NIH-PA Author Manuscript
NIH-PA Author Manuscript

Published in final edited form as:
Int J Stroke. 2009 June ; 4(3): 187–199. doi:10.1111/j.1747-4949.2009.00276.x.

A Comprehensive Review of Prehospital and In-hospital Delay Times in Acute Stroke Care

Kelly R. Evenson, Ph.D[1], **Randi Foraker, M.A.**[1], **Dexter L. Morris, Ph.D. M.D.**[2,3], and **Wayne D. Rosamond, Ph.D.**[1]

[1]Department of Epidemiology, School of Public Health, University of North Carolina, Chapel Hill, NC

[2]Department of Emergency Medicine, School of Medicine, University of North Carolina, Chapel Hill, NC

[3]Neurology Medicines Development Center, GlaxoSmithKline, Research Triangle Park, NC

Abstract

The purpose of this study was to systematically review and summarize prehospital and in-hospital stroke evaluation and treatment delay times. We identified 123 unique peer-reviewed studies published from 1981 to 2007 of prehospital and in-hospital delay time for evaluation and treatment of patients with stroke, transient ischemic attack, or stroke-like symptoms. Based on studies of 65 different population groups, the weighted Poisson regression indicated a 6.0% annual decline ($p<0.001$) in hours/year for prehospital delay, defined from symptom onset to emergency department (ED) arrival. For in-hospital delay, the weighted Poisson regression models indicated no meaningful changes in delay time from ED arrival to ED evaluation (3.1%, $p=0.49$ based on 12 population groups). There was a 10.2% annual decline in hours/year from ED arrival to neurology evaluation or notification ($p=0.23$ based on 16 population groups) and a 10.7% annual decline in hours/year for delay time from ED arrival to initiation of computed tomography ($p=0.11$ based on 23 population groups). Only one study reported on times from arrival to computed tomography scan interpretation, two studies on arrival to drug administration, and no studies on arrival to transfer to an in-patient setting, precluding generalizations. Prehospital delay continues to contribute the largest proportion of delay time. The next decade provides opportunities to establish more effective community based interventions worldwide. It will be crucial to have effective stroke surveillance systems in place to better understand and improve both prehospital and in-hospital delays for acute stroke care.

Keywords

acute stroke therapy; CT scan; neurology; stroke; tPA; treatment

INTRODUCTION

Annually an estimated 15 million people worldwide suffer a stroke, resulting in 5 million deaths and another 5 million with permanent disability (1). Over the next decade, the stroke burden

Address for Correspondence and Reprint Requests: Kelly R. Evenson, Bank of America Center, 137 East Franklin Street, Suite 306, University of NC School of Public Health, Department of Epidemiology, Chapel Hill, NC 27514, USA; kelly_evenson@unc.edu, phone: 919-966-1967, fax: 919-966-9800..

Financial Disclosures: Dr. Morris works at GlaxoSmithKline. GlaxoSmithKline has in the past, and likely will in the future, participate in clinical trials of agents for stroke. Dr. Morris is currently not directly involved in any clinical trials for stroke and the publication of this manuscript would not affect the authors or the institution's financial situation. There are no other financial disclosures.

is projected to rise, particularly in developing countries (2). Timely access to effective medical treatment will be an important element to combat this public health challenge. Acute therapies for stroke, such as tissue plasminogen activator (tPA) was approved more than 10 years ago (3,4), emphasizing the need for rapid assessment of stroke patients. There was early hope that this new treatment would benefit many stroke patients, but this promise has yet to be realized. For example, over a decade later only 1% of stroke patients in the US received tPA from 1999 to 2002, although this may be an underestimate (5).

With the passing of a decade since tPA was granted approval for use in ischemic stroke patients, an assessment of progress towards more rapid access to diagnostic and treatment for stroke is warranted. This study systematically reviewed and summarized studies of time delay in prehospital and in-hospital evaluation and treatment, by updating our prior review of studies through the year 2000 (6). This review is an effort to understand changes over time and to provide insight for future research and practice directions.

METHODS

We conducted this systematic review using the same methods as described in our previous review (6), initially performed through March 2000. All published journal articles which reported on prehospital or in-hospital delay time for acute stroke care, including intervention studies, were included in this review. Abstracts, articles that were not peer reviewed, or dissertation works were not included. We also excluded studies that limited the description of delay time to aneurysmal subarachnoid hemorrhage, children, clinical trials, and studies limited only to patients receiving tPA.

A search was performed in two databases using subject headings and keywords, including studies published through December 2007. First, in the Medical Literature Analysis and Retrieval System Online (MEDLINE) the following search was performed: explode cerebrovascular disorders (medical subject heading) or stroke (keyword); explode emergency medical services (medical subject heading) or any form of delay (keyword); and combine the two with “and.” Second, in the Cumulated Index to Nursing and Allied Health Literature (CINAHL) the following search was performed: cerebral vascular accident (subject heading) or stroke (keyword); explode emergency medical services (subject heading) or treatment delay (subject heading) or any form of delay (keyword); and combine the two with “and”. For both MEDLINE and CINAHL, the search was limited to humans, age 19 years or older, and published in English. We also reviewed the references cited in each of published studies, which were identified through the search strategy, to capture any other potential studies for inclusion.

We extracted and report here only delay time related to total prehospital delay (e.g., onset of symptoms to hospital arrival) or in-hospital delays (e.g., time from emergency department (ED) arrival to ED physician evaluation, neurology evaluation, computed tomography (CT) scan or interpretation, tPA administration, and transfer to an in-patient setting, similar to those reported on the National Institute of Neurological Disorders and Stroke (NINDS) guidelines (7)). We do not, for example, describe components of prehospital delay, such as time from symptom onset to seeking medical help or time from calling emergency medical services (EMS) to arrival of either EMS or to the ED. For prehospital delay, we included the study if it reported a mean or median delay or a percent of the population arriving in so many hours. For in-hospital delay, we included the study if it reported a mean or median delay. In the summary tables provided, sample sizes are based on the number of patients with delay time reported and not on the initial study population size. If such a sample size was not given, we reported the initial study population size. If more than one article described results, we reported from the one with the larger sample size but reference both in the tables. Delay times were rounded off to the nearest tenth of an hour whenever possible. In some studies, means and medians were provided for samples of participants rather than for the whole sample and are therefore reported as such in the tables and summaries. For intervention studies, pre-test and post-test data are reported in the tables. If methodological information (e.g., dates) was missing from the primary reference, we examined a secondary reference cited in the primary publication to obtain the information where possible or we attempted to contact the lead author. The same two reviewers conducted data extraction from all included studies to ensure consistency and reliability.

All median delay times were graphed with the circle size proportional to the study sample. When a study was conducted over several years, we plotted the midpoint of the range in years. For studies not reporting the year of enrollment, we attempted to contact the authors to extract this information in order to plot the figures by year. If we still could not identify a date of the study, it was not included in the model or graphed. The Poisson model using the Pearson scale for over-dispersion provided an acceptable fit to the data, based on the ratio of the deviance to the degrees of freedom from the goodness-of-fit. A Poisson regression equation, unweighted and weighted by sample size, was calculated for median delay times across years using SAS (Cary, NC). Intervention studies were included only once (e.g., if both pre- and post-test medians were reported then only pre-test medians were graphed).

