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Mobile Stroke Units for Prehospital Care of Ischemic Stroke

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Summary

- Stroke is a leading cause of death and disability in Canada, and early diagnosis and treatment are essential to improving patient outcomes.
- Mobile stroke units are similar to ambulances but are equipped with a portable computed tomography (CT) scanner and specially trained staff for the rapid diagnosis and treatment of ischemic stroke.
- Evidence suggests that mobile stroke units reduce the time it takes for people who have suffered a stroke to receive appropriate treatment.
- It is still unclear if earlier treatment in a mobile stroke unit improves long-term functional outcomes.
- Mobile stroke units are expensive to purchase and operate, but evidence suggests that they may be cost-effective.

Background

Stroke is a condition caused when blood vessels in the brain become blocked or rupture, preventing oxygen and nutrient-rich blood from reaching brain cells.[1,2] Signs and symptoms of stroke appear suddenly and may include numbness or loss of strength in the face, arm, or leg; difficulty seeing or speaking; impaired comprehension; confusion; headache; and dizziness or loss of balance.[3]

Ischemic stroke, the most common type of stroke, occurs when a blood clot disrupts blood flow to the brain.[1] Other types of stroke are caused by bleeding within the brain (intracranial hemorrhage) or when a blood vessel at the base of the brain bursts and causes bleeding into the lining of the brain (atraumatic subarachnoid hemorrhage).[1]

The longer the brain goes without oxygen and other nutrients, the more likely a stroke will lead to permanent damage to the brain.[2] When people have an ischemic stroke, restoring blood flow as quickly as possible is key. This treatment strategy, called "time is brain," uses medications that break up blood clots (thrombolytic drugs, such as tissue plasminogen activator [t-PA] or recombinant tissue plasminogen activator) or mechanical means of retrieving and removing the blood clot (endovascular therapy).[4,5]

Stroke costs Canadians an estimated C$3.6 billion annually in health care costs and lost productivity.[1] Although hospitalization rates for stroke have declined since the 1990s, with an increasingly aging population, this decline is expected to flatten, and the number of Canadians who suffer a stroke is expected to increase in the future.[1,3]

People treated in-hospital after a stroke also have increasingly complex medical conditions, and most have at least one pre-existing chronic health condition.[3]

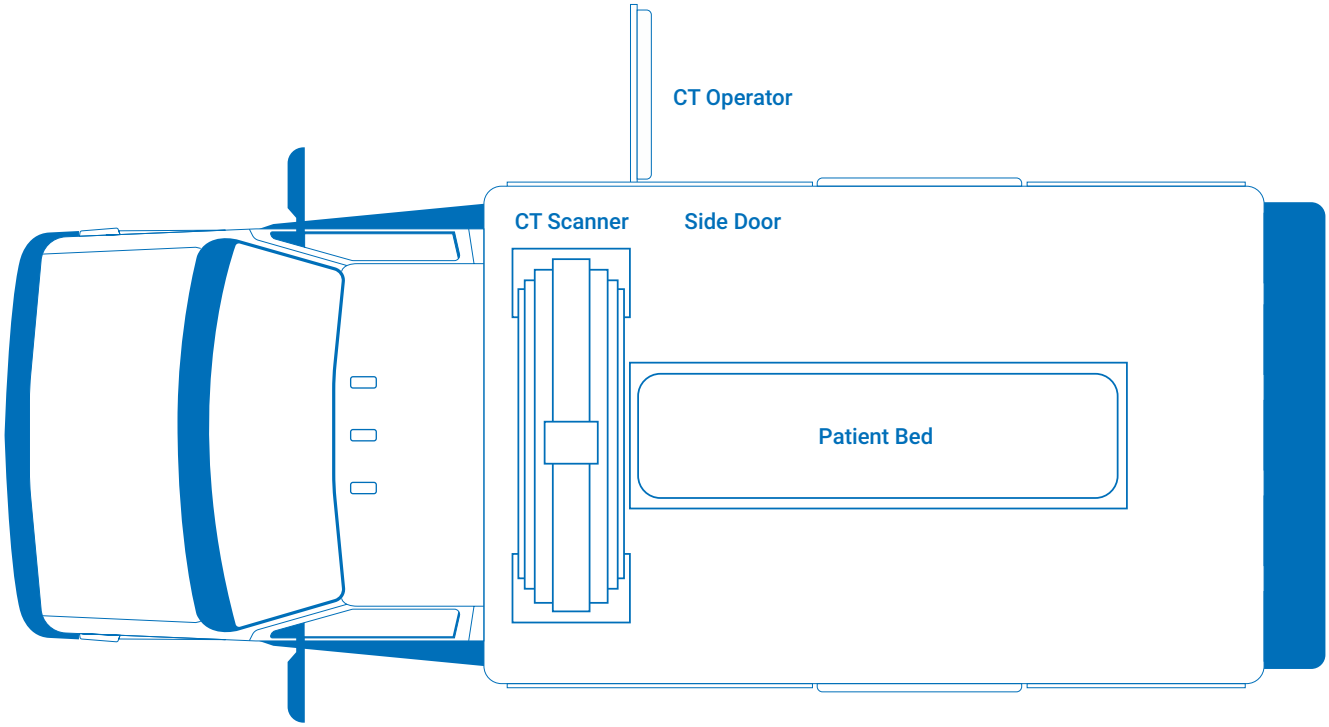
Improvements in stroke care mean that more Canadians have access to comprehensive stroke centres, are treated in dedicated stroke units staffed by multidisciplinary stroke teams, have access to telestroke services (audio and video connections to stroke specialists), and have faster access to appropriate treatments, such as medications to break up blood clots in the brain.[3]

Mobile stroke units are being investigated as a way to provide earlier care to people who may have suffered a stroke.

