ORIGINAL ARTICLE

Geographic Access to Stroke Care Services in Rural Communities in Ontario, Canada

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ABSTRACT: ***Background:*** Optimal stroke care requires access to resources such as neuroimaging, acute revascularization, rehabilitation, and stroke prevention services, which may not be available in rural areas. We aimed to determine geographic access to stroke care for residents of rural communities in the province of Ontario, Canada. ***Methods:*** We used the Ontario Road Network File database linked with the 2016 Ontario Acute Stroke Care Resource Inventory to estimate the proportion of people in rural communities, defined as those with a population size <10,000, who were within 30, 60, and 240 minutes of travel time by car from stroke care services, including brain imaging, thrombolysis treatment centers, stroke units, stroke prevention clinics, inpatient rehabilitation facilities, and endovascular treatment centers. ***Results:*** Of the 1,496,262 people residing in rural communities, the majority resided within 60 minutes of driving time to a center with computed tomography (85%), thrombolysis (81%), a stroke unit (68%), a stroke prevention clinic (74%), or inpatient rehabilitation (77.0%), but a much lower proportion (32%) were within 60 minutes of driving time to a center capable of providing endovascular thrombectomy (EVT). ***Conclusions:*** Most rural Ontario residents have appropriate geographic access to stroke services, with the exception of EVT. This information may be useful for jurisdictions seeking to optimize the regional organization of stroke care services.

RÉSUMÉ : L'accès aux soins de santé à la suite d'un AVC dans des communautés rurales de l'Ontario. ***Contexte*** : Des soins optimaux donnés à des patients victimes d'un AVC vont nécessiter l'accès aux ressources et aux services suivants : neuro-imagerie, revascularisation aigüe, réadaptation et prévention des AVC. Cela dit, il est possible que ces ressources et ces services ne soient pas disponibles dans certaines régions rurales. Nous avons ainsi voulu déterminer le niveau d'accès aux soins de santé prodigués à des patients victimes d'un AVC qui vivent au sein de communautés rurales de l'Ontario (Canada). ***Méthodes*** : De concert avec la base de données tirée du Fichier du réseau routier de l'Ontario, nous avons utilisé le *Ontario Acute Stroke Care Resource Inventory* (2016) afin d'estimer le pourcentage d'individus établis dans des communautés rurales. Pour définir de telles communautés, nous avons adopté les critères suivants : un nombre d'habitants inférieur à 10 000 ; des trajets en voiture dont les délais vont varier entre 30, 60 et 240 minutes pour atteindre des centres de soins de l'AVC (lesquels incluent des services d'imagerie cérébrale, de thrombolyse et de prise en charge des patients) ainsi que des centres de réadaptation et de traitement endovasculaire. ***Résultats*** : Sur les 1 496 262 individus établis dans des communautés rurales, la majorité d'entre eux habitent à 60 minutes ou moins en voiture d'un centre de soins doté d'équipements de tomographie par ordinateur (85 %), d'un service de thrombolyse (81 %), d'un service de prise en charge des AVC (68 %), d'une clinique de prévention des AVC (74 %), d'une unité de réadaptation pour patients hospitalisés (77 %). Cela dit, une proportion plus faible d'individus habitant à 60 minutes d'un centre de soins avait accès à des services de thrombectomie endovasculaire (32 %). ***Conclusions*** : Hormis la thrombectomie endovasculaire, la plupart des individus établis dans des communautés rurales de l'Ontario jouissent d'un accès adéquat à des centres de soins de l'AVC. Cette information pourrait s'avérer utile pour des instances gouvernementales cherchant à optimiser l'organisation régionale de soins destinés à des patients victimes d'un AVC.

Keywords: Stroke, Rural health, Geographic access

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Introduction

Approximately 20% of North Americans live in rural areas, where stroke incidence and mortality are higher than in urban areas.[1–3] Interventions such as thrombolysis, endovascular thrombectomy (EVT), stroke unit care, and rehabilitation are associated with improved outcomes after stroke, but require

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resources and expertise that are not available in all centers and are less likely to be located in rural areas.[1,4–7] Poor geographic access to medical care has been associated with lower quality of care and with worse outcomes for a variety of medical conditions.[8,9] Although organized systems of stroke care in Ontario are designed to optimize care across the continuum for an entire region, it is not known whether current stroke systems provide adequate access for residents of rural areas. Previous geospatial analyses have provided important information on access to stroke care across Ontario and Canada, but did not specifically evaluate access to care for rural residents.[10–12]

We aimed to quantify geographic access to stroke care for rural residents of Ontario, Canada, using linked population-based administrative data sources to estimate the proportion of people in rural communities who were within 30, 60, and 240 minutes of travel time by car (at posted speed limits) from stroke care services, including neuroimaging, thrombolysis, EVT, stroke unit care, stroke prevention clinics, and inpatient rehabilitation facilities.