RESULTS

We report results first describing the update (2000 to 2007) since our prior review of the literature (6) that described studies published from 1981 through 2000, followed by a summary of the entire literature (1981 to 2007, labeled “Comprehensive Review Summary”) for prehospital and in-hospital delay times.

Prehospital Delay for Acute Stroke Care

Since our initial review (6) which included 48 unique studies through early 2000, at least 73 more unique reports on prehospital delay for acute stroke care were identified (Table 1). These studies were published through the year 2007 and included two studies (one published in 1997 (8) and one in 1998(9)) not identified on the first review.

These more recent 73 studies included patients worldwide from Asia, Europe, North America, Oceania (e.g., Australia, New Zealand), and South America. Inclusion criteria varied across the studies, including patients with hemorrhagic or ischemic stroke or both. Some studies also included patients with stroke-like symptoms or with transient ischemic attack (TIA). Only a few studies reported truncating the delay time in their analysis (e.g., excluding patients from the analysis with extreme delay time values); these truncated times included 4 hours (10), 24 hours (11-13), 48 hours (14-19), 72 hours (20), and 168 hours (21-23). Additionally, stroke patient enrollment was optional in a study by Katzan et al (24) for prehospital delay times greater than 6 hours. By not excluding extreme times in presentation, the stroke delay time may be affected if outliers occur in the distribution, especially for mean values. Thus, in Table 1 both means and medians are reported, as well as percent of patients arriving within 3, 6, or 24 hours. Among the studies of prehospital delay, the time from symptom onset to ED arrival ranged from a median of 0.8 hours to ~24 hours and a mean of 1.2 hours to 98.8 hours, although not all studies reported both. The 50th percentile of the median prehospital delays reported in Table 1 occurred between 3 and 4 hours and the percent arriving within 3 hours ranged from 6% to 92%.

Comprehensive Review Summary

Figure 1 summarizes all published studies that reported a median prehospital delay time for acute stroke care since 1981. Studies that did not report a median delay time are not graphed. As evidenced by the size of the circles which are proportional to the sample size, only a few studies included more than 1000 patients. Based on the studies of 65 different populations, the weighted Poisson regression indicated an annual decline of 6.0% (model parameter −0.060 hours/year, p<0.001) and the unweighted Poisson regression indicated an annual decline of 2.9% (model parameter −0.029 hours/year, p=0.05). In the modeling, we did not include two outliers, studies with a median prehospital delay of 16.1 hours (25) and 24 hours.(26)

In-hospital Delay for Acute Stroke Care

We identified fewer studies of in-hospital delay for acute stroke patients (25 unique papers since the year 2000) compared to our previous review (6). The studies published between 2000 to 2007 are summarized in Tables 2 and 3, examining the time from ED arrival to ED physician evaluation, neurology evaluation, CT scan or interpretation, and tPA administration. We did not identify any studies reporting on the time from arrival to transfer to an in-patient setting.

Time to an Emergency Department Physician Evaluation

Only four studies published between 2000 and 2007 reported on acute stroke care times from ED arrival to ED physician evaluation (24,27-29). These three studies reported median delays ranging from 0.2 to 1.0 hours.

Comprehensive Review Summary

Overall, based on 10 studies (24,27-35) of 12 different population samples with enrollment dating back to 1991, the weighted and unweighted Poisson regression calculating median study year by median time reported from ED arrival to ED evaluation indicated no decline, respectively (weighted model parameter 0.031 hours/year, p=0.49; unweighted model parameter 0.045 hours/year, p=0.25) (Figure 2a).

Time to Expert Physician (Neurologist) Notification

Twelve unique studies (10,13,16,18,[21],24,29,36-40) published between 2000 and 2007 described acute stroke care time from ED arrival to neurology (defined as the expert physician) notification or evaluation. The median delay times for 10 of these studies ranged from 0.2 to 3.1 hours (10,13,16,21,24,29,36-39), with an additional study conducted in the Philippines reporting a median delay of 7.5 hours (18). The final study reported a mean rather than a median delay time (40). Definitions for neurology timing varied across studies, including time to neurology consultation, time neurologist is notified, and time seen by a neurologist.

Comprehensive Review Summary

Overall, based on 14 unique studies (10,13,16,18,[21],[24],[29],30,32,35-39) with 16 different populations with enrollment dating back to 1991, the weighted Poisson regression calculating median study year by median time from arrival to neurology notification or evaluation indicated a nonsignificant annual decline of 10.2% (model parameter −0.102 hours/year, p=0.23) and the unweighted Poisson regression indicated a nonsignificant annual decline of 10.4% (model parameter −0.104 hours/year, p=0.17) (Figure 2b).

Time to a CT Scan or Interpretation

Nineteen unique studies (10,13,18,21,[23],[24],[29],37,38,40-49) describe acute stroke care time from ED arrival to CT scan, published between 2000 and 2007. The median delay times ranged from 0.1 to 3.1 hours for 13 of 14 studies, (10,13,21,23,[24],[29],[37],[38],41-43,46,49) with an additional study conducted in the Philippines reporting a median delay of 5.5 hours (18). The remaining 5 studies reported a mean delay time rather than a median delay time (40,44,45, 47,48).

Comprehensive Review Summary

Overall, based on the 19 studies of 23 different samples (10,13,18,21,[23],[24],[29],[33]-[35],[37],[38], 41-43,49-51), the weighted Poisson regression calculating median study year by median time from arrival to CT scan indicated an annual decline of 10.7% (model parameter −0.107 hours/year, p=0.11) and the unweighted Poisson regression indicated an annual decline of 11.3% (model parameter −0.113 hours/year, p=0.06) (Figure 2c). In the modeling, we did not include one outlier, a study reporting a median delay of 48 hours from ED arrival to CT scan (52).

Hospital Arrival to tPA Administration

Prior to the year 2000, no studies reported time from hospital arrival to tPA administration. Of the studies reviewed between 2000 and 2007, four (41,44,45,53) reported this time. Two studies reported a mean time from ED arrival to tPA administration as 0.8 (44) and 1.4 hours (45); two other studies reported median times of 1.3 hours (53) and 1.5 hours (41).

DISCUSSION

We identified 123 unique studies reporting on prehospital and in-hospital delay to diagnosis and care for acute stroke have been published since 1981. These studies enrolled patients dating back to 1971 from more than 30 countries worldwide. Globally, we identified only one study from South America, conducted in Brazil.(40) Africa is the only continent not represented by this research, despite a significant rising number of deaths occurring there from stroke each year (1). For these worldwide studies of acute stroke, the majority of the delay to treatment continues to be attributable to the prehospital portion consistent with what others have reported (54).

Delay Time

Our summary indicates, using weighted Poisson regression, an annual decline in prehospital delay time of 6.0% percent based on the studies of 65 different populations, since the first study published in 1980 that reported a median prehospital delay for stroke patients. While this is a meaningful decline, as evidenced from Figure 1, this decline has slowed in more recent years for the published studies in our review. Studies published since the year 2000 reporting a median delay of symptom onset to ED arrival indicate that the 50th percentile for delay occurred between 3 and 4 hours. This relatively long delay time excludes many patients from being considered for tPA therapy and may contribute to longer subsequent in-hospital delays to full evaluation and care. Few studies explore how prehospital delay subsequently affects in-hospital delay times for stroke patients, especially given that these events are not independent of one another (13,24).