The Technology

A mobile stroke unit is a modified ambulance or custom-built vehicle, resembling a large ambulance, that contains a small CT scanner to provide on-site imaging of patients with suspected stroke.[6-14] Other features of mobile stroke units vary from region to region and include telestroke equipment, point-of-care laboratories, thrombolytic drugs, and standard emergency response equipment, as in a regular ambulance.[6-14]

Mobile stroke units also differ from regular ambulances in the way they are staffed. In addition to a paramedic or an emergency medical technician, mobile stroke units may be staffed by neurologists, nurses, radiology or CT technicians, or other health professionals.[6-14] In vehicles in which telestroke equipment is available, the mobile stroke unit is also connected to specialists, such as radiologists and neurologists, in the hospital.[15,16]



Adapted with permission from Wolters Kluwer: Health Physics, 2016; 110(5):S73–S80.[53]

Who Might Benefit?

Approximately 62,000 Canadians experience a stroke each year, and approximately 14,000 die after having a stroke[1,2,17] Another 741,800 Canadians are living with the effects of stroke.[1,2,17] However, these numbers are likely underestimates because they do not include people who died outside the health care system or from a silent stroke.[18]

Although stroke occurs most often in people older than 70 years, stroke rates in people in their 50s and 60s are increasing, and rates in younger people (between the ages of 24 and 64) are expected to double by 2030.[3] One-third to two-thirds of all people who survive a stroke need some form of rehabilitation.[18] Early treatment with thrombolytic drugs reduces both the mortality and the morbidity of stroke, and more patients who receive early treatment are discharged home (rather than to a nursing home).[19]

Availability

Canada's first mobile stroke unit began operating in January 2017, as part of a three-year pilot project out of the University of Alberta Hospital in Edmonton.[11]

Elsewhere in the world, mobile stroke units are in use or are being evaluated for use in Germany (where the model originated), the UK, France, Belgium, Switzerland, Finland, Norway, Qatar, Thailand, Australia, Argentina, and in several US cities.[6-10,12-14,20]

Regulation of Mobile Stroke Units in Canada

In Canada, some components of a mobile stroke unit (e.g., the CT scanner) are regulated by Health Canada, but the mobile stroke unit vehicle is not, as it is designed for the transportation of this medical equipment (Gary Scott Holub, Media Spokesperson, Health Canada, Ottawa, ON: personal communication, 2017 Feb 9). How the equipment in a mobile stroke unit is regulated depends on the component; for example, CT scanners are considered a Class III medical device by Health Canada. This designation means that CT scanners are considered a moderate risk and require scientific evaluation to confirm that they comply with regulations. CT scanners are therefore regulated by *Medical Devices Regulations*, but they must also comply with the Food and Drugs Act and the Radiation Emitting Devices Act (Gary Scott Holub: personal communication, 2017 Feb). Small CT scanners, like the one being used in Edmonton's mobile stroke unit,[11] are licensed for use in Canada (Gary Scott Holub: personal communication, 2017 Feb).

In addition to national standards and regulations, mobile stroke units may also be subject to provincial policies on the design, construction, and operation of emergency vehicles.[21-24]

How Much Does It Cost?

The costs of operating a mobile stroke unit include the initial investment in the vehicle and equipment and the ongoing operating, maintenance, and staffing costs.[8,25-27] In Edmonton,

the reported cost of the stroke ambulance is more than C$1 million.[11] In Germany, the vehicle and equipment costs have been reported to be €405,000 and €955,666.[26,27] The vehicle and equipment for the Houston unit cost US$600,000.[25]

Current Practice

Prevention strategies, such as quitting smoking, losing weight, eating a healthier diet, and engaging in more exercise, can reduce the risk of having a stroke.[1-3] The early detection and management of conditions that can lead to stroke, such as atrial fibrillation (irregular heartbeat), high blood pressure, and diabetes, also help reduce the risk of stroke.[1] However, not all strokes can be prevented, and when a stroke occurs, Canadian guidelines recommend the following approaches to prehospital care, thrombolysis, and other management considerations.[4,5]

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Prehospital and Early Care

The 2015 *Canadian Stroke Best Practice Recommendations* note that the use of paramedics to transport people with suspected stroke to hospital is important to patient safety and to patients being appropriately routed to specialized stroke centres, if needed, as quickly as possible.[4] The recommendations for prehospital care and management include:

