

Predictors of diagnostic neuroimaging delays among adults presenting with symptoms suggestive of acute stroke in Ontario: a prospective cohort study

Kirsteen R. Burton MD, Moira K. Kapral MD, Shudong Li PhD, Jiming Fang PhD, Alan R. Moody MChB, Murray Krahn MD, Andreas Laupacis MD

Abstract

Background: Many studies have examined the timeliness of thrombolysis for acute ischemic stroke, but less is known about door-to-imaging time. We conducted a prospective cohort study to assess the timing of neuroimaging among patients with suspected acute stroke in the province of Ontario, Canada, and to examine factors associated with delays in neuroimaging.

Methods: We included all patients 18 years and older with suspected acute stroke seen at hospitals with neuroimaging capacity within the Ontario Stroke Registry between Apr. 1, 2010, and Mar. 31, 2011. We used a hierarchical, multivariable Cox proportional hazards model to evaluate the association between patient and hospital factors and the likelihood of receiving timely neuroimaging (≤ 25 min) after arrival in the emergency department.

Results: A total of 13 250 patients presented to an emergency department with stroke-like symptoms during the study period. Of the 3984 who arrived within 4 hours after symptom onset, 1087 (27.3%) had timely neuroimaging. The factors independently associated with an increased likelihood of timely neuroimaging were less time from symptom onset to presentation, more severe stroke, male sex, no history of stroke or transient ischemic attack, arrival to hospital from a setting other than home and presentation to a designated stroke centre or an urban hospital.

Interpretation: A minority of patients with stroke-like symptoms who presented within the 4-hour thrombolytic treatment window received timely neuroimaging. Neuroimaging delays were influenced by various patient and hospital factors, some of which are modifiable.

Timely access to diagnostic neuroimaging is critical to the management of patients with suspected acute ischemic stroke. Thrombolysis with intravenous tissue plasminogen activator can reduce the risk of disability after stroke, but it must be administered within 4.5 hours after stroke onset and be preceded by brain imaging to confirm eligibility for the treatment.¹ Stroke guidelines developed by the Brain Attack Coalition and the American Heart Association advise the completion of computed tomography (CT) within 25 minutes after arrival to the emergency department.¹⁻³ The Canadian best practice recommendations for stroke care note that patients with suspected acute stroke or transient ischemic attack (TIA) should receive neuroimaging immediately.⁴

Numerous studies have examined the association between the time from symptom onset to arrival at the emergency department and the time from arrival to thrombolysis (frequently termed door-to-needle time).⁵⁻¹⁰ However, fewer studies have investigated the door-to-imaging time — one of the first windows in the management of patients with acute

stroke — and there is little information on factors associated with delays in brain imaging.¹¹

We undertook this study to assess the timing of neuroimaging (computed tomography [CT] or magnetic resonance imaging [MRI] of the brain) in patients with symptoms suggestive of acute stroke who presented to hospitals with neuroimaging capacity in the province of Ontario, Canada. We determined the proportion of patients presenting within 4 hours after symptom onset (and thus were potentially eligible for

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Correspondence to: Kirsteen Burton, kirsteen.burton@utoronto.ca

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intravenous thrombolysis) who underwent timely neuroimaging. We also identified factors that predicted the likelihood of timely neuroimaging.

Methods

Data sources

The Ontario Stroke Registry (formerly known as the Registry of the Canadian Stroke Network) performs a biennial audit (the Ontario Stroke Audit) of patients with suspected stroke or TIA seen in an emergency department or admitted to hospital at any acute care institution in Ontario, excluding psychiatric hospitals.¹² Chart abstraction is performed by specially trained neurology research personnel and includes abstraction of important timing variables, including time of stroke onset, time of arrival at the emergency department and time of first brain imaging.^{13,14} We used data from the audit performed in fiscal year 2010/11 and included only hospitals that had neuroimaging capacity, defined as having CT or MRI on site. We defined timely neuroimaging as the receipt of brain imaging within 25 minutes after arrival at the emergency department.

Setting

Hospitals included in the study were categorized as regional stroke centres, district stroke centres and nondesignated hospitals. Regional stroke centres use written stroke protocols for emergency services and within the emergency department. In addition, they have CT neuroimaging capability, clinicians with stroke expertise, neurosurgical and neurointerventional radiology facilities, and resources similar to those found in American comprehensive stroke centres. District stroke centres share the features of regional stroke centres, but they do not have on-site neurosurgical or neurointerventional radiology facilities and are similar to American primary stroke centres. Nondesignated hospitals do not fit the definition of a regional or district stroke centre but do have neuroimaging capability.