For the in-hospital portion of delay, ED delays have not appreciably changed, but delays to provision of neurology evaluation (10.2% annual decline) and CT scan (10.7% annual decline) appear to have improved, although not reaching statistical significance. It should be noted that studies limited to only patients receiving tPA were excluded from our review, as we were interested in describing results from a broader population perspective, including all patients arriving at the hospital regardless of receipt of tPA. By including only studies of patients receiving tPA, the delay times reported would have been reduced by design, because of the time requirements of the drug, resulting in selection bias.

It is helpful to compare these in-hospital times against some standard or guideline. One approach would be to use as a benchmark the NINDS recommendations (7) published in 1996 that outline the following goals for acute stroke patients: 10 minutes from the hospital door to emergency physician evaluation, 15 minutes from the door to stroke team or expert physician notification (interpreted as a neurologist), 25 minutes from the door to initiation of the CT scan, 45 minutes from the door to expert CT interpretation, 60 minutes from the door to drug administration, and 3 hours or less from the door to transfer to an in-patient setting. Using these benchmarks applied to all studies we reviewed reporting median times, of 10 studies or 12 population groups no studies met the ED delay time of 10 minutes (24,27-35). Two (10,24) of 12 studies or 14 population samples reporting median delay times met the neurology delay time of 15 minutes (13,16,18,21,[29],30,32,35-39). Two more recent studies (10,41), using their median delay time, met the 25 minutes goal from arrival to CT scan initiation, but not in 18 other studies reporting a median delay time (13,18,21,23,[24],[29],[33]-[35],[37],[38],[42],43,46,49-52). Only one study reported median time to CT interpretation (24), for which it was not met. Neither of the two studies (41,53) reporting a median value fell within the 60 minute time recommendation from arrival to tPA administration. We did not identify any studies reporting on the time from arrival to transfer to an in-patient setting. From this, we conclude that few studies report that NINDS in-hospital goals (7) are being met based on median reported times. This review provides the times in Tables 1 and 2 and the prior paper (6), so comparisons to other guidelines, either established or yet to be written can be made.

We found that there is little standardization as to how delay components are defined and reported. Such inconsistency makes comparisons across studies and countries difficult. For example, “time to CT scan” could be interpreted as time transported to CT (such as defined in Katzan et al (24)), arrival at the CT, initiation of the CT scan, or completion of the CT. As another example, “time to stroke team evaluation” is often interpreted as time to the neurologist, especially in hospitals without stroke teams, although it is not clear if it was intended to be this way.

Intervention Studies

Several studies have evaluated the effect of smaller scale community-wide campaigns on stroke awareness, knowledge, and/or delay (55-63). In addition, system changes, such as professional education (37,46,55,59,60,64,65), altering emergency dispatch and transport protocols (66, 67), instigating an ED fee (68), creating a rapid ED assessment (41), and implementing a stroke code team or call system (42,58,64,69) have been all evaluated in an effort to reduce delay in stroke evaluation and care during either the prehospital or the in-hospital phase. Even so, effective interventions targeting those at highest risk for stroke are still needed and it would be desirable if interventions and even observational description of these associations were driven by a theoretical framework.

Limitations of this Review

Summarizing the literature in this way poses several challenges. First, these conclusions are drawn from a variety of data sources, countries, time periods, and patient populations. The type of surveillance data truly needed to monitor these trends is only now becoming available (70) (examples include (71,72)). As countries worldwide establish stroke-based surveillance systems with comparable data elements, a better interpretation of trends over time and comparisons within and across countries can be accomplished. Until then, we feel this review provides the best worldwide interpretation of these trends, through the use of peer-reviewed publications. Second, the case definition of stroke varied across studies, although the interest was always acute stroke. Occasionally, studies applied exclusions due to extreme prehospital delay times for acute stroke. These exclusions were also inconsistent, hampering direct comparisons across studies. Third, not all studies reported a median delay time. While some studies provided a mean, subject to outliers, a few studies only reported the percentage receiving care within a given number of hours. Fourth, the definition of symptom onset of stroke was not defined consistently across studies, particularly when the patient awoke with stroke symptoms. Fifth, information on whether or not each participating hospital was approved to provide tPA or had a transfer protocol to a hospital providing tPA treatment of ischemic stroke was not available across all studies. The inclusion of data from hospitals that were not approved to administer tPA for ischemic stroke may have lengthened both prehospital and in-hospital delay times. However, this review represents published delay times in a variety of settings. Finally, we included only peer reviewed studies; thus, we are unsure if these results reflect the broader population. All of these limitations should be considered when interpreting these results.

Reporting Suggestions

Making comparisons across studies would be greatly enhanced if standardization in definitions were established. We suggest that delay time be reported as both a mean and a median and noting if the delay times were truncated. Other suggestions for observational or surveillance studies include designating clear entry criteria into the study that can be replicated across countries and using a standardized method for determining onset time when the patient awoke with symptoms, such as the one developed by Rosamond et al (73). Missing information on key data elements can also hamper surveillance of studies of delay (19). Weintraub (74) suggests that legible records of stroke patients should reflect the time of onset, the time of workup completion, examination findings, the diagnosis and differential diagnosis as well as the proposed treatments (e.g., use or not of tPA), and informed consent. We concur with Katzan et al (24), suggesting placement of the data form in the ED record and developing a standard documentation sheet for stroke patients as part of their medical record.

Extensive work evaluating the different treatment-seeking delay phases in acute coronary syndromes can be useful to studies of delay in accessing acute stroke evaluation and care (54). These phases have been broken down into 1) symptom onset to decision to seek medical attention, 2) decision to seek medical attention to first medical contact, and 3) first medical contact to hospital arrival. We suggest that the initial phase could be defined even further to make the distinction between *onset* of stroke-like symptoms and *recognition* of those symptoms, by patient, family, or observer, as to being symptoms warranting medical attention. Sometimes the onset of symptoms may not correspond to the onset of *recognition* of the symptoms, with the former influencing the consideration of tPA therapy, if applicable, and the latter influencing the likely seeking of medical attention.

Though numerous studies examine factors associated with prehospital delays of acute stroke (54,75), very few have examined these time phases involved in prehospital delay. In addition, it is known that prehospital delay for acute stroke care affects in-hospital delay (13,24). Because the timing of these events are not independent, future studies should consider examining these factors simultaneously rather than separately as has traditionally been done. To do this, timing data will need to be collected for all phases of delay.

Conclusions

We found a decreasing trend in prehospital delay time for acute stroke patients, the time from onset of symptoms to hospital arrival. While time from hospital arrival to ED physician evaluation changed very little over time, there was suggestion that trends for the time from hospital arrival to CT scan and neurology evaluation may be declining. However, lack of standardization in data collection and measurement across studies made comparisons challenging. The data for the most clinically pertinent time span, that of onset of stroke symptoms to onset of tPA administration for treatment of ischemic stroke, where indicated and not contraindicated, have been seldom specifically collected, studied, or reported in observational studies. Quality improvement initiatives, such as the World Health Organization's stepwise approach to stroke (2,76) or the Centers for Disease Control and Prevention Coverdell National Acute Stroke Registries (71), address in-hospital diagnostic and treatment care indicators, including those related to timely initiation of care. These and other programs promise to accelerate progress toward achieving established in-hospital delay time goals. These programs, however, currently do not directly address patient-oriented delay factors associated with care seeking behavior after symptom onset, which continue to be the major source of delay in accessing medical care for stroke. The next decade provides opportunities to establish more effective community based interventions worldwide. It will be crucial to have effective stroke surveillance systems in place to better understand and improve prehospital and in-hospital delays for acute stroke care.