Methods

Setting

Ontario is Canada's most populous province, with over 13 million people residing in over 1 million square kilometres, and with many smaller communities located far from large medical centers.[13] Ontario has a well-established system of regional stroke care delivery, with a hub-and-spoke model including regional stroke centers with advanced stroke care resources and expertise for thrombolysis and/or EVT, centers capable of facilitating thrombolysis through telemedicine and the Ontario Telestroke Program, district stroke centers capable of providing more basic stroke treatment, and designated stroke secondary prevention clinics. The stroke system incorporates regional transfer agreements and ambulance bypass protocols for the transport of patients with suspected stroke to designated centers. Air ambulances may be used for residents in remote areas. The provincial health insurance plan provides coverage for all hospital and physician services.

Population, Data Sources, and Analyses

We determined the size of the Ontario population in 2016 by summing the populations for each postal code from the 2016 Postal Code Conversion File (PCCF), a digital file of all postal codes linked to census data from Statistics Canada. We used the PCCF to identify communities and their population sizes, and defined rural communities as those with a population size under 10,000.[14] There are various definitions of rurality, some based on population size (with varying sizes used in the literature), some on commuting flow to metropolitan areas, and some on the availability of health care and other resources.[13,15–17] We selected a definition based on a population size under 10,000 as this aligns with the "rural and small town" community size category available in the PCCF datafile.[18] We used the 2016 Ontario Stroke Care Resource Inventory, an annual survey of all Ontario acute care institutions, to determine the location of stroke care services. This inventory identifies all rehabilitation facilities, both hospital-based and free-standing, and all designated provincially funded stroke prevention clinics. We then used the PCCF Plus to assign geographic coordinates to postal codes of health services and communities, with each subject within a community assigned the same coordinate, and geocoded locations using ArcGIS version 10.2 by the Environmental Systems Research Institute. Most postal codes representing health care facilities have small areas (mean of 0.04 km^2 and median 2.89 km^2), as do those representing small populated areas (mean of 0.01 km^2 and median 21.06 km^2), with the exception of those in the north where population postal codes can represent larger areas.

We used the 2017 Ontario Road Network (ORN) Road Net Element File from Land Information Ontario to provide a listing of Ontario roads with their posted speed limits to calculate travel times by car. We then used network analysis to calculate the travel time from each stroke care service outward through all existing roads using ORN's posted speed limits. We evaluated access to the following stroke care services: (1) computed tomography (CT); (2) CT angiography (CTA); (3) magnetic resonance imaging (MRI); (4) thrombolysis centers; (5) stroke units; (6) stroke prevention clinics; (7) inpatient rehabilitation facilities; and (8) EVT centers. We calculated the percentage of the rural population with geographic access to the specified services by summing the populations of communities that had access on the road network within the stated travel time and then dividing by the total population of Ontario communities with 10,000 or fewer residents. We performed analyses of the proportion located beyond 240 minutes of driving time stratified by area of residence into northern Ontario, defined as Local Health Integration Network (LHIN) regions 13 and 14, and southern Ontario, defined as LHIN regions 1–12. For endovascular centers and inpatient rehabilitation facilities, we created maps that showed the rural communities located within 30, 60, and 240 minutes of driving time of these services. 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.

Table 1: Percentage of population in rural communities in Ontario, Canada, with access to various stroke care services within 30, 60, and 240 minutes of travel time by car

Total rural population (N = 1,496,262)	Within 30 minutes	Within 60 minutes	Within 240 minutes
	% within driving time		
Brain imaging			
CT	61.0	85.3	96.3
MRI	26.4	72.9	92.6
CTA	51.1	83.4	96.3
Thrombolysis center	29.5	81.3	96.3
Stroke unit	22.0	67.9	91.5
Stroke prevention clinic	27.2	73.5	96.3
Inpatient rehabilitation	32.6	77.0	94.4
Endovascular center	3.3	32.1	83.9

CT = computed tomography; MRI = magnetic resonance imaging; CTA = CT angiography; endovascular center = center with the capacity to perform mechanical thrombectomy.
Rural population defined as those residing in a community with 10,000 or fewer residents.

