5%)	681 (94.3%)	59 (8.2%)
5- CENTRAL WEST	389	362 (93.1%)	167 (42.9%)	89 (22.9%)	151 (38.8%)	269 (69.2%)	359 (92.3%)	14 (3.6%)
7- TORONTO CENTRAL	709	665 (93.8%)	350 (49.4%)	151 (21.3%)	170 (24.0%)	488 (68.8%)	654 (92.2%)	6 (0.8%)
11- CHAMPLAIN	649	587 (90.4%)	369 (56.9%)	155 (23.9%)	63 (9.7%)	443 (68.3%)	599 (92.3%)	46 (7.1%)
9- CENTRAL EAST	1,146	1,097 (95.7%)	631 (55.1%)	233 (20.3%)	183 (16.0%)	789 (68.8%)	1,069 (93.3%)	41 (3.6%)
1- ERIE ST. CLAIR	482	468 (97.1%)	237 (49.2%)	137 (28.4%)	113 (23.4%)	338 (70.1%)	459 (95.2%)	34 (7.1%)
3- WATERLOO WELLINGTON	483	455 (94.2%)	217 (44.9%)	117 (24.2%)	139 (28.8%)	350 (72.5%)	451 (93.4%)	≤5 (≤1.0%)
12- NORTH SIMCOE MUSKOKA	398	388 (97.5%)	115 (28.9%)	117 (29.4%)	141 (35.4%)	266 (66.8%)	379 (95.2%)	6 (1.5%)
2- SOUTH WEST	834	794 (95.2%)	314 (37.6%)	166 (19.9%)	277 (33.2%)	570 (68.3%)	784 (94.0%)	13 (1.6%)
10- SOUTH EAST	487	457 (93.8%)	208 (42.7%)	147 (30.2%)	85 (17.5%)	325 (66.7%)	454 (93.2%)	≤5 (≤1%)
4- HAMILTON NIAGARA	1,399	1,333 (95.3%)	585 (41.8%)	503 (36.0%)	417 (29.8%)	987 (70.6%)	1,330 (95.1%)	48 (3.4%)
13- NORTH-EAST	769	739 (96.1%)	447 (58.1%)	137 (17.8%)	346 (45.0%)	644 (83.7%)	739 (96.1%)	18 (2.3%)
14- NORTH-WEST	415	379 (91.3%)	17 (4.1%)	123 (29.6%)	151 (36.4%)	233 (56.1%)	396 (95.4%)	0 (0.0%)

[a] Regions are ordered from lowest to highest major amputation rate
[b] General Practitioner
[c] The majority of podiatry and chiropody services are not publicly funded in Ontario

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Appendix 3- Secondary Analysis Limited to Amputations Related to Diabetes

Supplemental Table 5. Health Services within 365 Days Prior to Index Diabetic Amputation Admission

Region [a]	No. of Amputees	At least one Hospitalization - N (%)	At least one ED [b] visit - N (%)	Home care nursing - N (%)	Revascularization - N (%)			Minor [c] Amputation - N (%)	Total Health Care Costs [d] - Mean
					Open surgery	Endovascular	Open or endovascular		
6- MISSISSAUGA HALTON	350	256 (73.1%)	297 (84.9%)	257 (73.4%)	55 (15.7%)	59 (16.9%)	91 (26.0%)	41 (11.7%)	$74,532
8- CENTRAL	722	514 (71.2%)	633 (87.7%)	546 (75.6%)	100 (13.9%)	106 (14.7%)	172 (23.8%)	84 (11.6%)	$67,711
5- CENTRAL WEST	389	266 (68.4%)	326 (83.8%)	259 (66.6%)	38 (9.8%)	69 (17.7%)	86 (22.1%)	44 (11.3%)	$65,705
7- TORONTO CENTRAL	709	452 (63.8%)	615 (86.7%)	472 (66.6%)	67 (9.4%)	123 (17.3%)	153 (21.6%)	100 (14.1%)	$75,650
11- CHAMPLAIN	649	431 (66.4%)	574 (88.4%)	457 (70.4%)	55 (8.5%)	94 (14.5%)	129 (19.9%)	57 (8.8%)	$72,772
9- CENTRAL EAST	1,146	701 (61.2%)	1,020 (89.0%)	834 (72.8%)	101 (8.8%)	91 (7.9%)	168 (14.7%)	155 (13.5%)	$57,051
1- ERIE ST. CLAIR	482	319 (66.2%)	408 (84.6%)	365 (75.7%)	50 (10.4%)	79 (16.4%)	107 (22.2%)	74 (15.4%)	$56,284
3- WATERLOO WELLINGTON	483	333 (68.9%)	420 (87.0%)	390 (80.7%)	65 (13.5%)	38 (7.9%)	90 (18.6%)	110 (22.8%)	$72,535
12- NORTH SIMCOE MUSKOKA	398	268 (67.3%)	370 (93.0%)	322 (80.9%)	62 (15.6%)	31 (7.8%)	79 (19.8%)	55 (13.8%)	$54,793
2- SOUTH WEST	834	569 (68.2%)	726 (87.1%)	631 (75.7%)	77 (9.2%)	47 (5.6%)	110 (13.2%)	171 (20.5%)	$58,745
10- SOUTH EAST	487	306 (62.8%)	415 (85.2%)	346 (71.0%)	38 (7.8%)	35 (7.2%)	69 (14.2%)	94 (19.3%)	$51,189
4- HAMILTON NIAGARA	1,399	940 (67.2%)	1,220 (87.2%)	1,076 (76.9%)	215 (15.4%)	139 (9.9%)	290 (20.7%)	142 (10.2%)	$59,288
13- NORTH-EAST	769	552 (71.8%)	679 (88.3%)	534 (69.4%)	67 (8.7%)	24 (3.1%)	81 (10.5%)	184 (23.9%)	$61,716
14- NORTH-WEST	415	285 (68.7%)	376 (90.6%)	201 (48.4%)	18 (4.3%)	10 (2.4%)	22 (5.3%)	50 (12.0%)	$63,113