- using emergency medical services (EMS) dispatch processes designed to recognize the signs of probable stroke
- using out-of-hospital screening tools to assess patients on arrival at the scene
- limiting the amount of time spent at the scene to 20 minutes or less
- measuring the patient's blood glucose level
- directly transferring patients with suspected stroke eligible for thrombolysis to an appropriate centre in less than 3.5 hours from symptom onset, with a target door-to-needle time in the emergency department of 30 minutes and no more than 60 minutes.[4]

After discussing EMS handover to the emergency department, the recommendations emphasize the importance of rapidly assessing patients with suspected stroke and beginning treatment as soon as possible.[4] Initial in-hospital care should include immediate clinical examination to confirm stroke, rule out conditions that resemble stroke, and determine if the patient is eligible for thrombolysis (including ordering blood work).[4] Neuroimaging with noncontrast CT must be done for any patient with suspected stroke.[4]

The 2015 Canadian Association of Emergency Physicians' *Position Statement on Acute Ischemic Stroke* also recommends prehospital protocols, which include the transportation of patients to facilities designed to receive stroke patients, if such facilities are available.[5] Stroke protocols should be in place to evaluate, image, and treat people with stroke as soon as possible, and telemedicine should be available in places where access to specialized care is limited.[5] In the EMS stage of care, stroke calls should be given the highest transportation priority, the time symptoms began should be determined, blood glucose should be measured, and standardized tools should be used on-site to ensure immediate transportation to an appropriate health care facility, if necessary.[5]

Thrombolysis

The 2015 *Canadian Stroke Best Practice Recommendations* for managing acute ischemic stroke state that thrombolysis using t-PA is the standard of care and that screening by a stroke physician (on-site or by telestroke) should take place as soon as possible.[4] Initial imaging should be evaluated using the Alberta Stroke Program Early CT Score, and if a patient is eligible, t-PA should be provided within 4.5 hours of the time symptoms began and as soon as possible after arrival at a hospital.[4] If there is uncertainty about whether a patient is eligible to receive t-PA or if imaging results are unclear, specialists should be consulted as soon as possible.[4]

The Canadian Association of Emergency Physicians' 2015 position statement strongly recommends providing recombinant tissue plasminogen activator to patients with acute ischemic stroke within three hours of the time symptoms began, provided the patients' imaging results rule out any contraindications.[5] The statement also strongly recommends a door-to-needle time of less than 60 minutes in eligible patients.[5]

Other Management Recommendations

A significant change in the 2015 *Canadian Stroke Best Practice Recommendations* is new guidance about endovascular therapy (mechanical clot retrieval) in people with acute ischemic stroke.[4] The decision to provide endovascular therapy should be coordinated in a system that includes EMS; rapid imaging; in-hospital arrangements between the emergency department, the radiology department, and a stroke team; expertise performing the procedure; and access to a stroke unit for ongoing patient management.[4] Patients may be eligible for endovascular therapy within six to 12 hours of when symptoms began and should ideally begin treatment within 60 minutes of CT imaging.[4]

The Evidence

We found two randomized controlled trials of mobile stroke unit models in Germany (cities of Saarland and Berlin) reported in the literature.[6,7] We also found additional observational studies, case studies, and cost studies from Europe and the US.[26-40]

In 2012, researchers in Saarland compared the treatment of 100 adult patients living in a mixed rural-urban setting with at least one symptom of stroke that began no more than 2.5 hours before calling EMS.[6] Patients were randomized in week-long blocks to either mobile stroke unit care (n = 53) or conventional, but optimized care with point-of-care laboratory testing (n = 47).[6] Mobile stroke unit care included a CT scan, point-of-care laboratory testing, thrombolytic treatment when indicated, and transportation to a stroke centre.[6]

The 2014 Prehospital Acute Neurological Treatment and Optimization of Medical Care in Stroke Study (PHANTOM-S), like the Saarland trial, randomized patients in week-long blocks to mobile stroke unit care (n = 310) or conventional stroke care (n = 220). The PHANTOM-S trial looked at adult patients in urban Berlin.[7]

Time to Treatment

Much of the research about mobile stroke units evaluates the time it takes for a patient to receive treatment. However, the outcome measured varies from study to study. For example, the primary end point of the Saarland trial[6] was the time from when dispatchers activated the stroke alarm to the time a treatment decision was made (reported as the "alarm-to-treatment time"); the primary end point of the PHANTOM-S trial[7] was the time from alarm to the time t-PA was administered (also reported as the "alarm-to-treatment time").

The Saarland trial found that patients treated in the mobile stroke unit had a shorter median alarm-to-treatment decision time (35 minutes) than patients who received conventional treatment (median alarm-to-treatment decision time of 76 minutes).[6] Similarly, the PHANTOM-S trial found a reduction in the average alarm-to-t-PA administration time in mobile stroke unit patients (64.1 minutes) compared with patients who received conventional care (76.3 minutes).[7]

Functional Outcomes

The way prehospital care in a mobile stroke unit affects the ability of people to perform the activities of their daily lives after a stroke was also assessed.[6,28] Researchers in Berlin used data collected from patients (n = 932) who had experienced acute ischemic stroke before, during, and after the PHANTOM-S study to compare the proportion of patients living without disability (modified Rankin score of 0 to 1) three months after being treated with prehospital intravenous thrombolysis in a mobile stroke unit (n = 427) with patients who received standard hospital care (n = 505).[28] No difference was found between the two groups.