Study population

We included all patients 18 years and older with suspected acute stroke seen at hospitals with neuroimaging capacity between Apr. 1, 2010, and Mar. 31, 2011. If a patient presented more than once during the study period, data from only the first presentation were retained for analysis. We excluded patients who died before receipt of neuroimaging, those who were transferred from another hospital and patients for whom the exact time of stroke symptom onset was unknown. To limit our analyses to patients for whom rapid neuroimaging would guide decisions about eligibility for thrombolysis, we excluded patients who presented to hospital more than 4 hours after symptom onset.

Statistical analysis

We compared the characteristics of patients who received and did not receive neuroimaging using a χ^2 test for categorical variables and a *t* test for continuous variables. When the

National Institutes of Health Stroke Scale (NIHSS) score was missing, we used a formula to convert the Canadian Neurological Scale score to the NIHSS score.¹⁵ We created a hierarchical Cox proportional hazards model to estimate the effect of time from presentation to neuroimaging and of demographic, medical history, patient presentation and hospital factors on the receipt of neuroimaging. To account for clustering by hospital type, we performed a random-effects multilevel (2-level) regression analysis, with patients being level 1 units and hospitals level 2 units in the model. We used the χ^2 test for model hypothesis testing. We reported adjusted hazard ratios with 95% confidence intervals. Analyses were performed using SAS statistical software version 9.3. We considered *p* values less than 0.05 to be statistically significant, and all *p* values were based on 2-tailed tests.

Results

In 2010/11, 13 250 patients were enrolled in the Ontario Stroke Registry. After we applied the exclusion criteria, our study cohort consisted of 3984 patients (Figure 1). The mean time from symptom onset to arrival at the emergency department was 1.49 (SD 0.89) hours. A total of 1087 patients (27.3%) underwent timely neuroimaging after presentation (Table 1); 94.0% of the examinations were CT and 6.0% were MRI. The greatest proportion of patients who received timely neuroimaging were those who presented to the emergency department within 30 to 60 minutes after symptom onset. The

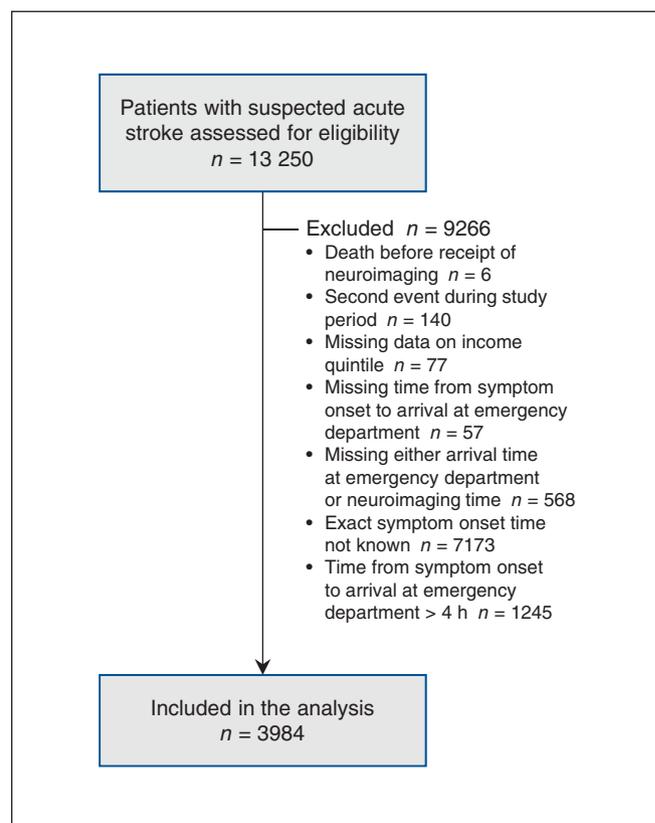


Figure 1: Selection of patients for the study cohort.