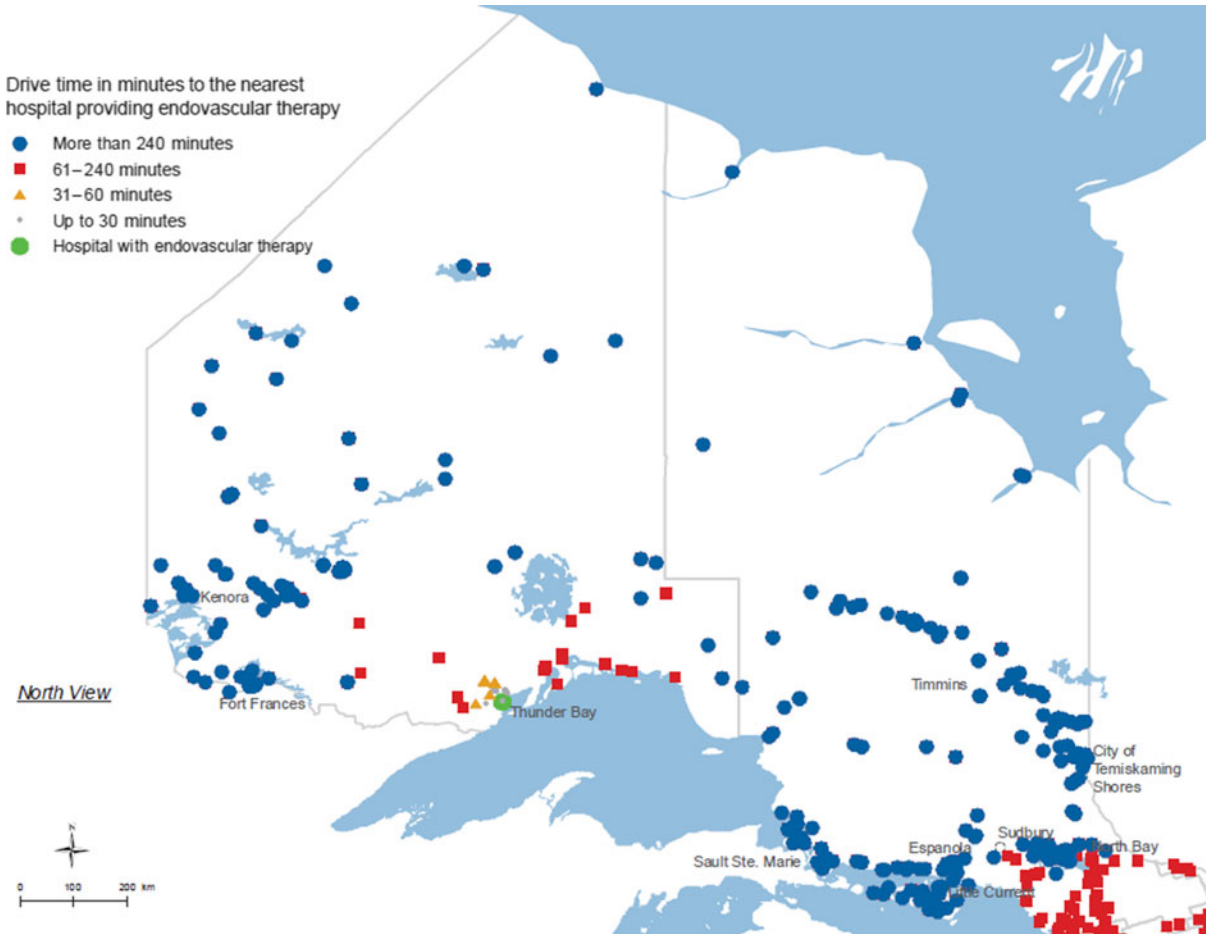

Figure 1: *Map of rural communities (population size less than 10,000) in* Northern Ontario *within 30, 60, and 240 minutes of driving time to the nearest hospital (N = 1) providing endovascular thrombectomy.*

