

## **Access to Primary Percutaneous Coronary Intervention for ST-Segment Elevation Myocardial Infarction in Canada: A Geographic Analysis**

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## **Abstract**

### **Background**

Primary percutaneous coronary intervention (PCI) is the preferred treatment over fibrinolytics for ST-segment elevation myocardial infarction (STEMI). In the United States it has been estimated that nearly 80% of the adult population has access to PCI within a 60-minute pre-hospital time. No such estimates exist for Canada.

### **Methods**

Geographic Information Systems were used to estimate pre-hospital times by ground to PCI facilities across Canada. Time to dispatch, time to patient and time at patient scene were considered in the overall access times.

### **Results**

Only a small proportion of Canada's geographic surface area is accessible to PCI facilities within 60 minutes. Despite this, Canada's population distribution is such that 59.1% of the population can access PCI within a 60-minute period. The population proportion with 60-minute access varied widely across provinces, from a low of 16.0% in New Brunswick to a high of 75% in Ontario. The strategic addition of a single hypothetical facility to four selected province could increase the population proportion with timely PCI access by 3.0% to 4.1%, depending upon the province in which it is located. Approximately 600,000 adults would gain access in such a scenario of new facilities.

## **Conclusions**

Only a subset of Canada's population can achieve timely access to PCI facilities for primary PCI, and the proportion with such access varies widely across provinces. Such information can inform the development of regionalized STEMI care models.

## **Background**

Primary percutaneous coronary intervention (PCI) is a preferred treatment for ST-segment elevation myocardial infarction (STEMI) when compared to fibrinolytic therapy in terms of reducing mortality rate, stroke and recurrence of myocardial infarction (MI) [1-4]. However, the success of using primary PCI to treat STEMI is dependent on a number of access considerations, and in particular, time to treatment [5-7]. Current American, Canadian and European guidelines suggest performing primary PCI within 90 minutes of first medical contact [8-10].

Despite primary PCI being a preferred therapy for STEMI, it is being offered to a minority of patients due to various limitations. The transportation time of a STEMI patient is one important barrier to timely primary PCI [11]. This time constraint for optimal outcomes has led to a focus on the development of regional STEMI care models to treat MI. These models implement expedited diagnosis and direct transfer for primary PCI. Regional care models are currently being implemented and tested across North America [12-15] and internationally [5, 16, 17].

In order to create regionalized care models, policy makers must first evaluate the areas and populations where timely access to PCI-hospitals is possible. The implications of driving times to hospitals with PCI facilities in terms of pre-hospital triage has been studied for the United States [18, 19], and it has been estimated that nearly 80% of American adults have access to PCI within 60 minutes [19]. No such estimate exists for Canada.

Geographic Information Systems (GIS) are valuable tools for evaluating access to health services [20-23] and specifically for studies evaluating access to PCI facilities

[19]. In this paper we use GIS and existing data to: 1) determine the current Canadian areas and populations with timely access to PCI facilities (within 60, 90, and 120 minutes) and 2) determine how the hypothetical addition of new facilities in underserved areas could change the population and area access to PCI.

## **Methods**

### Data Sources

Road network analysis evaluates geographic access based upon travel along a road network, and thus requires data representing origins, destinations and the linear features along which travel occurs. The origins of travel in this study were individual Statistics Canada 2006 dissemination areas (DA). The geographic center of each DA was used as the originating point of travel. In Canada, DAs are the smallest geographic unit at which the census is publically distributed. There are a total of 54626 DAs within the country. As this study focused primarily on travel in and surrounding the immediate vicinity of urban areas, the DA level of data was considered appropriate [24, 25].

The road network used in this study was the CanMap® RouteLogistics file created by DMTI Spatial [26]. This file can be used for shortest route analyses of both time and distance. In addition to containing detailed street names and address locations along each segment of road, there are fields included for the length and speed limit along each segment of road.

The destinations used in this study were the PCI facilities within Canada. A comprehensive list of these facilities was compiled through consultation with experts [27, 28], and each facility was geocoded based on its street address location. The process of

geocoding allowed for the creation of spatial files from text descriptions of addresses [29]. All GIS analyses and map production were conducted using ESRI ArcGIS 9.2 [30].