The proportion of patients living without severe disability or able to walk without assistance (modified Rankin score of 0 to 3) was also assessed in the two groups, and the difference was found to be statistically significant. In the mobile stroke unit group, 83% of patients (n = 253) were living without severe disability or were able to walk on their own three months after treatment, compared with 74% (n = 260) of those in the conventional care group; however, the study was not designed to detect differences in this outcome.[28]

Functional ability (modified Rankin score of less than 2) at one and seven days after mobile stroke unit treatment or conventional treatment was also a secondary end point in the 2012 Saarland trial.[6] No difference was found between the two groups.[6]

Further research to assess the impact of mobile stroke unit care on functional outcomes is being conducted as part of the Benefits of Stroke Treatment Delivered Using a Mobile Stroke Unit study, an observational study in Houston,[29] and the Berlin Prehospital or Usual Delivery of Acute Stroke Care trial, a randomized controlled trial in Berlin.[30]

Triage

The use of mobile stroke units to refer patients to appropriate treatment facilities has been studied in Germany and the US.[31-34] Using data from the PHANTOM-S trial[7] and its pilot study,[41] researchers in Berlin evaluated how care in a mobile stroke unit affected the transport of patients with cerebrovascular disease to appropriate health care facilities.[31] When compared with standard prehospital treatment, patients with cerebrovascular disease or ischemic stroke treated in the mobile stroke unit were more likely to be transported to a facility with a stroke unit, and those with intracranial hemorrhage were more likely to be transported to a hospital with a neurosurgery department.[31]

Investigators in Cleveland, using data from five mobile stroke unit patients and historical controls, found that treatment in a mobile stroke unit may reduce the time it takes for a patient in need of clot retrieval to be brought to an appropriate care facility and receive treatment.[33] A case report in Cleveland also concluded that a CT angiography performed in a mobile stroke unit may be a helpful tool to triage patients eligible for mechanical clot retrieval.[34]

Safety

The available evidence indicates that mobile stroke unit care is as safe as conventional care for treating people with stroke. Both the Saarland and PHANTOM-S trials found no differences between deaths at seven days or intracranial hemorrhages in patients treated in the mobile stroke unit compared with patients who received conventional treatment.[6,7]

Cost-Effectiveness

In Germany, separate cost-effectiveness and benefit-cost studies about the use of mobile stroke units have been conducted.[26,27] In Berlin, on the basis of data from the PHANTOM-S study, researchers found that the use of mobile stroke units, despite large initial and ongoing costs, may be cost-effective compared with conventional treatment (incremental cost-effectiveness ratio = €32,456).[26] In Saarland, researchers calculated the benefit-cost ratio of delivering care using a mobile stroke unit at different distances from its home base and found that at a distance of 30 km, the benefits of providing prehospital care with a mobile stroke unit exceeded the costs (benefit-cost ratio = 1.96).[27]

Other Uses

Researchers are also investigating the speed and reliability of on-board laboratories[35] and the use of mobile stroke units to evaluate and reverse warfarin-related intracranial hemorrhage[36] and diagnose intracranial hemorrhage.[37,38] Wanting to evaluate other uses of the on-board CT scanner, researchers in Saarland assessed a patient with head trauma in the mobile stroke unit and concluded that this additional use of the mobile stroke unit was worthy of research.[32] Also under investigation is the feasibility of using automated stroke imaging software on a mobile stroke unit to assist decision-making in the treatment and triage of patients[39] and to distinguish stroke from other conditions that can cause similar symptoms (stroke mimics).[40]

Concurrent Developments

Other interventions that may improve the early care and management of people who have had a stroke include high-tech solutions, such as using mobile telestroke systems to assess patients in prehospital settings[42-45] or sending a neurologist with a portable ultrasound machine to respond to stroke calls.[46,47] Another option may be to improve dispatchers' abilities to screen for stroke.[48] Allowing paramedics to administer medications (such as NA-1, lisinopril, or transdermal glyceryl trinitrate) may also help improve functional outcomes after a stroke.[49-51]

Implementation Issues

How a mobile stroke unit service would function in Canada is not yet known. Evidence from the pilot project in Edmonton will help address this gap.[11] There is limited information about how mobile stroke units are implemented in other countries, but some common issues are described below.

Using Mobile Stroke Units in Urban and Rural Settings

Currently, the most robust evidence for the use of mobile stroke units comes from the PHANTOM-S trial, which took place within the densely populated urban centre of Berlin.[7] Although the Saarland trial[6] included both urban and rural dispatches of its mobile stroke unit, there is little evidence about how mobile stroke unit services may be impacted by the locations they serve.