Acknowledgments

Funding: Randi Foraker was funded by the National Institutes of Health (NIH), NHLBI NRSA Training Grant No. 5-T32-HL007055-30.

Additional Contributions: The authors thank Fang Wen for help with the figures and Dr. Leslie Bunce for reviewing an earlier version of the paper.

REFERENCES

1. World Health Organization. The Atlas of Heart Disease and Stroke. 15 - Global Burden of Stroke. Mackay, J.; Mensah, G., editors. Geneva, Switzerland: 2004. Accessed July 14, 2007 at http://www.who.int/cardiovascular_diseases/resources/atlas/en/:Report No.: ISBN 92 4 156276 5 Contract No.: Document Number|
2. World Health Organization. NCD Surveillance: Stroke. Geneva, Switzerland: 2008. [updated 2008; cited September 22, 2008 at http://www.who.int/ncd_surveillance/ncds/strokerationale/en/]; Available from
3. Weiss, K.; Food and Drug Administration. Letter to MD MacFarlane, Genentech, Inc. Rockville, MD: 1996. Reference No. 96-0350Dated June 18, 1996. Accessed August 1, 2007 at http://www.fda.gov/cder/foi/appletter/1996/altegen061896l.pdf;Contract No.: Document Number|
4. Food and Drug Administration. P87-32. TPA Approval -- Blood Clot Dissolver. 1987 Sect. http://www.fda.gov/bbs/topics/NEWS/NEW00191.html accessed August 1, 2007.
5. Bateman B, Schumacher H, Boden-Albala B, et al. Factors associated with in-hospital mortality after administration of thrombolysis in acute ischemic stroke patients: An analysis of the Nationwide Inpatient Sample 1999 to 2002. Stroke 2006;37:440–6. [PubMed: 16397164]
6. Evenson K, Rosamond W, Morris D. Prehospital and in-hospital delays in acute stroke care. Neuroepidemiol 2001;20:65–76.
7. National Institute of Neurological Disorders and Treatment of Acute Stroke. , editor. Proceedings of a National Symposium on Rapid Identification and Treatment of Acute Stroke; Washington, D.C.. 1997 December 12-13; 1996. NIH Publication No. 97-4239Accessed August 1, 2007 at http://wwwnindsnihgov/news_and_events/proceedings/strokeworkshophtm;
8. de Wang Z, Guo H, Zhang XY, Zhu H, Li YH, Zhou G. An observation on the time of hospital arrival and correct diagnosis with CT in acute cerebral stroke patients. Cerebrovasc Dis 1997;7:89–93.
9. Zweifler R, Brody M, Graves G, et al. Intravenous t-PA for acute ischemic stroke: Therapeutic yield of a stroke code system. Neurology 1998;50(2):501–3. [PubMed: 9484380]
10. Chen CH, Huang P, Yang YH, Liu CK, Lin TJ, Lin RT. Pre-hospital and in-hospital delays after onset of acute ischemic stroke --- a hospital-based study in southern taiwan. The Kaohsiung journal of medical sciences 2007;23(11):552–9. [PubMed: 18055303]
11. Konstantopoulos WM, Pliakas J, Hong C, et al. Helicopter emergency medical services and stroke care regionalization: measuring performance in a maturing system. Am J Emerg Med 2007;25(2):158–63. [PubMed: 17276804]
12. Nedeltchev K, Schwegler B, Haefeli T, et al. Outcome of stroke with mild or rapidly improving symptoms. Stroke 2007;38(9):2531–5. [PubMed: 17673713]
13. Morris DL, Rosamond W, Madden K, Schultz C, Hamilton S. Prehospital and emergency department delays after acute stroke : The Genentech Stroke Presentation Survey. Stroke 2000;31(11):2585–90. [PubMed: 11062279]

14. Candelise L, Gattinoni M, Bersano A, Micieli G, Sterzi R, Morabito A. Stroke-unit care for acute stroke patients: an observational follow-up study. The Lancet 2007;369(9558):299–305.
15. Agyeman O, Nedeltchev K, Arnold M, et al. Time to admission in acute ischemic stroke and transient ischemic attack. Stroke 2006;37(4):963–6. [PubMed: 16514096]
16. Keskin O, Kalemoglu M, Ulusoy RE. A clinic investigation into prehospital and emergency department delays in acute stroke care. Med Princ Pract 2005;14(6):408–12. [PubMed: 16220014]
17. Chang K-C, Tseng M-C, Tan T-Y. Prehospital delay after acute stroke in Kaohsiung, Taiwan. Stroke 2004;35(3):700–4. [PubMed: 14963279]
18. Yu RF, San Jose MCZ, Manzanilla BM, Oris MY, Gan R. Sources and reasons for delays in the care of acute stroke patients. J Neurol Sci 2002;199(12):49–54. [PubMed: 12084442]
19. Evenson KR, Rosamond WD, Vallee JA, Morris DL. Concordance of stroke symptom onset time: The Second Delay in Accessing Stroke Healthcare (DASH II) Study. Ann Epidemiol 2001;11(3): 202–7. [PubMed: 11248584]
20. Srivastava A, Prasad K. A study of factors delaying hospital arrival of patients with acute stroke. Neurol India 2001;49(3):272–6. [PubMed: 11593245]
21. Jungehulsing GJ, Rossnagel K, Nolte CH, et al. Emergency department delays in acute stroke - analysis of time between ED arrival and imaging. Eur J Neurol 2006;13(3):225–32. [PubMed: 16618337]
22. Kimura K, Kazui S, Minematsu K, Yamaguchi T. Analysis of 16,922 patients with acute ischemic stroke and transient ischemic attack in Japan. Cerebrovasc Dis 2004;18(1):47–56. [PubMed: 15178987]
23. Yoneda Y, Mori E, Uehara T, Yamada O, Tabuchi M. Referral and care for acute ischemic stroke in a Japanese tertiary emergency hospital. Eur J Neurol 2001;8(5):483–8. [PubMed: 11554914]
24. Katzan IL, Graber TW, Furlan AJ, et al. Cuyahoga County operation stroke speed of emergency department evaluation and compliance with National Institutes of Neurological Disorders and Stroke time targets. Stroke 2003;34(4):994–8. [PubMed: 12624218]
25. De Silva DA, Ong SH, Elumbra D, Wong MC, Chen CL, Chang HM. Timing of hospital presentation after acute cerebral infarction and patients' acceptance of intravenous thrombolysis. Annals of the Academy of Medicine, Singapore 2007;36(4):244–6.
26. Misbach J, Ali W. Stroke in Indonesia: A first large prospective hospital-based study of acute stroke in 28 hospitals in Indonesia. J Clin Neurosci 2001;8(3):245–9. [PubMed: 11386799]
27. Boode B, Welzen V, Franke C, van Oostenbrugge R. Estimating the number of stroke patients eligible for thrombolytic treatment if delay could be avoided. Cerebrovasc Dis 2007;23(4):294–8. [PubMed: 17199087]
28. Harraf F, Sharma A, Brown M, et al. A multicentre observational study of presentation and early assessment of acute stroke. BMJ 2002;325(7354):17–21. [PubMed: 12098723]
29. Schroeder EB, Rosamond WD, Morris DL, Evenson KR, Hinn AR. Determinants of use of emergency medical services in a population with stroke symptoms : The Second Delay in Accessing Stroke Healthcare (DASH II) Study. Stroke 2000;31(11):2591–6. [PubMed: 11062280]
30. Ferro J, Melo T, Oliveira V, Crespo M, Canhao P, Pinto A. An analysis of the admission delay of acute strokes. Cerebrovasc Dis 1994;4:72–5.
31. Salisbury H, Banks B, Footitt D, Winner S, Reynolds D. Delay in presentation of patients with acute stroke to hospital in Oxford. QJM 1998;91(9):635–40. [PubMed: 10024918]
32. Menon SC, Pandey DK, Morganstern LB. Critical factors in determining access to acute stroke care. Neurol 1998;51:427–32.
33. Kothari R, Jauch E, Broderick J, et al. Acute stroke: Delays to presentation and emergency department evaluation. Ann Emerg Med 1999;33(1):3–8. [PubMed: 9867880]
34. Lannehoa Y, Bouget J, Pinel J, Garnier N, Leblanc J, Branger B. Analysis of time management in stroke patients in three French emergency departments: From stroke onset to computed tomography scan. Eur J Emerg Med 1999;6(2):95–103. [PubMed: 10461550]
35. Morris DL, Rosamond WD, Hinn AR, Gorton RA. Time delays in accessing stroke care in the emergency department. Acad Emerg Med 1999;6(3):218–23. [PubMed: 10192674]