Table 1 (part 1 of 2): Characteristics of patients with suspected acute stroke who arrived at emergency department within 4 hours after symptom onset and received timely neuroimaging (≤ 25 min) or delayed neuroimaging

Characteristic	Total <i>n</i> = 3984	Timely neuroimaging <i>n</i> = 1087 (%)	Delayed neuroimaging <i>n</i> = 2897 (%)	<i>p</i> value
Patient				
Time from symptom onset to arrival at emergency department, h, mean \pm SD	1.49 \pm 0.89	1.33 \pm 0.75	1.55 \pm 0.93	< 0.001
Time from symptom onset, h				
≤ 0.5	280	64 (22.9)	216 (77.1)	< 0.001
> 0.5–1.0	1245	399 (32.0)	846 (68.0)	
> 1.0–1.5	939	273 (29.1)	666 (70.9)	
> 1.5–2.0	580	169 (29.1)	411 (70.9)	
> 2.0–3.0	585	132 (22.6)	453 (77.4)	
> 3.0–4.0	355	50 (14.1)	305 (85.9)	
Age, yr				
18–44	149	38 (25.5)	111 (74.5)	0.7
45–64	985	282 (28.6)	703 (71.4)	
65–79	1446	391 (27.0)	1055 (73.0)	
≥ 80	1404	376 (26.8)	1028 (73.2)	
NIHSS score				
≤ 4	2352	383 (16.3)	1969 (83.7)	< 0.001
> 4	1348	642 (47.6)	706 (52.4)	
Missing data	284	62 (21.8)	222 (78.2)	
Sex				
Female	1947	484 (24.9)	1463 (75.1)	< 0.001
Male	2037	603 (29.6)	1434 (70.4)	
Income quintile				
1 (lowest)	785	202 (25.7)	583 (74.3)	0.8
2	799	219 (27.4)	580 (72.6)	
3	778	216 (27.8)	562 (72.2)	
4	791	224 (28.3)	567 (71.7)	
5 (highest)	831	226 (27.2)	605 (72.8)	
Preferred language				
English	3509	926 (26.4)	2583 (73.6)	0.002
Other	383	132 (34.5)	251 (65.5)	
UTD	92	29 (31.5)	63 (68.5)	
Living independently before admission				
No	1117	278 (24.9)	839 (75.1)	0.03
Yes	2867	809 (28.2)	2058 (71.8)	
Medical history				
Stroke, TIA or ICH				
No	2789	810 (29.0)	1979 (71.0)	< 0.001
Yes	1195	277 (23.2)	918 (76.8)	
Carotid revascularization				
No	3935	1073 (27.3)	2862 (72.7)	0.8
Yes	49	14 (28.6)	35 (71.4)	

Table 1 (part 2 of 2): Characteristics of patients with suspected acute stroke who arrived at emergency department within 4 hours after symptom onset and received timely neuroimaging (≤ 25 min) or delayed neuroimaging

Characteristic	Total <i>n</i> = 3984	Timely neuroimaging <i>n</i> = 1087 (%)	Delayed neuroimaging <i>n</i> = 2897 (%)	<i>p</i> value
Diabetes mellitus				
No	3084	834 (27.0)	2250 (73.0)	0.5
Yes	900	253 (28.1)	647 (71.9)	
Hypertension				
No	1332	326 (24.5)	1006 (75.5)	0.005
Yes	2652	761 (28.7)	1891 (71.3)	
Hyperlipidemia				
No	2333	618 (26.5)	1715 (73.5)	0.2
Yes	1651	469 (28.4)	1182 (71.6)	
Dementia				
No	3660	999 (27.3)	2661 (72.7)	0.9
Yes	324	88 (27.2)	236 (72.8)	
Other cardiovascular disease				
No	2831	732 (25.9)	2099 (74.1)	0.002
Yes	1153	355 (30.8)	798 (69.2)	
Presentation				
During business hours				
No	2552	714 (28.0)	1838 (72.0)	0.2
Yes	1432	373 (26.0)	1059 (74.0)	
Arrived to hospital from				
Home	3539	972 (27.5)	2567 (72.5)	0.02
Nursing, retirement home or complex continuing care	327	95 (29.1)	232 (70.9)	
Other	14	≤ 5 (35.7)	9 (64.3)	
Missing or UTD	104	15 (14.4)	89 (85.6)	
Hospital				
Type				
Regional stroke centre	1798	523 (29.1)	1275 (70.9)	< 0.001
District stroke centre	1404	521 (37.1)	883 (62.9)	
Not a stroke centre	782	43 (5.5)	739 (94.5)	
Location				
Rural (population < 10 000)	3785	1081 (28.6)	2704 (71.4)	< 0.001
Urban	199	6 (3.0)	193 (97.0)	
Annual stroke volume				
High (> 200)	3341	1005 (30.1)	2336 (69.9)	< 0.001
Medium (101–200)	375	65 (17.3)	310 (82.7)	
Low (≤ 100)	268	17 (6.3)	251 (93.7)	

Note: ICH = intracranial hemorrhage, IQR = interquartile range, NIHSS = National Institutes of Health Stroke Scale, TIA = transient ischemic attack, UTD = unable to determine.

median time from presentation to neuroimaging was 0.80 (interquartile range 0.38–2.30) hours.