Results

In total, there were 1,496,262 Ontarians living in communities with 10,000 or fewer people, representing 11% of the total population. Over 90% of rural residents lived within 240 minutes of driving time of all stroke care services, with the exception of EVT centers at 83.9% (Table 1 and Figures 1–4). A substantial proportion of rural residents also lived within 60 minutes of driving time to all stroke care services, at 85.3% for CT, 83.4% for CTA, 92.9% for MRI, 81.3% for thrombolysis centers, 67.9% for stroke units, 73.5% for stroke prevention clinics, and 77.0% for inpatient rehabilitation; the proportion residing within 60 minutes of an EVT center was lower at 32.1% (Table 1 and Figures 1–4). The proportion of rural residents living within 30 minutes of driving time of stroke care services was generally low, at 61% for CT, 51.1% for CTA, 26.4% for MRI, 29.5% for thrombolysis, 22.0% for stroke units, 27.2% for stroke prevention clinics, 32.6% for inpatient rehabilitation, and only 3.3% for EVT. There were marked regional variations in geographic access, with many northern Ontario rural communities located beyond 240 minutes of driving time of stroke care services (Figures 1–4). No southern Ontario residents lived beyond 240 minutes of driving time of any stroke care services; in contrast, the proportion of rural residents in northern Ontario living beyond 240 minutes of driving time was 8.7% for CT, 28.4% for MRI, 9.0% for CTA, 9.0% for thrombolysis, 33.9% for stroke units, 8.9% for stroke prevention clinics, 28.3% for inpatient rehabilitation, and 73.9% for EVT (Table 2).

Discussion

We found that the majority of rural residents in Ontario lived within 60 minutes of driving time from key stroke services, including neuroimaging and thrombolysis. However, geographic access was substantially lower for EVT, and many rural communities in northern Ontario did not have timely road access to any stroke services.

Previous studies evaluating geographic access to stroke services have estimated that over 80% of the US population has access to thrombolysis-capable hospitals within 60 minutes, with similar results seen in Ontario and other Canadian provinces.[10,12,19] However, these studies assessed the entire population rather than rural communities, where access might be anticipated to be lower. Our finding that over 81% of rural residents lived within 60 minutes of driving time to thrombolysis centers provides evidence of very good rural access to this treatment. This is consistent with previously observed high

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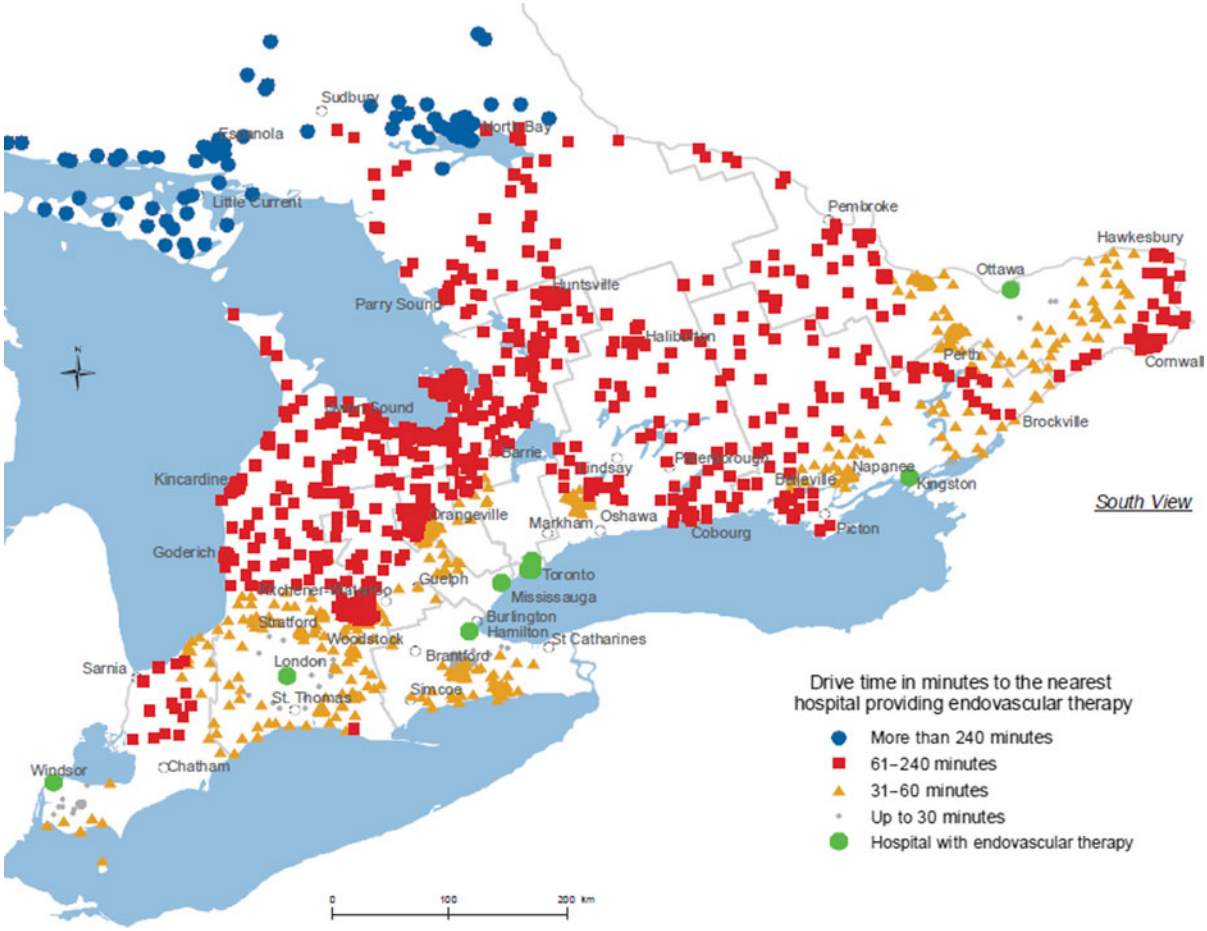