36. Mosley I, Nicol M, Donnan G, Patrick I, Kerr F, Dewey H. The impact of ambulance practice on acute stroke care. Stroke 2007;38(10):2765–70. [PubMed: 17717317]
37. Bray J, Martin J, Cooper G, Barger B, Bernard S, Bladin C. An interventional study to improve paramedic diagnosis of stroke. Prehosp Emerg Care 2005;9(3):297–302. [PubMed: 16147479]
38. Koutlas E, Rudolf J, Grivas G, Fitsioris X, Georgiadis G. Factors influencing the pre- and in-hospital management of acute stroke - data from a Greek tertiary care hospital. Eur Neurol 2004;51(1):35–7. [PubMed: 14685017]
39. Wang S, Gross H, Lee SB, et al. Remote evaluation of acute ischemic stroke in rural community hospitals in Georgia. Stroke 2004;35(7):1763–8. [PubMed: 15166386]
40. Leopoldino JFS, Fukujima MM, Silva GS, do Prado GF. Time of presentation of stroke patients in Sao Paulo Hospital. Arq Neuropsiquiatr 2003;61(2A):186–7. [PubMed: 12806494]
41. Batmanian JJ, Lam M, Matthews C, et al. A protocol-driven model for the rapid initiation of stroke thrombolysis in the emergency department. The Medical journal of Australia 2007;187(10):567–70. [PubMed: 18021045]
42. Hamidon BB, Dewey HM. Impact of acute stroke team emergency calls on in-hospital delays in acute stroke care. J Clin Neurosci 2007;14(9):831–4. [PubMed: 17588762]
43. Chen EH, Mills AM, Lee BY, et al. The impact of a concurrent trauma alert evaluation on time to head computed tomography in patients with suspected stroke. Acad Emerg Med 2006;13(3):349–52. [PubMed: 16495426]
44. Lindsberg P, Happola O, Kallela M, Valanne L, Kuisma M, Kaste M. Door to thrombolysis: ER reorganization and reduced delays to acute stroke treatment. Neurology 2006;67(2):334–6. [PubMed: 16864834]
45. Di Legge S, Fang J, Saposnik G, Hachinski V. The impact of lesion side on acute stroke treatment. Neurology 2005;65(1):81–6. [PubMed: 16009890]
46. Behrens S, Daffertshofer M, Interthal C, Ellinger K, van Ackern K, Hennerici M. Improvement in stroke quality management by an educational programme. Cerebrovasc Dis 2002;13(4):262–6. [PubMed: 12011551]
47. Quaba O, Robertson CE. Thrombolysis and its implications in the management of stroke in the accident and emergency department. Scot Med J 2002;47(3):57–9. [PubMed: 12193005]
48. Riopelle RJ, Howse DC, Bolton C, et al. Regional access to acute ischemic stroke intervention. Stroke 2001;32(3):652–5. [PubMed: 11239182]
49. Schellinger PD, Jansen O, Fiebach JB, et al. Feasibility and practicality of MR imaging of stroke in the management of hyperacute cerebral ischemia. AJNR Am J Neuroradiol 2000;21(7):1184–9. [PubMed: 10954266]
50. Wester P, Radberg J, Lundgren B, Peltonen M, Seek-Medical-Attention-in-Time Study Group. Factors associated with delay admission to hospital and in-hospital delays in acute stroke and TIA. Stroke 1999;30(1):40–8. [PubMed: 9880386]
51. Charleston A, Barber P, Bennett P, Spriggs D, Harris R, Anderson N. Management of stroke in Auckland Hospital in 1996. NZ Med J 1999;112(1083):71–4.
52. Cassidy T, Lewis S, Gray C. Computerised tomography and stroke. Scot Med J 1993;38(5):136–8. [PubMed: 8290937]
53. Owe JF, Sanaker PS, Naess H, Thomassen L. The yield of expanding the therapeutic time window for tPA. Acta Neurol Scand 2006;114(5):354–7. [PubMed: 17022786]
54. Moser D, Kimble L, Alberts M, et al. Reducing delay in seeking treatment by patients with acute coronary syndrome and stroke: A scientific statement from the American Heart Association Council on Cardiovascular Nursing and Stroke Council. Circ 2006;114:175–89.
55. Alberts M, Perry A, Dawson D, Bertels C. Effects of public and professional education on reducing the delay in presentation and referral of stroke patients. Stroke 1992;23(3):352–6. [PubMed: 1542895]
56. Becker K, Fruin M, Gooding T, Tirschwell D, Love P, Mankowski T. Community-based education improves stroke knowledge. Cerebrovas Dis 2001;11:34–43.
57. Morgenstern LB, Staub L, Chan W, et al. Improving delivery of acute stroke therapy: The TLL Temple Foundation Stroke Project. Stroke 2002;33(1):160–6. [PubMed: 11779906]