In Berlin, researchers used data from the PHANTOM-S trial to evaluate whether time-to-treatment benefits seen in the trial were affected by the distance the mobile stroke unit must travel to provide care.[45] Of the 530 patients included in the analysis, the 200 in the mobile stroke unit group received care more quickly than the 330 patients treated conventionally at all dispatch distances.[45] However, these results may not be generalizable to other systems because of geographic differences.[45]

In Saarland, the benefit-cost analysis conducted by researchers included a distance component and found that although denser populations (such as city centres) are associated with greater benefit-cost ratios, even in rural settings the benefit of providing care using a mobile stroke unit exceeds the costs.[27]

Another proposed option is that in rural areas or areas with low population density, a mobile stroke unit could be dispatched to meet regular emergency services at predesignated points to transfer patients en route.[20]

Equipment Reliability

Observational research about implementing mobile stroke unit services have briefly described issues with equipment reliability.[6,8,15,41] Communication disruptions caused by operator error or poor wireless network connections between the mobile stroke unit and the hospital have been reported, but these disruptions did not impact patient care.[15,41] In Saarland, the point-of-care laboratory was unavailable (reasons not provided) for 10 patients.[6] Difficulties using the CT scanner because of steep streets,[6,8] blocked equipment,[41] and overweight patients[6] have also been reported. Edmonton's mobile stroke unit includes a self-levelling feature to address problems with terrain.[11]

Staffing Models

The staffing of mobile stroke unit teams varies and is one of the largest ongoing costs of operating the service. Several suggestions for containing these costs and streamlining care have been proposed, including cross-training a paramedic as a CT technician;[8] replacing specialists, such as radiologists, with technicians;[6] and reducing the team to essential members (e.g., stroke-trained paramedics).[27]

Substituting on-board physicians with telestroke consultation may also be possible.[15,52] In Cleveland, early observational research of 100 patients evaluated in a mobile stroke unit found that telestroke consultations were successful 99% of the time and concluded that safe and timely care can be provided without having a physician physically present on the mobile stroke unit.[15] In Houston, researchers also found good agreement between on-board assessments and those done by telestroke consultation.[52]

> **"Because mobile stroke units contain a CT scanner, health care providers may be exposed to radiation (or in the case of the CT operator, will be exposed to radiation) they would not otherwise encounter in other prehospital care models."**

Radiation Safety

Because mobile stroke units contain a CT scanner, health care providers may be exposed to radiation (or in the case of the CT operator, will be exposed to radiation) they would not otherwise encounter in other prehospital care models.[8,41,53] Articles describing the initial setup of mobile stroke units note that radiation exposure is a concern.[8,41] In Houston, the mobile

stroke unit team created a radiation safety manual, in part to ensure the safety of the operators and to meet requirements before operating the mobile stroke unit.[8] Radiation shielding of the CT scanner was also assessed by a medical physicist before putting the mobile stroke unit into service.[8]

In Berlin, the mobile stroke unit includes a small, shielded compartment to protect staff when running the CT scanner.[41] Radiation shielding and operating procedures were also tested in simulations for two weeks before seeing patients. The radiation levels measured throughout the course of the PHANTOM-S pilot study were within normal ranges.[41] A 2016 study from Houston that examined radiation exposure in a mobile stroke unit found that the CT operator was exposed to radiation levels well below acceptable limits.[53]

Final Remarks

Currently, there is no published evidence on the use of mobile stroke units in Canada, but research from other countries indicates that these units may allow earlier treatment with thrombolytic medicines for people with acute ischemic stroke. Moreover, mobile stroke units do not pose additional safety risks to patients.

There is limited evidence that mobile stroke units can improve functional outcomes, and further research is under way. There is also limited evidence about how staffing models and the distances mobile stroke units must travel to provide care impact patient outcomes. Additional research is needed to determine if mobile stroke units will be cost-effective in Canadian health care settings and how they might impact care in locations where patients are separated by large distances from centres that provide specialty stroke care.

Methods — Literature Search Strategy

A limited literature search was conducted using the following bibliographic databases: MEDLINE, PubMed, Embase, and the Cochrane Library. Grey literature searching included relevant sections of the *Grey Matters* checklist (cadth.ca/grey-matters). No methodological filters were applied. The search was limited to English language documents published between January 1, 2011, and August 18, 2017. Regular alerts updated the search until project completion; only citations retrieved before March 19, 2017, were incorporated into the analysis.