Figure 2: *Map of rural communities (population size less than 10,000) in* Southern Ontario *within 30, 60, and 240 minutes of driving time to the nearest hospital (N = 10) providing endovascular thrombectomy.*

thrombolysis treatment rates in both rural and urban areas of Ontario, and with elimination of rural/urban disparities in use over time, and may reflect the impact of a well-established regional system of coordinated stroke care in Ontario for this treatment.[20–22]

Most existing systems of stroke care were developed prior to the demonstration of the effectiveness of EVT for acute ischemic stroke and were therefore not designed to ensure equitable access to this treatment.[4,23] Studies from the USA have documented marked geographic variations in access to care, with lower access in states with a large proportion of rural residents.[19,24] Our findings suggest that the majority of rural Ontarians cannot reach existing EVT centers within 60 minutes of driving time, and that the proportion living within 30 minutes of driving time is exceedingly small at 3.3%. Further, EVT is only indicated in patients with large vessel occlusion, which is estimated to be present in only 20% of patients with stroke.[25] Identifying the presence of large vessel occlusion requires CTA, and the ability of only 51.1% of the population to reach this imaging modality within 30 minutes of driving time limits the ability to systematically screen potential EVT candidates and may result in suboptimal use of treatment and transportation resources. Although EVT can be provided to selected patients up to 24 hours after stroke symptom onset, outcomes are better with early therapy, so timely access is essential.[26,27] Furthermore, patient selection in the post-6-hour window is based on CT perfusion imaging that is currently not available in most Ontario hospitals.[28]

Potential solutions to improve rural EVT access include promoting the use of emergency medical services for acute stroke, as previous research suggests that rural residents with suspected stroke are less likely than those in large urban centers to arrive at hospital by ambulance.[21] For some remote communities, the use of air rather than ground transportation will be necessary, although factors such as availability of aircraft, airports, and fly time from base to community may all affect transit times, and air transportation may be particularly unreliable in northern communities because of poor weather. Other potential solutions include the use of mobile stroke units, prehospital triage, telemedicine for decision support, and flying intervention teams.[29–36] Direct transportation to intervention centers may be preferable to interhospital transfers, which can be associated with delays in treatment and worse outcomes.[23,37–39] The designation of additional endovascular centers in underserved areas may be part of the solution, although it may be challenging to maintain a roster of staff and neurocritical care services in such areas, and one Korean study found that outcomes were worse at small-volume compared to large-volume sites.[40] Finally, allowing patients to seek care across provincial boundaries may reduce travel time to stroke care services.[11]