58. Malik M, Gomez C, Tulyapronchote R, Malkoff M, Bandamudi R, Banet G. Delay between emergency room arrival and stroke consultation. J Stroke Cerebrovasc Dis 1993;3(3):177–80.
59. Barsan W, Brott T, Broderick J, Haley E, Levy D, Marler J. Time of hospital presentation in patients with acute stroke. Arch Intern Med 1993;153:2558–61. [PubMed: 7598755]
60. Barsan W, Brott T, Broderick J, Haley, Levy D, Marler J. Urgent therapy for acute stroke: Effects of a stroke trial on untreated patients. Stroke 1994;25(11):2132–7. [PubMed: 7974533]
61. Morgenstern L, Bartholomew L, Grotta J, Staub L, King M, Chan W. Sustained benefit of a community and professional intervention to increase acute stroke therapy. Arch Intern Med 2003;163:2198–202. [PubMed: 14557217]
62. Silver FL, Rubini F, Black D, Hodgson CS. Advertising strategies to increase public knowledge of the warning signs of stroke. Stroke 2003;34(8):1965–8. [PubMed: 12855823]
63. Hodgson C, Lindsay P, Rubini F. Can mass media influence emergency department visits for stroke? Stroke 2007;38:2115–22. [PubMed: 17540967]
64. Zweifler R, Drinkard R, Cunningham S, Brody M, Rothrock J. Implementation of a stroke code system in Mobile, Alabama. Stroke 1997;28:981–3. [PubMed: 9158637]
65. Lellis J, Brice J, Evenson K, Rosamond W, Kingdon D, Morris D. Launching online education for 911 telecommunicators and EMS personnel: Experiences from the North Carolina Rapid Response to Stroke Project. Prehosp Emerg Care 2007;11(3):298–306. [PubMed: 17613903]
66. Culley L, Henwood D, Clark J, Eisenberg M, Horton C. Increasing the efficiency of emergency medical services by using criteria based dispatch. Annals of Emergency Medicine 1994;24(5):867–72. [PubMed: 7978559]
67. Harbison J, Massey A, Barnett L, Hodge D, Ford G. Rapid ambulance protocol for acute stroke. Lancet 1999;353(9168):1935. [PubMed: 10371574]
68. Chow KM, Hui ACF, Szeto CC, Wong KS, Kay R. Hospital arrival after acute stroke: Any better after 10 years? Cerebrovasc Dis 2004;17(4):346. [PubMed: 15103185]
69. Gomez C, Malkoff M, Sauer C, Tulyapronchote R, Burch C, Banet G. Code stroke: An attempt to shorten inhospital therapeutic delays. Stroke 1994;25(10):1920–3. [PubMed: 8091434]
70. Goff D Jr. Brass L, Braun L, et al. Essential features of a surveillance system to support the prevention and management of heart disease and stroke. Circ 2007;115:127–55.
71. The Paul Coverdell Prototype Registries Writing Group. Acute Stroke Care in the US: Results from 4 Pilot Prototypes of the Paul Coverdell National Acute Stroke Registry. Stroke 2005;36(6):1232–40. [PubMed: 15890989]
72. Heuschmann PU, Berger K, Misselwitz B, et al. Frequency of thrombolytic therapy in patients with acute ischemic stroke and the risk of in-hospital mortality: The German Stroke Registers Study Group. Stroke 2003;34(5):1106–12. [PubMed: 12663875]
73. Rosamond W, Reeves M, Johnson A, Evenson K, Paul Coverdell National Acute Stroke Registry Prototype Investigators. Documentation of stroke onset time: Challenges and recommendations. Am J Prev Med 2006;31(6S2):S230–S4. [PubMed: 17178308]
74. Weintraub M. Thrombolysis (tissue plasminogen activator) in stroke: A medicolegal quagmire. Stroke 2006;37:1917–22. [PubMed: 16728683]
75. Kwan J, Hand P, Sandercock P. A systematic review of barriers to delivery of thrombolysis for acute stroke. Age Ageing 2004;33(2):116–21. [PubMed: 14960425]
76. Dalal, P.; Bhattacharjee, M.; Vairale, J.; Bhat, P. Mumbai Stroke Registry (2005-2006) - Surveillance using WHO Steps Stroke Instrument - Challenges and Opportunities; J Assoc Physician India. 2008. p. 675-80.Accessed at http://www.japi.org/september_2008/o_675.pdf
77. Carter KN, Anderson CS, Hackett ML, Barber PA, Bonita R. Improved survival after stroke: Is admission to hospital the major explanation? Trend analyses of the Auckland Regional Community Stroke Studies. Cerebrovasc Dis 2007;23(23):162–8. [PubMed: 17124398]
78. Chiti A, Fanucchi S, Giorli E, Sonnoli C, Morelli N, Orlandi G. Thrombolysis for Acute Stroke: What about the Actual Impact on Patients Older Than 80 Years? Cerebrovasc Dis 2007;24(6):548. [PubMed: 18042983]
79. Foerch C, Misselwitz B, Humpich M, et al. Sex disparity in the access of elderly patients to acute stroke care. Stroke 2007;38(7):2123–6. [PubMed: 17525398]

80. Frankel M, Kinchey J, Schwamm LH, et al. Prehospital and hospital delays after stroke onset--United States, 2005-2006. MMWR Morb Mortal Wkly Rep 2007;56(19):474–8. [PubMed: 17510611]
81. Heidrich J, Heuschmann PU, Kolominsky-Rabas P, Rudd AG, Wolfe CDA. Variations in the use of diagnostic procedures after acute stroke in Europe: results from the BIOMED II study of stroke care. European Journal of Neurology 2007;14(3):255–61. [PubMed: 17355544]
82. Kleindorfer D, Broderick J, Khoury J, et al. Emergency department arrival times after acute ischemic stroke during the 1990s. Neurocritical Care 2007;7(1):31–5. [PubMed: 17622492]
83. Kobayashi A, Skowronska M, Litwin T, Czlonkowska A. Lack of experience of intravenous thrombolysis for acute ischaemic stroke does not influence the proportion of patients treated. Emerg Med J 2007;24(2):96–9. [PubMed: 17251612]
84. Majersik JJ, Smith MA, Zahuranec DB, Sanchez BN, Morgenstern LB. Population-based analysis of the impact of expanding the time window for acute stroke treatment. Stroke 2007;38(12):3213–7. [PubMed: 17962593]
85. Muller R, Pfefferkorn T, Vatankhah B, et al. Admission facility is associated with outcome of basilar artery occlusion. Stroke 2007;38(4):1380–3. [PubMed: 17322095]
86. Nowacki P, Nowik M, Bajer-Czajkowska A, et al. Patients' and bystanders' awareness of stroke and pre-hospital delay after stroke onset: perspectives for thrombolysis in West Pomerania Province, Poland. Eur Neurol 2007;58(3):159–65. [PubMed: 17622722]
87. Ritter MA, Brach S, Rogalewski A, et al. Discrepancy between theoretical knowledge and real action in acute stroke: self-assessment as an important predictor of time to admission. Neurological research 2007;29(5):476–9. [PubMed: 17535554]
88. Zerwic J, Hwang SY, Tucco L. Interpretation of symptoms and delay in seeking treatment by patients who have had a stroke: exploratory study. Heart Lung 2007;36(1):25–34. [PubMed: 17234474]
89. Barr J, McKinley S, O'Brien E, Herkes G. Patient recognition of and response to symptoms of TIA or stroke. Neuroepidemiol 2006;26(3):168–75.
90. Giles MF, Flossman E, Rothwell PM. Patient behavior immediately after transient ischemic attack according to clinical characteristics, perception of the event, and predicted risk of stroke. Stroke 2006;37(5):1254–60. [PubMed: 16574923]
91. Iguchi Y, Wada K, Shibazaki K, et al. First impression at stroke onset plays an important role in early hospital arrival. Intern Med 2006;45(7):447–51. [PubMed: 16679699]
92. Rossnagel K, Jungehulsing GJ, Nolte CH, et al. Out-of-hospital delays in patients with acute stroke. Ann Emerg Med 2004;44(5):476–83. [PubMed: 15520707]
93. Silvestrelli G, Parnetti L, Tambasco N, Corea F, Capocchi G, Stroke P. Characteristics of delayed admission to stroke unit. Clin Exp Hypertens 2006;28(3 4):405–11. [PubMed: 16833053]
94. Ferro JM, Lopes MG, Rosas MJ, Fontes J. Delay in hospital admission of patients with cerebral vein and dural sinus thrombosis. Cerebrovasc Dis 2005;19(3):152–6. [PubMed: 15644627]
95. Gilligan AK, Thrift AG, Sturm JW, Dewey HM, Macdonell RAL, Donnan GA. Stroke units, tissue plasminogen activator, aspirin and neuroprotection: Which stroke intervention could provide the greatest community benefit? Cerebrovasc Dis 2005;20(4):239–44. [PubMed: 16123543]
96. John M, Palmer P, Faile E, Broce M. Factors causing patients to delay seeking treatment after suffering a stroke. W V Med J 2005;101(1):12–5. [PubMed: 15861865]
97. Li C-S, Chang K-C, Tan T-Y. The role of emergency medical services in stroke: A hospital-based study in Kaohsiung, Taiwan. Acta Neurol Taiwan 2005;14(3):126–30. [PubMed: 16252614]
98. Tan T-Y, Chang K-C, Liou C-W. Factors delaying hospital arrival after acute stroke in Southern Taiwan. Chang Gung Med J 2002;25(7):458–63. [PubMed: 12350032]
99. Mandelzweig L, Goldbourt U, Boyko V, Tanne D. Perceptual, social, and behavioral factors associated with delays in seeking medical care in patients with symptoms of acute stroke. Stroke 2006;37(5):1248–53. [PubMed: 16556885]
100. Nolte CH, Rossnagel K, Jungehuelsing GJ, et al. Gender differences in knowledge of stroke in patients with atrial fibrillation. Prev Med 2005;41(1):226–31. [PubMed: 15917015]
101. Qureshi AI, Kirmani JF, Sayed MA, et al. Time to hospital arrival, use of thrombolytics, and in-hospital outcomes in ischemic stroke. Neurology 2005;64(12):2115–20. [PubMed: 15985583]