References

1. Stroke in Canada [Internet]. Ottawa (ON): Public Health Agency of Canada; 2016 Oct 27. [cited 2017 Feb 7]. Available from: https://www.canada.ca/en/public-health/services/publications/diseases-conditions/stroke-in-canada.html
2. Stroke stats & facts [Internet]. Toronto (ON): Ontario Stroke Network; 2016. [cited 2017 Feb 7]. Available from: http://ontariostrokenetwork.ca/information-about-stroke/stroke-stats-and-facts/
3. Together against a rising tide: advancing stroke systems of care [Internet]. Ottawa (ON): Heart and Stroke Foundation; 2014. [cited 2017 Feb 8]. (Stroke report). Available from: http://www.strokebestpractices.ca/wp-content/uploads/2014/06/HSF_SMReport2014E_Final.pdf
4. Casaubon LK, Boulanger JM, Blacquiere D, Boucher S, Brown K, Goddard T, et al. Canadian Stroke Best Practice Recommendations: Hyperacute Stroke Care Guidelines, Update 2015. Int J Stroke. 2015 Aug;10(6):924-40.
5. Harris D, Hall C, Lobay K, McRae A, Monroe T, Perry JJ, et al. Canadian Association of Emergency Physicians position statement on acute ischemic stroke. CJEM. 2015 Mar;17(2):217-26.
6. Walter S, Kostopoulos P, Haass A, Keller I, Lesmeister M, Schlechtriemen T, et al. Diagnosis and treatment of patients with stroke in a mobile stroke unit versus in hospital: a randomised controlled trial. Lancet Neurol. 2012 May;11(5):397-404.
7. Ebinger M, Winter B, Wendt M, Weber JE, Waldschmidt C, Rozanski M, et al. Effect of the use of ambulance-based thrombolysis on time to thrombolysis in acute ischemic stroke: a randomized clinical trial. JAMA. 2014 Apr 23;311(16):1622-31.
8. Parker SA, Bowry R, Wu TC, Noser EA, Jackson K, Richardson L, et al. Establishing the first mobile stroke unit in the United States. Stroke [Internet]. 2015 May [cited 2016 Aug 29];46(5):1384-91. Available from: http://stroke.ahajournals.org/content/46/5/1384.full.pdf+html
9. Erich J. Mobile stroke units bring the hospital to the home. EMS World. 2016;45(8):26-34.
10. Australian first stroke ambulance to save more lives [press release on the Internet]. Melbourne (AU): Victoria State Government; 2016 Dec 22. [cited 2017 Feb 7]. Available from: http://www.premier.vic.gov.au/australian-first-stroke-ambulance-to-save-more-lives/
11. Neufeld L. Edmonton area gets Canada's first stroke ambulance. CBC [newspaper on the Internet]. 2016 Nov 21 [cited 2017 Feb 7]. Available from: http://www.cbc.ca/news/canada/edmonton/edmonton-ambulance-stroke-university-of-alberta-hospital-neurology-brain-1.3861069
12. Shaneyfelt CL. CT Technologist joins mobile stroke unit: R.T. takes unexpected journey while training with first responders. ASRT Scanner. 2015;48(2):17.
13. Mobile stroke units bring treatment to patients, potentially improving long-term outcomes. ED Manag. 2016 Jan;28(1):6-9.
14. Hov MR, Lindner T, Lund CG. Prehospital radiological diagnosis of SAH and triage for neurosurgery [abstract]. Cerebrovasc Dis. 2016;41 Suppl 1:193. (Presented at 25th European Stroke Conference Proceedings; 2016 Apr 13-15; Venice, Italy).
15. Itrat A, Taqui A, Cerejo R, Briggs F, Cho SM, Organek N, et al. Telemedicine in prehospital stroke evaluation and thrombolysis: taking stroke treatment to the doorstep. JAMA Neurol. 2016 Feb;73(2):162-8.
16. Bowry R, Parker S, Rajan SS, Yamal JM, Wu TC, Richardson L, et al. Benefits of stroke treatment using a mobile stroke unit compared with standard management: The BEST-MSU Study Run-In Phase. Stroke. 2015 Dec;46(12):3370-4.
17. Mind the connection: preventing stroke and dementia. 2016 stroke report [Internet]. Ottawa (ON): Heart & Stroke Foundation; 2017. [cited 2017 Feb 24]. Available from: http://www.strokebestpractices.ca/wp-content/uploads/2016/06/HSF_StrokeReport2016_EN-Rev-1.pdf
18. Tracking heart disease and stroke in Canada: stroke highlights 2011 [Internet]. Ottawa (ON): Public Health Agency of Canada; 2011. [cited 2017 Feb 27]. Available from: http://www.phac-aspc.gc.ca/cd-mc/cvd-mcv/sh-fs-2011/pdf/StrokeHighlights_EN.pdf
19. Saver JL, Fonarow GC, Smith EE, Reeves MJ, Grau-Sepulveda MV, Pan W, et al. Time to treatment with intravenous tissue plasminogen activator and outcome from acute ischemic stroke. JAMA [Internet]. 2013 Jun 19 [cited 2017 Mar 28];309(23):2480-8. Available from: http://jamanetwork.com/journals/jama/fullarticle/1697967
20. Fassbender K, Grotta JC, Walter S, Grunwald IQ, Ragoschke-Schumm A, Saver JL. Mobile stroke units for prehospital thrombolysis, triage, and beyond: benefits and challenges. Lancet. 2017;16:227-37.
21. Safety standards for vehicles [Internet]. Ottawa: Transport Canada; 2016. [cited 2017 Mar 7]. Available from: http://www.tc.gc.ca/eng/motorvehiclesafety/safety-standards-vehicles.html
22. The ambulance regulations: being Chapter A-18.1 Reg 1 (effective July 1, 1989) as amended by Saskatchewan Regulations 52/2009 [Internet]. Regina: Government of Saskatchewan; 2009. [cited 2017 Mar 7]. Available from: http://www.qp.gov.sk.ca/documents/English/Regulations/Regulations/A18-1R1.pdf
23. Provincial equipment standards for Ontario Ambulance Services [Internet]. Toronto: Ministry of Health and Long-Term Care, Emergency Health Services Branch; 2011. [cited 2017 Mar 7]. Available from: http://www.msdsb.net/images/EMS/policies/Provincial%20Equipment%20Standards_Version%202.0_December%202011_FINAL.pdf
24. Ambulance vehicle standards code: January 2010 [Internet]. Edmonton: Alberta Health and Wellness; 2010. [cited 2017 Mar 7]. Available from: http://www.health.alberta.ca/documents/EHS-Ambulance-Standards-Code.pdf
25. Rajan SS, Baraniuk S, Parker S, Wu TC, Bowry R, Grotta JC. Implementing a mobile stroke unit program in the United States: why, how, and how much? JAMA Neurol. 2015 Feb;72(2):229-34.
26. Gyrd-Hansen D, Olsen KR, Bollweg K, Kronborg C, Ebinger M, Audebert HJ. Cost-effectiveness estimate of prehospital thrombolysis: results of the PHANTOM-S study. Neurology. 2015 Mar 17;84(11):1090-7.
27. Dietrich M, Walter S, Ragoschke-Schumm A, Helwig S, Levine S, Balucani C, et al. Is prehospital treatment of acute stroke too expensive? An economic evaluation based on the first trial. Cerebrovasc Dis [Internet]. 2014 [cited 2016 Aug 29];38(6):457-63. Available from: http://www.karger.com/Article/Pdf/371427
28. Kunz A, Ebinger M, Geisler F, Rozanski M, Waldschmidt C, Weber JE, et al. Functional outcomes of pre-hospital thrombolysis in a mobile stroke treatment unit compared with conventional care: an observational registry study. Lancet Neurol. 2016 Jul 15.