### Analysis of Travel Times

The methodology used in this study was adapted from a 2006 study by Nallamothu *et al.* that studied geographic access to PCI facilities in the United States [19]. Since the recommended time to reperfusion after first medical contact is 90 minutes or less, a 60-minute baseline time constraint was considered, allowing 30 minutes from hospital door to first balloon inflation. This time constraint has been used in previous studies focussed on access to PCI [19, 31]. In Canada, one quality of care indicator for acute MI is reperfusion within 120 minutes from first medical contact [32]. Recognizing this, additional pre-hospital time scenarios were also considered (90 and 120 minutes).

First the DA boundaries were used to calculate individual DA areas and centroids. The population density was calculated at the DA level based on the total population and DA area for each province (residents/km<sup>2</sup>). The population densities were divided into tertiles with the top third of DA population densities categorized as urban, the middle third categorized as suburban and the bottom third categorized as rural. This density designation was based on a prior study [19].

The Network Analyst extension of ESRI ArcGIS 9.2 was used to evaluate travel time by ground. Travel cost matrices were used to determine the travel time in minutes from each DA centroid to its nearest PCI facility within a province. The travel times were then spatially joined to the DA where travel originated. This method allowed for each DA polygon to have an associated travel time to its nearest facility. In order to more



realistically determine pre-hospital times between DA and PCI facilities, additional time factors were added to the baseline travel times.

These additional times were based on pre-hospital time studies conducted in the United States and accounted for time to dispatch, time to patient and time spent at patient scene. Dispatch times of 1.4 minutes were added to urban and suburban areas and 2.9 minutes were added for dispatch in rural areas [33]. In the absence of information on ambulance locations at time of dispatch, in order to account for the time for an ambulance to reach a patient, empirically derived constants were used based on the literature. Multipliers of 1.6 were used for travel time in urban areas, 1.5 in suburban areas, and 1.4 in rural areas [34, 35]. Time at patient scene was also incorporated through fixed additions of 8 minutes in urban and suburban areas and 9 minutes in rural areas [8, 19].

Sensitivity tests were conducted to allow for an understanding of how changes in the overall travel time would affect the calculation of populations with access. These sensitivity tests could simulate situations where travel time is increased or decreased due to conditions such as changes in speed, changes due to different times of day and changes in weather conditions. Absolute pre-hospital time changes were evaluated based on an increase or decrease of ten minutes to the overall pre-hospital time. Relative pre-hospital time changes were evaluated based on an increase or decrease of 25% to the overall pre-hospital time. One American study showed that approximately 50% of MI patients transport themselves to the hospital [36]. Recognizing this, a final sensitivity test was conducted to model a scenario of patient self transport to a PCI facility. This scenario would remove the dispatch time, time to patient and time at patient scene from the models of pre-hospital time.

Population access was determined for each province by selecting those DAs within a specified pre-hospital time and summing the total adult population over 20 years of age within them. This was done separately for each pre-hospital time constraint under consideration (60, 90, and 120 minutes) as well as each sensitivity test. The population with access was then divided by the total adult provincial population to obtain the proportion of the adult population with access.

#### Hypothetical addition of PCI facilities

To evaluate how the addition of new facilities would affect the adult population access in Canada, a hypothetical situation was created whereby an additional facility was added to each of the four most populated provinces in the country (Ontario, Quebec, British Columbia and Alberta). The selection of specific urban sites for hypothetical facilities within these four provinces was guided by GIS analysis. The Census Metropolitan Area (CMA) with substantial population density that fell outside of existing timely access zones was selected for each province. Within selected sites, the current major hospital providing advanced services was chosen as the hypothetical location for a new PCI facility. The pre-hospital times were evaluated for these hypothetical PCI facilities using the methods described above for existing facilities.

### **Results**

#### Geographic Analysis of Populations with Timely Access

The total adult population ( $\geq 20$  years old) in Canada was approximately 23.8 million based on the 2006 Statistics Canada Census. There were 40 PCI facilities identified across Canada. Figure 1 Panel A presents the PCI facilities in each province and illustrates the areas within a pre-hospital time of 60 minutes to PCI facilities. The figure

shows that the number of PCI facilities varies by province. For example, Quebec and Ontario have 13 and 14 PCI facilities, respectively, while all three territories and one province (Prince Edward Island) do not have a single facility.

Only a small proportion of the country's geographic area is within 60 minutes of PCI facilities. Despite this, there is actually a reasonably large proportion of the adult population with access. Figure 1 Panel B highlights the population dense areas in Canada where each dot represents 1000 people within a DA. The population density is highest in Ontario and Quebec adjacent to the United States border. There are additional population dense areas on the West Coast of British Columbia and in pockets of southern Alberta. These population-dense areas generally correspond to the location of PCI facilities.