102. Katzan IL, Hammer MD, Hixson ED, Furlan AJ, Abou-Chebl A, Nadzam DM. Utilization of intravenous tissue plasminogen activator for acute ischemic stroke. Arch Neurol 2004;61(3):346–50. [PubMed: 15023810]

103. Maze LM, Bakas T. Factors associated with hospital arrival time for stroke patients. J Neurosci Nurs 2004;36(3):136–55. [PubMed: 15233413]

104. Bohannon RW, Silverman IE, Ahlquist M. Time to emergency department arrival and its determinants in patients with acute ischemic stroke. Conn Med 2003;67(3):145–8. [PubMed: 12687788]

105. Harbison J, Hossain O, Jenkinson D, Davis J, Louw SJ, Ford GA. Diagnostic accuracy of stroke referrals from primary care, emergency room physicians, and ambulance staff using the face arm speech test. Stroke 2003;34(1):71–6. [PubMed: 12511753]

106. Nedeltchev K, Arnold M, Brekenfeld C, et al. Pre- and in-hospital delays from stroke onset to intra-arterial thrombolysis. Stroke 2003;34:1230–4. [PubMed: 12702836]

107. Pittock SJ, Meldrum D, Hardiman O, et al. Patient and hospital delays in acute ischaemic stroke in a Dublin teaching hospital. Ir Med J 2003;96(6):167–71. [PubMed: 12926756]

108. Silliman SL, Quinn B, Huggett V, Merino JG. Use of a field-to-stroke center helicopter transport program to extend thrombolytic therapy to rural residents. Stroke 2003;34(3):729–33. [PubMed: 12624299]

109. Wojner AW, Morgenstern LB, Alexandrov AV, Rodriguez D, Persse D, Grotta JC. Paramedic and emergency department care of stroke: baseline data from a citywide performance improvement study. Am J Crit Care 2003;12(5):411–7. [PubMed: 14503424]

110. Derex L, Adeleine P, Nighoghossian N, Honnorat J, Trouillas P. Factors influencing early admission in a French stroke unit. Stroke 2002;33:153–9. [PubMed: 11779905]

111. Barber PA, Zhang J, Demchuk AM, Hill MD, Buchan AM. Why are stroke patients excluded from TPA therapy? An analysis of patient eligibility. Neurology 2001;56(8):1015–20. [PubMed: 11320171]

112. Cheung R. Hong Kong patients' knowledge of stroke does not influence time-to-hospital presentation. J Clin Neurosci 2001;8(4):311–4. [PubMed: 11437568]

113. Goldstein LB, Edwards MG, Wood DP. Delay between stroke onset and emergency department evaluation. Neuroepidemiol 2001;20(3):196–200.

114. Johnston SC, Fung LH, Gillum LA, et al. Utilization of intravenous tissue-type plasminogen activator for ischemic stroke at academic medical centers: The influence of ethnicity. Stroke 2001;32(5):1061–8. [PubMed: 11340210]

115. Lacy CR, Suh D-C, Bueno M, Kostis JB. Delay in presentation and evaluation for acute stroke : Stroke Time Registry for Outcomes Knowledge and Epidemiology (S.T.R.O.K.E.). Stroke 2001;32 (1):63–9. [PubMed: 11136916]

116. Villa A, Bacchetta A, O E. Time as responsible of ineligibility for thrombolytic treatment in stroke patients. Am J Emerg Med 2000;18(3):745. [PubMed: 11043642]

117. Villa A, Bonacina M, Paese S, Omboni E. Letter to the Editor. JAMA 1999;281(1):32–3. [PubMed: 9892442]

118. Yip P, Jeng J, Lu C. Hospital arrival time after onset of different types of stroke in greater Taipei. J Formos Med Assoc 2000;99(7):532–7. [PubMed: 10925562]

119. Harper G, Haigh R, Potter J, Castleden C. Factors delaying hospital admission after stroke in Leicestershire. Stroke 1992;23(6):835–8. [PubMed: 1595101]

120. Herderschee D, Limburg M, Hijdra A, Bollen A, Pluvier J, te Water W. Timing of hospital admission in a prospective series of stroke patients. Cerebrovasc Dis 1991;1:165–7.