29. Grotta J. BEnefits of Stroke Treatment Delivered Using a Mobile Stroke Unit (BEST-MSU). 2014 Jul 10 [cited 2017 Feb 7; updated 2016 Sep 12]. In: ClinicalTrials.gov [Internet]. Bethesda (MD): U.S. National Library of Medicine; 2000 - . Available from: https://clinicaltrials.gov/ct2/show/NCT02190500?term=BEST-MSU&rank=1 Identifier: NCT02190500.

30. Ebinger M. Berlin PRehospital Or Usual Delivery of Acute Stroke Care (B_PROUD). 2016 Aug 8 [cited 2017 Feb 7]. In: ClinicalTrials.gov [Internet]. Bethesda (MD): U.S. National Library of Medicine; 2000 - . Available from: https://clinicaltrials.gov/ct2/show/NCT02869386?term=b_proud&rank=1 Identifier: NCT02465346.

31. Wendt M, Ebinger M, Kunz A, Rozanski M, Waldschmidt C, Weber JE, et al. Improved prehospital triage of patients with stroke in a specialized stroke ambulance: results of the pre-hospital acute neurological therapy and optimization of medical care in stroke study. Stroke [Internet]. 2015 Mar [cited 2016 Aug 29];46(3):740-5. Available from: http://stroke.ahajournals.org/content/46/3/740.full.pdf+html

32. Schwindling L, Ragoschke-Schumm A, Kettner M, Helwig S, Manitz M, Roumia S, et al. Prehospital Imaging-Based Triage of Head Trauma with a Mobile Stroke Unit: First Evidence and Literature Review. J Neuroimaging. 2016 Sep;26(5):489-93.

33. Cerejo R, John S, Buletko AB, Taqui A, Itrat A, Organek N, et al. A mobile stroke treatment unit for field triage of patients for intraarterial revascularization therapy. J Neuroimaging. 2015 Nov;25(6):940-5.

34. John S, Stock S, Masaryk T, Bauer A, Cerejo R, Uchino K, et al. Performance of CT Angiography on a Mobile Stroke Treatment Unit: Implications for Triage. J Neuroimaging. 2016 Jul;26(4):391-4.

35. Organek N, Taqui A, Cerejo R, Itrat A, Buletko A, Cho S, et al. The speed and reliability of pre-hospital point-of-care laboratory testing on the mobile stroke treatment unit [abstract]. Neurology [Internet]. 2015 [cited 2016 Aug 31];84(14 Suppl):P4.314. Available from: http://www.neurology.org/content/84/14_Supplement/P4.314 (Presented at 67th American Academy of Neurology Annual Meeting, AAN 2015; 2015 Apr 18-25; Washington, DC).

36. Gomes JA, Ahrens CL, Hussain MS, Winners S, Rasmussen PA, Uchino K, et al. Prehospital reversal of warfarin-related coagulopathy in intracerebral hemorrhage in a mobile stroke treatment unit. Stroke [Internet]. 2015 May [cited 2016 Aug 29];46(5):e118-e120. Available from: http://stroke.ahajournals.org/content/46/5/e118.full.pdf+html

37. Vela-Duarte D, Ramanathan RS, Zafar A, Taqui A, Winners S, Sheikhi L, et al. Prehospital diagnosis of intracerebral hemorrhage in a mobile stroke treatment unit [abstract]. Stroke. 2016;47 Suppl 1. (Presented at American Heart Association/American Stroke Association 2016 International Stroke Conference and State-of-the-Science Stroke Nursing Symposium; 2016 Feb 16-19; Los Angeles, CA).