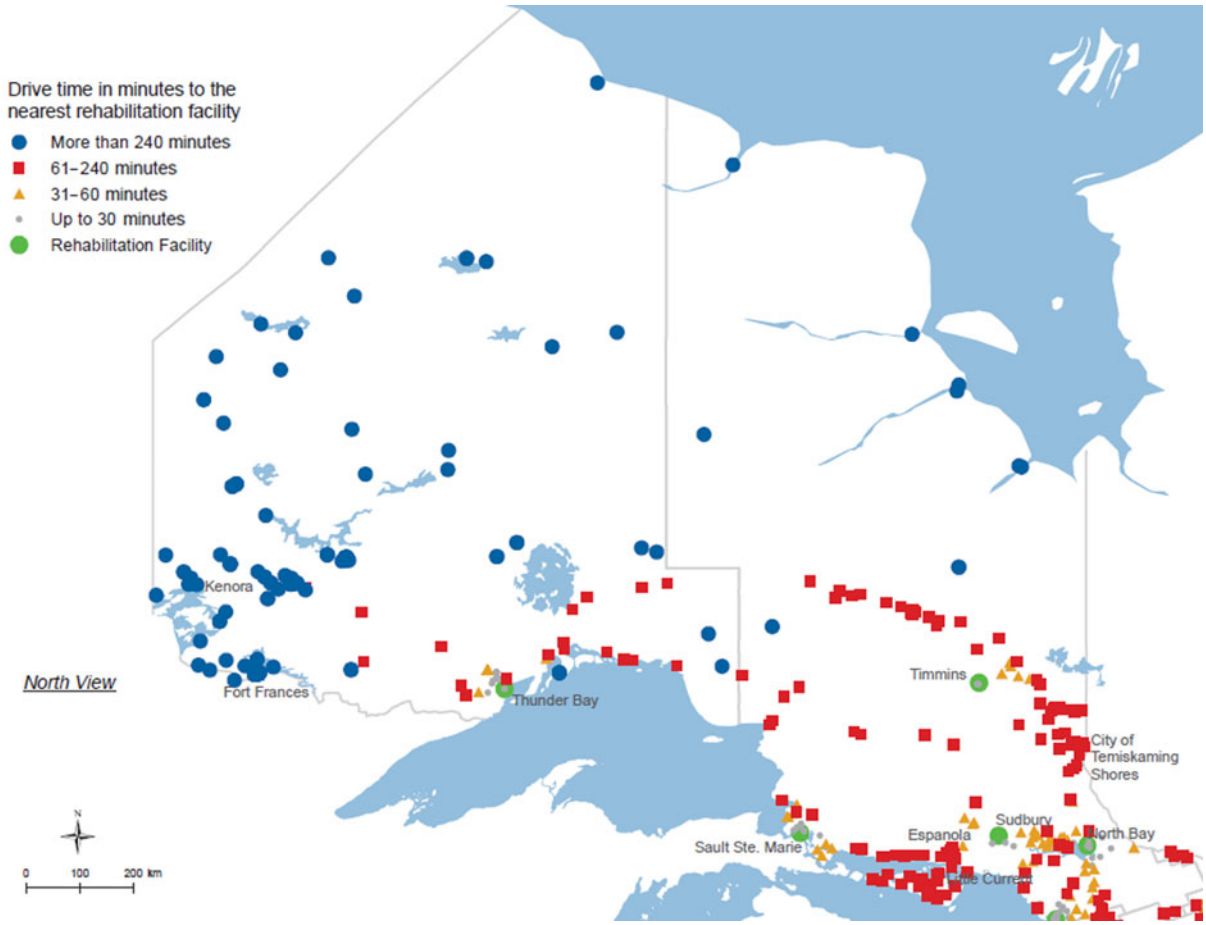

Figure 3: *Map of rural communities (population size less than 10,000) in* Northern Ontario *within 30, 60, and 240 minutes of driving time to the nearest hospital providing inpatient rehabilitation.*