[a] Regions are ordered from lowest to highest major amputation rate
[b] ED – Emergency Department
[c] Minor amputation – below ankle
[d] Costs in 2017 Canadian dollars from the perspective of Ontario Ministry of Health & Long Term Care

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Appendix 3- Secondary Analysis Limited to Amputations Related to Diabetes

Supplemental Table 6. Revascularization on Index Hospitalization – Diabetes-related Amputations

Region [a]	No. of amputees	Revascularization – N (%)		
		Open surgery	Endovascular	Open or endovascular
6- MISSISSAUGA HALTON	350	35 (10.0%)	31 (8.9%)	56 (16.0%)
8- CENTRAL	722	46 (6.4%)	44 (6.1%)	82 (11.4%)
5- CENTRAL WEST	389	39 (10.0%)	29 (7.5%)	61 (15.7%)
7- TORONTO CENTRAL	709	89 (12.6%)	46 (6.5%)	120 (16.9%)
11- CHAMPLAIN	649	43 (6.6%)	28 (4.3%)	62 (9.6%)
9- CENTRAL EAST	1,146	62 (5.4%)	51 (4.5%)	102 (8.9%)
1- ERIE ST. CLAIR	482	25 (5.2%)	27 (5.6%)	45 (9.3%)
3- WATERLOO WELLINGTON	483	20 (4.1%)	37 (7.7%)	54 (11.2%)
12- NORTH SIMCOE MUSKOKA	398	21 (5.3%)	24 (6.0%)	42 (10.6%)
2- SOUTH WEST	834	20 (2.4%)	36 (4.3%)	50 (6.0%)
10- SOUTH EAST	487	21 (4.3%)	14 (2.9%)	34 (7.0%)
4- HAMILTON NIAGARA	1,399	54 (3.9%)	119 (8.5%)	151 (10.8%)
13- NORTH-EAST	769	8 (1.0%)	35 (4.6%)	43 (5.6%)
14- NORTH-WEST	415	10 (2.4%)	10 (2.4%)	16 (3.9%)

[a] Regions are ordered from lowest to highest major amputation rate

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Appendix 3- Secondary Analysis Limited to Amputations Related to Diabetes

Supplemental Table 7. Correlation of Regional Health Provider Counts and Health Care Utilization Among Diabetic Amputees with Regional Rates of Diabetes-related Major Amputation

	Range of Values Across 14 Regions	**Magnitude of Correlation** – R-squared	**Direction of Correlation** (Pearson Correlation Coefficient)
Health Providers within Each Region [a]			
Count of Vascular Surgeons	0 – 1.9	0.20	Negative (-0.44)
Count of Chiropodists-Podiatrists	3.7 – 36.6	0.14	Negative (-0.37)
Count of Orthopedic Surgeons	5.5 – 15.0	0.03	Positive (0.16)
Count of Vascular, General and Orthopedic Surgeons	14.1 – 33.4	0.07	Positive (0.27)
Count of General Surgeons	8.3 – 16.5	0.20	Positive (0.45)
Health Provider Visit – At least 1 Visit Within 1 Year Prior to Index Amputation Hospitalization [b]			
Vascular Surgeon Visit	4.1% – 61.4%	0.54	Negative (-0.74)
Publicly-Funded Podiatrist Visit [c]	0.0% – 8.2%	0.17	Negative (-0.41)
Vascular, General or Orthopedic Surgeon Visit	56.1% – 83.7%	0.16	Negative (-0.40)
General Practitioner Physician Visit	90.4% – 97.5%	0.004	Negative (-0.06)
Orthopedic Surgeon Visit	17.8% – 36.0%	0.04	Positive (0.21)
Specialist Physician Visit	92.2% – 96.1%	0.25	Positive (0.51)
General Surgeon Visit	9.7% – 45.0%	0.29	Positive (0.54)
Health Services and Interventions - Within 1 Year Prior to Index Amputation Hospitalization			
Endovascular or Open Vascular Intervention	5.3% – 26.0%	0.79	Negative (-0.89)
Endovascular Intervention	2.4% – 17.7%	0.66	Negative (-0.85)
Outpatient Nursing Care	48.4% – 80.9%	0.35	Negative (-0.60)
Open Vascular Intervention	4.3% – 15.7%	0.31	Negative (-0.56)
Total Health Care Costs	$51,189 – $75,650	0.18	Negative (-0.42)
Hospitalization (at least one)	61.2% – 73.1%	0.001	Negative (-0.01)
Minor Amputation	8.8% – 23.9%	0.06	Positive (0.25)
Emergency Department visit (at least one)	83.9% – 90.0%	0.22	Positive (0.47)
Intervention - Index Amputation Hospitalization			
Endovascular or Open Vascular Intervention	3.9% – 16.9 %	0.60	Negative (-0.78)
Open Vascular Intervention	1.0% – 12.6%	0.50	Negative (-0.71)
Endovascular Intervention	2.4% – 8.9%	0.36	Negative (-0.60)

[a] Counts of providers per 100,000 residents ≥40 years of age

[b] Excluding 30 days prior to amputation

[c] The majority of podiatry and chiropody visits are not publicly funded in Ontario

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