38. Rozanski M, Waldschmidt C, Kunz A, Ebinger M, Grittner U, Wendt M, et al. Hemorrhage - Intraparenchymal plasma glial fibrillary acidic protein (gfap) for differentiation between hemorrhagic and ischemic strokes in prehospital stroke care [abstract]. Int J Stroke. 2014;9:211. (Presented at 9th World Stroke Congress; 2014 Oct 22-25; Istanbul, Turkey).

39. Grunwald IQ, Ragoschke-Schumm A, Kettner M, Schwindling L, Roumia S, Helwig S, et al. First automated stroke imaging evaluation via dlectronic Alberta stroke program early CT score in a mobile stroke unit. Cerebrovasc Dis. 2016 Jun 16;42(5-6):332-8.

40. Wendt M, Ebinger M, Kunz A, Rozanski M, Waldschmidt C, Weber JE, et al. Copeptin Levels in Patients With Acute Ischemic Stroke and Stroke Mimics. Stroke. 2015 Sep;46(9):2426-31.

41. Weber JE, Ebinger M, Rozanski M, Waldschmidt C, Wendt M, Winter B, et al. Prehospital thrombolysis in acute stroke: results of the PHANTOM-S pilot study. Neurology. 2013 Jan 8;80(2):163-8.

42. Belt GH, Felberg RA, Rubin J, Halperin JJ. In-transit telemedicine speeds ischemic stroke treatment: preliminary results. Stroke. 2016 Sep;47(9):2413-5.

43. Valenzuela Espinoza A, Van Hooff RJ, De SA, Moens M, Yperzeele L, Nieboer K, et al. Development and Pilot Testing of 24/7 In-Ambulance Telemedicine for Acute Stroke: Prehospital Stroke Study at the Universitair Ziekenhuis Brussel-Project. Cerebrovasc Dis. 2016;42(1-2):15-22.

44. Eadie L, Regan L, Mort A, Shannon H, Walker J, Macaden A, et al. Telestroke assessment on the move: prehospital streamlining of patient pathways. Stroke [Internet]. 2015 Feb [cited 2016 Aug 29];46(2):e38-e40. Available from: http://stroke.ahajournals.org/content/46/2/e38.full.pdf+html

45. Koch PM, Kunz A, Ebinger M, Geisler F, Rozanski M, Waldschmidt C, et al. Influence of distance to scene on time to thrombolysis in a specialized stroke ambulance. Stroke. 2016 Aug;47(8):2136-40.

46. Schlachetzki F, Herzberg M, Holscher T, Ertl M, Zimmermann M, Ittner KP, et al. Transcranial ultrasound from diagnosis to early stroke treatment: part 2: prehospital neurosonography in patients with acute stroke: the Regensburg stroke mobile project. Cerebrovasc Dis. 2012;33(3):262-71.

47. Herzberg M, Boy S, Holscher T, Ertl M, Zimmermann M, Ittner KP, et al. Prehospital stroke diagnostics based on neurological examination and transcranial ultrasound. Crit Ultrasound J [Internet]. 2014 [cited 2016 Aug 29];6(1):3. Available from: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3996057/pdf/2036-7902-6-3.pdf

48. Oostema JA, Carle T, Talia N, Reeves M. Dispatcher stroke recognition using a stroke screening tool: a systematic review. Cerebrovasc Dis. 2016 Jun 28;42(5-6):370-7.

49. Morrison L, Hill MD, Tymianski M, Raftis P, Wright G, McAuley G, et al. The FRONTIER trial: Field randomization of NA-1 treatment by early responders [abstract]. Int J Stroke. 2015. (Presented at 2015 Canadian Stroke Conference; 2015 Sep 17-19; Toronto).

50. Shaw L, Price C, McLure S, Howel D, McColl E, Younger P, et al. Paramedic Initiated Lisinopril For Acute Stroke Treatment (PIL-FAST): results from the pilot randomised controlled trial. Emerg Med J [Internet]. 2014 Dec [cited 2016 Aug 29];31(12):994-9. Available from: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC4251169/pdf/emermed-2013-202536.pdf

51. Ankolekar S, Fuller M, Cross I, Renton C, Cox P, Sprigg N, et al. Feasibility of an ambulance-based stroke trial, and safety of glyceryl trinitrate in ultra-acute stroke: the rapid intervention with glyceryl trinitrate in Hypertensive Stroke Trial (RIGHT, ISRCTN66434824). Stroke [Internet]. 2013 Nov [cited 2016 Aug 29];44(11):3120-8. Available from: http://stroke.ahajournals.org/content/44/11/3120.full.pdf+html

52. Wu TC, Parker SA, Jagolino A, Yamal JM, Bowry R, Thomas A, et al. Telemedicine can replace the neurologist on a mobile stroke unit. Stroke. 2017 Feb;48(2):493-6.

53. Gutierrez JM, Emery RJ, Parker SA, Jackson K, Grotta JC. Radiation monitoring results from the first year of operation of a unique ambulance-based computed tomography unit for the improved diagnosis and treatment of stroke patients. Health Phys. 2016 May;110(5 Suppl 2):S73-S80.