In the univariable analysis, many factors were associated with timely neuroimaging (Table 1). The proportion of

patients who received timely neuroimaging was higher at the designated stroke centres than at the nondesignated hospitals (29.1% at regional and 37.1% at district stroke centres v. 5.5% at nondesignated hospitals). In the multivariable analy-

sis, the factors independently associated with an increased likelihood of timely neuroimaging were less time from symptom onset to presentation, more severe stroke symptoms (NIHSS score > 4), male sex, no history of stroke or TIA, arrival to hospital from a setting other than home and presentation to a designated district or regional stroke centre or to an urban hospital (Table 2).

Interpretation

Our study showed that timely neuroimaging was performed in less than one-third of patients with suspected acute stroke who presented to an emergency department within 4 hours after symptom onset (i.e., a time when neuroimaging could have reasonably been performed within the 4.5-hour thrombolytic treatment window). These results suggest that the management of some patients with acute ischemic stroke is suboptimal and that otherwise eligible patients are not receiving thrombolytic or endovascular therapy.

Few prior studies examined neuroimaging rates among patients with suspected acute stroke. A study from the United States found that 41.7% of patients with suspected stroke underwent neuroimaging within 25 minutes after hospital arrival; however, the study sample was limited to patients whose time from symptom onset to emergency department arrival was 2 hours or less.¹⁶ This timeframe reflected the previous recommendation of a 3-hour window for thrombolysis.¹⁶ A number of other studies also examined neuroimaging rates among patients with acute ischemic stroke or patients who presented with stroke-like symptoms.^{15–18} However, they restricted the study samples to patients who ultimately received thrombolytic therapy,^{17,18} or they estimated rates of imaging within 25 minutes among patients who presented either within 2 or within 4.5 hours after symptom onset.^{16,19,20}

We identified a number of factors independently associated with neuroimaging delays. Patients who presented to a rural hospital with imaging capacity were less likely than those presenting to urban hospitals to receive timely neuroimaging. This finding is consistent with previous studies whose findings suggested that patients seen at rural centres are less likely to receive neuroimaging,²¹ to use emergency medical services²² or to receive intravenous thrombolysis²³ and that hospitals with greater volumes of stroke patients have increased rates of neuroimaging.²⁴ Although we found that patients who presented to a designated stroke centre were more likely to receive timely neuroimaging than those seen at other centres, the proportion of patients who received timely neuroimaging was still surprisingly low.

Patients who presented with less severe stroke symptoms were more likely than those with more severe symptoms to experience a neuroimaging delay. These findings are consistent with other studies showing that patients with an NIHSS score of 4 or less had an increased door-to-needle time⁷ and that patients with more severe stroke symptoms at presentation were more likely to receive neuroimaging within 25 minutes.¹⁶ Possible explanations for these findings include a lower

Table 2: Factors associated with timely receipt of neuroimaging among patients with suspected acute stroke who presented within 4 hours after symptom onset

Factor	Hazard ratio (95% CI)
Time from symptom onset to arrival at hospital, h (v. ≤ 0.5 h)	
> 0.5–1.0	1.59 (1.21–2.08)
> 1.0–1.5	1.55 (1.18–2.05)
> 1.5–2.0	1.37 (1.02–1.84)
> 2.0–3.0	1.31 (0.96–1.77)
> 3.0–4.0	0.81 (0.56–1.19)
Age group, yr (v. ≥ 80)	
18–44	1.13 (0.79–1.61)
45–64	1.16 (0.98–1.39)
65–79	1.06 (0.91–1.24)
NIHSS score (v. ≤ 4)	
NIHSS > 4	3.54 (3.09–4.05)
Missing	2.21 (1.61–3.05)
Female sex	0.76 (0.67–0.86)
Income quintile (v. 1, lowest)	
2	1.10 (0.91–1.34)
3	1.19 (0.97–1.45)
4	1.15 (0.94–1.40)
5 (highest)	1.18 (0.97–1.44)
Preferred language (v. English)	
Other	1.06 (0.86–1.30)
UTD	0.82 (0.55–1.22)
Not living independently before admission	0.85 (0.72–1.01)
Medical history	
Stroke, TIA, ICH	0.78 (0.67–0.89)
Carotid therapy	0.66 (0.38–1.13)
Diabetes mellitus	0.96 (0.82–1.10)
Hypertension	1.11 (0.95–1.28)
Hyperlipidemia	1.01 (0.88–1.15)
Dementia	0.95 (0.74–1.21)
Other cardiovascular disease	1.08 (0.94–1.24)
Presentation	
Outside business hours	1.07 (0.94–1.22)
Arrived to hospital from (v. from home)	
Nursing, retirement home or complex continuing care	1.21 (0.94–1.56)
Other	1.90 (0.77–4.67)
Missing or UTD	0.44 (0.24–0.81)
Hospital	
Type (v. nondesignated hospital)	
Regional stroke centre	5.60 (2.70–11.62)
District stroke centre	6.78 (3.66–12.56)
Rural location (v. urban)	0.08 (0.02–0.36)
Annual stroke volume (v. high)	
Medium (101–200)	1.06 (0.54–2.05)
Low (≤ 00)	2.73 (1.00–7.47)