Geographic access is important not only for time-sensitive hyperacute stroke interventions, but also for rehabilitation and stroke secondary prevention. Patients whose only access to rehabilitation facilities is many hours of drive from their home communities may opt to forgo inpatient rehabilitation because of the distance from family and other supports, potentially squandering initial gains from acute stroke care. Minor strokes and transient ischemic attacks make up over half of the burden of ischemic cerebrovascular diseases and are harbingers of potentially preventable larger disabling strokes, and long driving times to stroke prevention clinics limit the ability to provide rapid outpatient diagnostic testing and management to reduce the risk of stroke in this group.[41] Our findings suggest that over one in five rural Ontarians are beyond 60 minutes of driving time of inpatient rehabilitation and stroke prevention clinics, and are consistent with a previous study that found that only 69% of Canadians had access to secondary prevention services that were operational 5 to 7 days a week.[11]

Some rural communities are in close proximity to metropolitan areas while others are in remote northern locations. Not surprisingly, we found that geographic access by car was particularly low in northern Ontario, with a substantial proportion of residents living beyond 240 minutes of driving time of key stroke services. Many of these communities will always require air transportation for care for medical emergencies; however, the targeted designation of additional facilities may improve access in such areas. Currently, there is only one endovascular center in northern Ontario, but a second site is now being developed. Other potential strategies to improve access to care in remote areas include the use of telemedicine (including innovative technology that allows procedures to be performed remotely), telerehabilitation, and rural stroke coordinators in strategic locations.[42–44]

A number of study limitations merit comment. Our findings are specific to the geography and health system in the province of Ontario. However, we anticipate that these will be applicable to other jurisdictions with hub-and-spoke models of stroke care covering large distances and encompassing both rural and urban areas. Most of the postal codes in our study represented fairly confined geographic areas, with the exception of some postal codes in northern areas where population postal codes could represent larger geographic areas. Although this introduces uncertainty to the estimation of drive times in the north, any potential bias would be minimized by the fact that these postal codes are all located well beyond 60 minutes of driving time to the nearest health care facility, and thus our conclusions are unlikely to be affected by errors in estimated travel time based on postal code representation. Although the Acute Stroke Care

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Table 2: Percentage of population in rural communities in Ontario, Canada, beyond 240 minutes of driving time to various stroke care services, stratified into northern and southern Ontario regions

Total rural population (N = 1,496,262)	Northern Ontario	Southern Ontario
	% beyond 240 minutes of driving time	
Brain imaging	8.7	0
CT	28.4	0
MRI	9.0	0
CTA		
Thrombolysis center	9.0	0
Stroke unit	33.9	0
Stroke prevention clinic	8.9	0
Inpatient rehabilitation	28.3	0
Endovascular center	73.9	0

CT = computed tomography; MRI = magnetic resonance imaging; CTA = CT angiography; endovascular center = center with the capacity to perform mechanical thrombectomy.
Rural population defined as those residing in a community with 10,000 or fewer residents.
Northern Ontario defined as Local Health Integration Network (LHIN) regions 13 and 14; Southern Ontario defined as LHIN regions 1–12.