Table 1 shows that 59.1% of the Canadian adult population had access to a PCI facility within a 60 minute pre-hospital time, 74.2% had access within 90 minutes and 80.0% had access within 120 minutes. The proportion of adults with timely access to PCI varies greatly, however, across provinces. New Brunswick had the lowest level of population access with only 16.0% of adults living within 60 minutes, while Ontario had the highest level of population access with 75.0% of adults living within 60 minutes of a PCI facility. There was an increase in the proportion with access across all provinces when 90 and 120-minute travel times were modelled.

Table 2 presents the results of sensitivity analyses. Altering the pre-hospital time by either absolute or relative times did not considerably alter the population access. Overall, the adult population proportion with timely access changed by an average of less than 10% in either direction, with sensitivity analyses of modification of travel time. A patient self-transport scenario suggests an increase of as much as 12% in populations

with access, because of the removal of ambulance dispatch and patient loading times (but with caveats mentioned in the Discussion section).

#### Hypothetical Addition of New PCI Facilities

**1** Hypothetical new PCI facilities were modeled for Kelowna (BC), Lethbridge (AB), [Trois-Rivières](#) (QC) and Saint Catharines (ON), and this resulted in an increase of the population with access within a 60-minute pre-hospital time (Figure 2 and Table 3). The population with access increased between 3.0% and 4.1% depending on provinces and approximately 600,000 adults would gain access in such a scenario of new PCI facilities.

#### **Discussion**

Our findings show that nearly 60% of the Canadian adult population has access to PCI facilities within a pre-hospital time of 60 minutes. However, the level of access varies substantially across provinces. The implication is that if a patient cannot be transported to a hospital within 60 minutes, the 90-minute time-to-reperfusion target for primary PCI may not be met.

Nallamotheu *et al.* showed that in the United States, nearly 80% of the adult population had geographic access to PCI facilities within a 60-minute pre-hospital time [19]. The geographic access of populations in Canada is thus lower than that of the United States, probably due to the much lower number of PCI facilities in Canada as compared to the US (40 vs. 1176 respectively) as well as differences in the population densities in the two countries. In Canada there is currently one PCI center for approximately every 595,000 adults (23.8 million adults with 40 PCI centers), while the

US has one PCI center for approximately every 176,000 adults (207.5 million adults with 1176 PCI centers) [19].

The hypothetical addition of facilities in four provinces increases the population proportion with timely access. In Ontario, for example, a province with relatively high population access due to a recent expansion of PCI facilities, the hypothetical addition of a PCI facility could provide additional access to nearly 275,000 adults. This type of GIS analysis could be applied to other provinces. The impact could be even more notable in terms of relative percentage of population with access if a new facility is added to a 'low access' province like New Brunswick, where increasing access to as few as 75,000 more adults could increase the provincial percentage with access by nearly 15%. Other studies have also shown that adding facilities to currently underserved areas improves access to PCI [31].

However, the logistics of adding new PCI facilities is complex. Barriers such as lack of funding, lack of experienced PCI operators and lack of technical staff are some of the reasons why 24-hour PCI facilities do not exist in all PCI-hospitals [37]. Another consideration when locating a PCI facility is its distance to the nearest cardiac surgery facility. Furthermore, regardless of how many PCI facilities are added, there will always be some inequity in population access to primary PCI. Some Canadians, as there are Americans, will not be able to access PCI for STEMI care simply because of the great geographic expanse and remoteness of certain areas of Canada.

Our analysis is focused on the geographic feasibility of various time scenarios. This contributes to the foundation for STEMI care models, but our findings do not in and of themselves constitute a care model. Building upon the information presented here,

individual centers and/or health regions and provinces need to decide if the implementation of a regional STEMI care model is feasible. Some considerations are operational hours for PCI facilities, local protocols for inter-hospital transfer and transfer for rescue PCI, balanced consideration of lytic therapy options and the overall structure of regional emergency medical services[38]. Canadian examples of successful STEMI care models involving regional access to direct PCI have been demonstrated and can provide guidance for the implementation of other local regional care models [12, 14].