Note: CI = confidence interval, ICH = intracranial hemorrhage, NIHSS = National Institutes of Health Stroke Scale, ref = reference category, TIA = transient ischemic attack, UTD = unable to determine.

diagnostic suspicion for stroke when patient symptoms are milder or an assumption that patients with milder symptoms are not candidates for thrombolytic therapy. Patients who had a shorter time from symptom onset to emergency department arrival received neuroimaging faster than patients with longer times to arrival. This is in contrast to earlier studies that reported a “neuroimaging paradox,” whereby patients who presented earlier experienced delayed neuroimaging or delayed thrombolytic therapy.^{5,7,10,16,25–27}

In our study, women were less likely than men to receive timely neuroimaging, which is consistent with findings in 4 other studies, 1 of which also found a delay in door-to-doctor time.^{16,28–30} Age and socioeconomic status were not factors influencing neuroimaging time in our study, which is in contrast to a study conducted in the United States.¹³ Ontario’s universal public coverage of hospital care may account for this difference.

Our results suggest an urgent need to focus on decreasing the door-to-imaging time among patients who present with suspected acute stroke in Ontario. This would be in keeping with recent recommendations to shift the focus of ischemic stroke policy from extending the window for thrombolytic therapy to providing more rapid treatment.³¹ Decreasing the door-to-imaging time should be part of an overall quality-improvement initiative, such as that suggested by Sauser and associates,¹⁷ wherein time to neuroimaging was 1 of 10 evidence-based strategies to increase the likelihood of timely reperfusion. Recent studies have reported substantial improvements in door-to-imaging performance with the adoption of these initiatives.^{17,32,33} Of note, Ontario has a regional system of stroke care that already endorses many interventions designed to facilitate timely reperfusion, including pre-notification of a suspected stroke by emergency medical services to the receiving hospital, formation of acute stroke teams, stroke-specific medical order sets, and encouragement of direct transfer of patients from the emergency department triage area to the imaging scanner where possible.³⁴

Strengths and limitations

The principal strengths of our study are the large population-based sample, the complete and high-quality data set, statistical analyses accounting for the hierarchical nature of the data, and the fact that patients were managed after the publication of recent stroke guidelines.³⁵

The primary limitation is, as with any observational study, the potential influence of confounding variables. The Ontario Stroke Audit did not collect information about some variables that may affect time to neuroimaging, such as patient preferences, the effect of stroke on the ability to communicate, existence of advanced care directives and emergency department overcrowding.

Conclusion

We found that only a minority of patients with suspected acute stroke who arrived at hospital within the 4-hour thrombolytic treatment window received timely neuroimaging in

Ontario hospitals with neuroimaging capability in 2010/11. Quality-improvement initiatives are urgently needed to address this issue, as a means of increasing the number of patients with acute stroke who receive appropriate revascularization therapy.

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Affiliations: Institute of Health Policy, Management and Evaluation (Burton, Kapral, Krahn, Laupacis), University of Toronto; Departments of Medical Imaging (Burton, Moody) and Medicine (Kapral, Krahn, Laupacis), University of Toronto; Institute for Clinical Evaluative Sciences (Kapral, Li, Fang); Institute of Medical Sciences (Moody), University of Toronto; Toronto Health Economics and Technology Assessment Collaborative (Krahn), University of Toronto; Li Ka Shing Knowledge Institute (Laupacis), St. Michael's Hospital, Toronto, Ont.

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