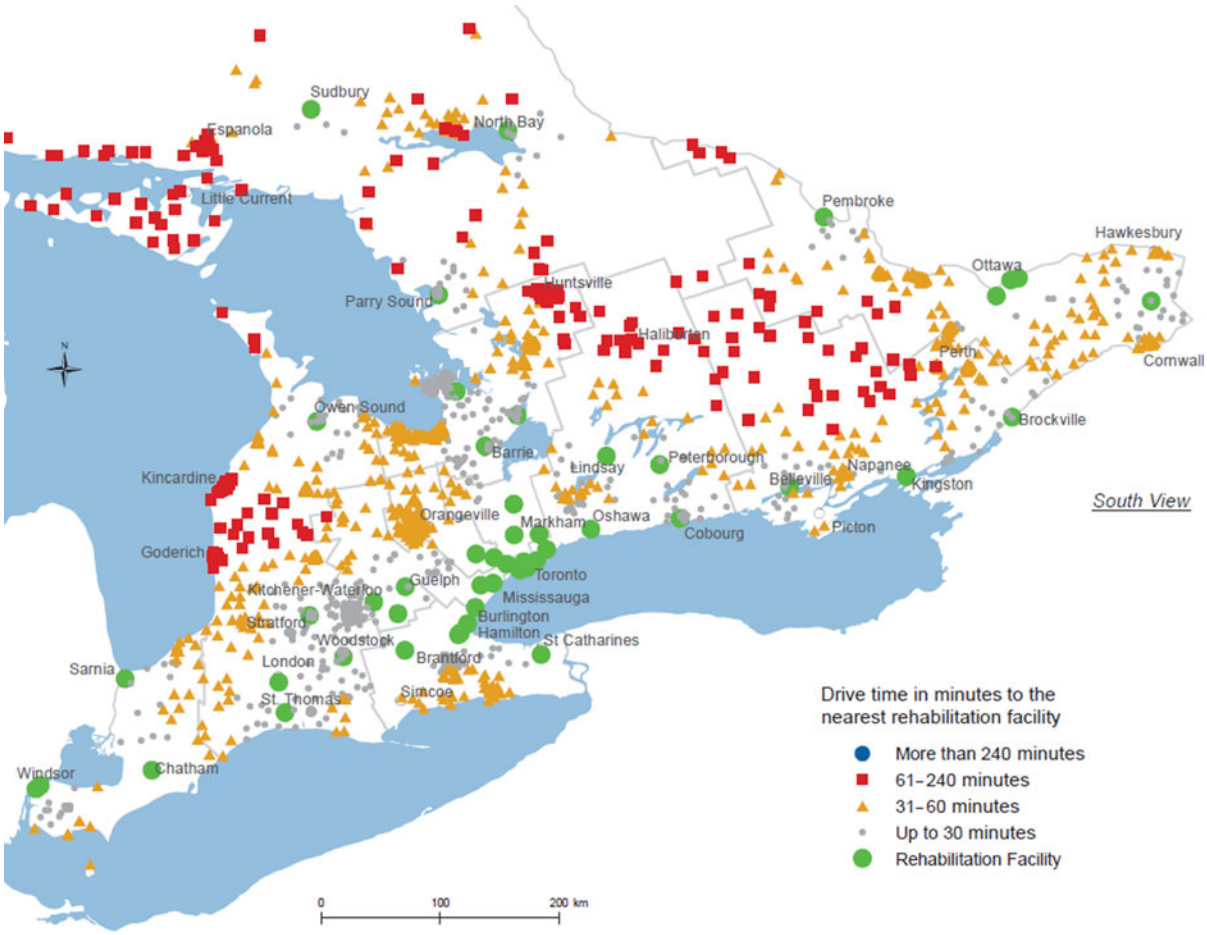

Figure 4: *Map of rural communities (population size less than 10,000) in* Southern Ontario *within 30, 60, and 240 minutes of driving time to the nearest hospital providing inpatient rehabilitation.*

Resource Inventory identified all designated stroke prevention clinics, stroke secondary prevention care may have been delivered through other mechanisms, such as cardiology clinics or individual clinicians' offices. We did not study actual delivery of stroke care, but only geographic access to services. For example, we evaluated geographic access to facilities with the capacity to perform CT; however, not all of these provide daily round-the-clock service, and even those that do may require a technologist to travel from home, thus introducing further delays. Fourth, our analyses focused on driving times based on posted speed limits; however, actual driving speeds will be higher than posted ones for emergency vehicles and lower during difficult weather conditions or heavy traffic.[45] Not all people have access to vehicles, and use of driving time as a surrogate for access may overestimate access to care, especially in subgroups of people with lower car ownership.[46,47] True transit time includes not only driving time but also emergency medical services activation time, response time, on-scene time, and "door-in door-out" times for those seen first at a local hospital and subsequently transferred to a stroke center.[48] For all of these reasons, our findings are likely to overestimate rural communities' geographic access to stroke services. Fifth, we did not study issues specifically related to Indigenous people, who are more likely than their non-Indigenous counterparts to live in rural areas, and who may face additional barriers to care related to the historic effects of colonization.[49,50] Finally, this study focused solely on rural communities, and thus the findings differ from those of studies of geographic access for all communities in the province.

This study provides evidence of very good overall geographic access to CT and thrombolysis from rural communities across Ontario. However, targeted solutions are needed to improve rural access to other stroke services, particularly EVT, and to improve access in northern Ontario.

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Disclosures

None.

Statement of Authorship

MKK drafted the manuscript. PG and JF performed the statistical analyses. All authors contributed to the study design, interpretation of the analyses, and revisions of the manuscript.

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