There are limitations to our study and caveats to its application. This analysis looked at geographic access in terms of a best-case scenario where all PCI facilities are providing primary PCI on a 24/7 schedule. However, there are PCI facilities in Canada that currently do not provide primary PCI and that do not operate on a 24/7 schedule [39]. Also, the pre-hospital times used in this study were based on assumptions founded on emergency transport studies conducted in the United States. Although, travel in the United States and Canada could be different, our sensitivity tests provide estimates of the proportions of population with timely access to primary PCI with adjustments in pre-hospital travel times. Also, a previous study using different methods had similar findings for population access within 90 minutes by ground ambulance to PCI in Alberta (69.6 versus 68.7 in this study) [40]. The results from the sensitivity tests and comparison to a prior study show that the variations in assumptions for travel time do not greatly alter the measure of population access to PCI.

The focus of this study was on prehospital times; we did not consider in-hospital delays that can be important barriers to timely primary PCI. Also, although self-transport of STEMI patients may increase the proportion of patients with timely access to primary

PCI, these patients may have longer in-hospital delay due to prolonged triage time [36]. Because of that consideration, and other benefits of pre-hospital care, we certainly do not advocate self transportation to save pre-hospital times, despite our geographic analysis findings.

In summary, our study evaluated the geographic areas with access to primary PCI, and provides information on the areas within Canada where timely access to PCI facilities is possible, and where regional STEMI care models could be implemented. This study demonstrates the potential utility of GIS analysis to inform strategic health system infrastructure decisions. These findings provide a foundation of knowledge for care providers and decision makers to explore approaches to improving access to urgent PCI-based STEMI care.

**Contributors**

All of the authors contributed to the conception and design of the study and to the interpretation of the data. Alka Patel acquired the data, performed the analysis and drafted the manuscript. William Ghali and Nigel Waters provided supervision and oversight of all aspects of the project. All of the listed authors revised the article for important intellectual content and approved the final version submitted for publication.

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## References

Figure 1: Geographic access to percutaneous coronary intervention (PCI) in Canada and  
Dot Density map of population within Canada

Panel A shows the geographic areas by dissemination area that have access to PCI within  
a 60-minute prehospital time. The number of PCI facilities in each province is

highlighted. Panel B is a dot density map highlighting the location of dissemination areas in Canada with a population count of 1000 or more people.

Figure 2: Geographic access to percutaneous coronary intervention (PCI) in four provinces with the addition of a hypothetical facility

This figure highlights the areas selected for the addition of a hypothetical facility in the four most populated provinces in Canada. It shows an increase in areas with access when a hypothetical facility is added.

Table 1: Adult population with access to PCI (proportion by province)

Pre-hospital Time			Total Adult Population
60 minutes	90 minutes	120 minutes	

Canada	59.1	74.2	80.0	23776870
Province				
British Columbia	60.7	65.6	66.7	3126140
Alberta	64.8	68.7	72.4	2408930
Saskatchewan	45.3	48.3	55.3	702115
Manitoba	64.3	69.6	73.7	836805
Ontario	75.0	84.9	92.5	9083215
Quebec	71.0	81.5	87.6	5791100
New Brunswick	16.0	19.3	24.4	563120
Newfoundland	36.1	38.6	43.7	391980
Nova Scotia	39.7	45.2	57.4	705175

Table 2: Sensitivity tests for proportion of population within a 60-minute pre-hospital time constraint

Sensitivity Tests (Changes to 60-minute pre-hospital time)						
Province	Main Analysis (60 minutes)	10-minute Increase	10-minute Decrease	25% Increase	25% Decrease	Self Transport *
British Columbia	60.7	59.1	63.2	58.7	64.2	66.1
Alberta	64.8	62.8	66.1	62.0	67.3	69.2
Saskatchewan	45.3	44.2	46.1	43.8	47.2	52.1
Manitoba	64.3	61.4	65.8	61.2	68.0	70.1
Ontario	75.0	70.5	79.5	69.2	82.4	87.2
Quebec	71.0	66.8	74.2	65.7	78.3	82.7
New Brunswick	16.0	15.0	16.9	14.6	17.6	19.7
Newfoundland	36.1	35.4	36.6	35.2	37.2	40.1
Nova Scotia	39.7	38.0	41.5	37.3	43.8	47.2

\* Remove dispatch time, time to patient and time at patient scene

Table 3: Population access changes with addition of a hypothetical PCI facility

Province	Standard 60-minute	Proportion Increase	Increased population
British Columbia	60.7	4.1%	125970
Alberta	64.8	3.2%	76630
Ontario	75.0	3.0%	274610
Quebec	71.0	3.4%	196425