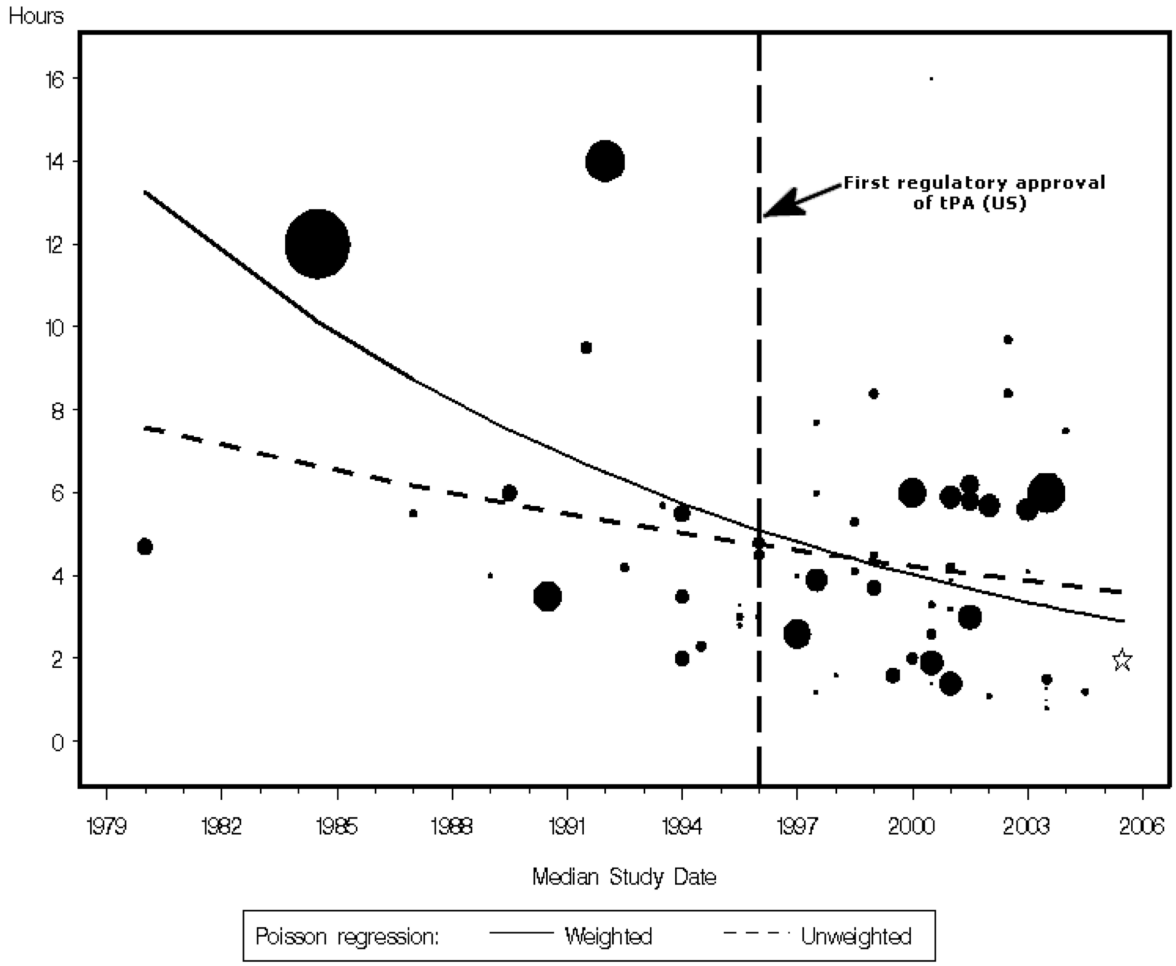
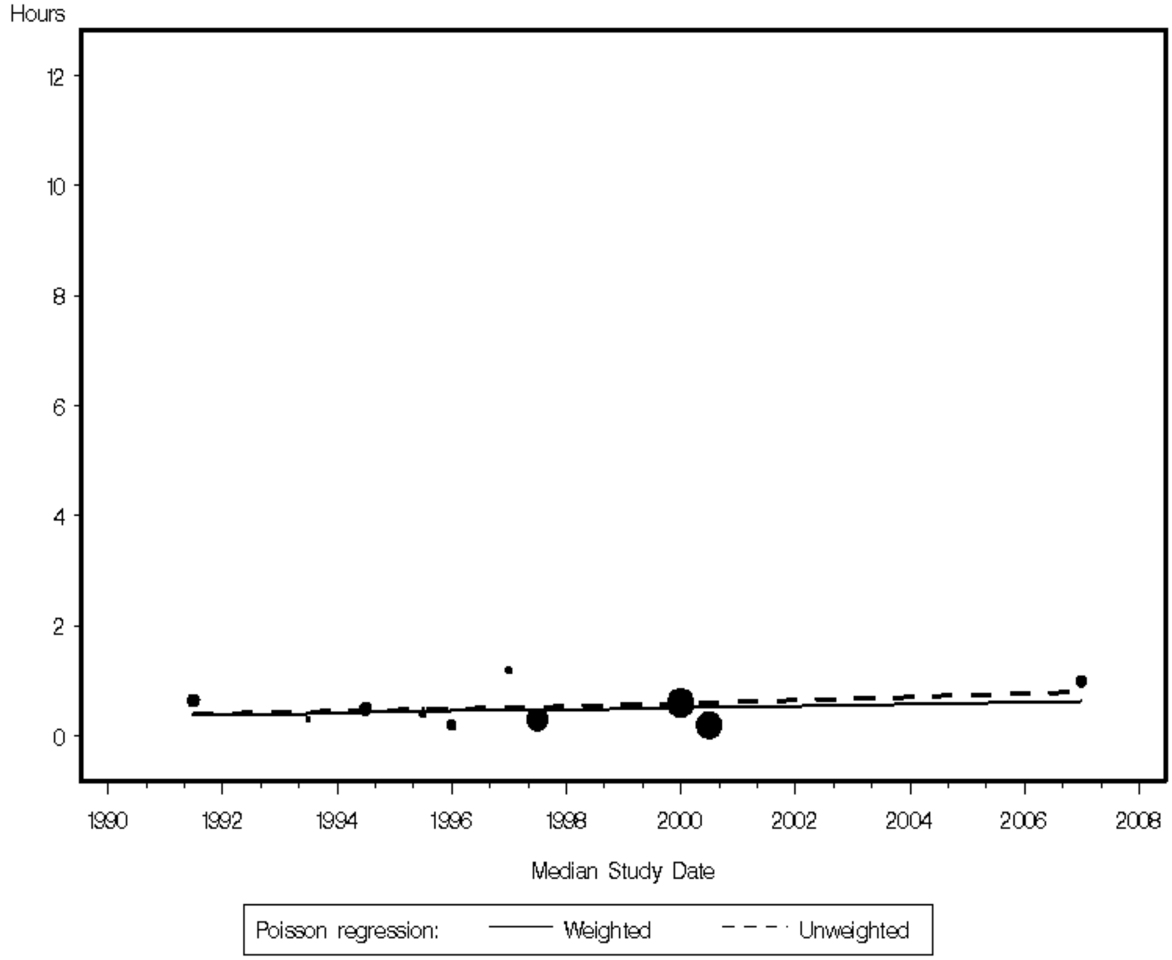


Figure 1.

Median prehospital delay time for stroke evaluation and care over time, with each study represented by a circle weighted for sample size

Note: Studies are plotted from either Table 1 of this paper or Table 1 from (6) if the study provided a median delay time. Two studies were not graphed because they represented outliers.(25,26) Studies with missing enrollment dates (27,46,103,116,117,119,120) or sample sizes that corresponded to the median delay time reported (114) were excluded. The star represents a large study with a sample size of 7901 that did not fit on the plot (80) but was included in the model calculation.


Hours
12
10
8
6
4
2
0
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
Median Study Date
Poisson regression:
Weighted
Unweighted

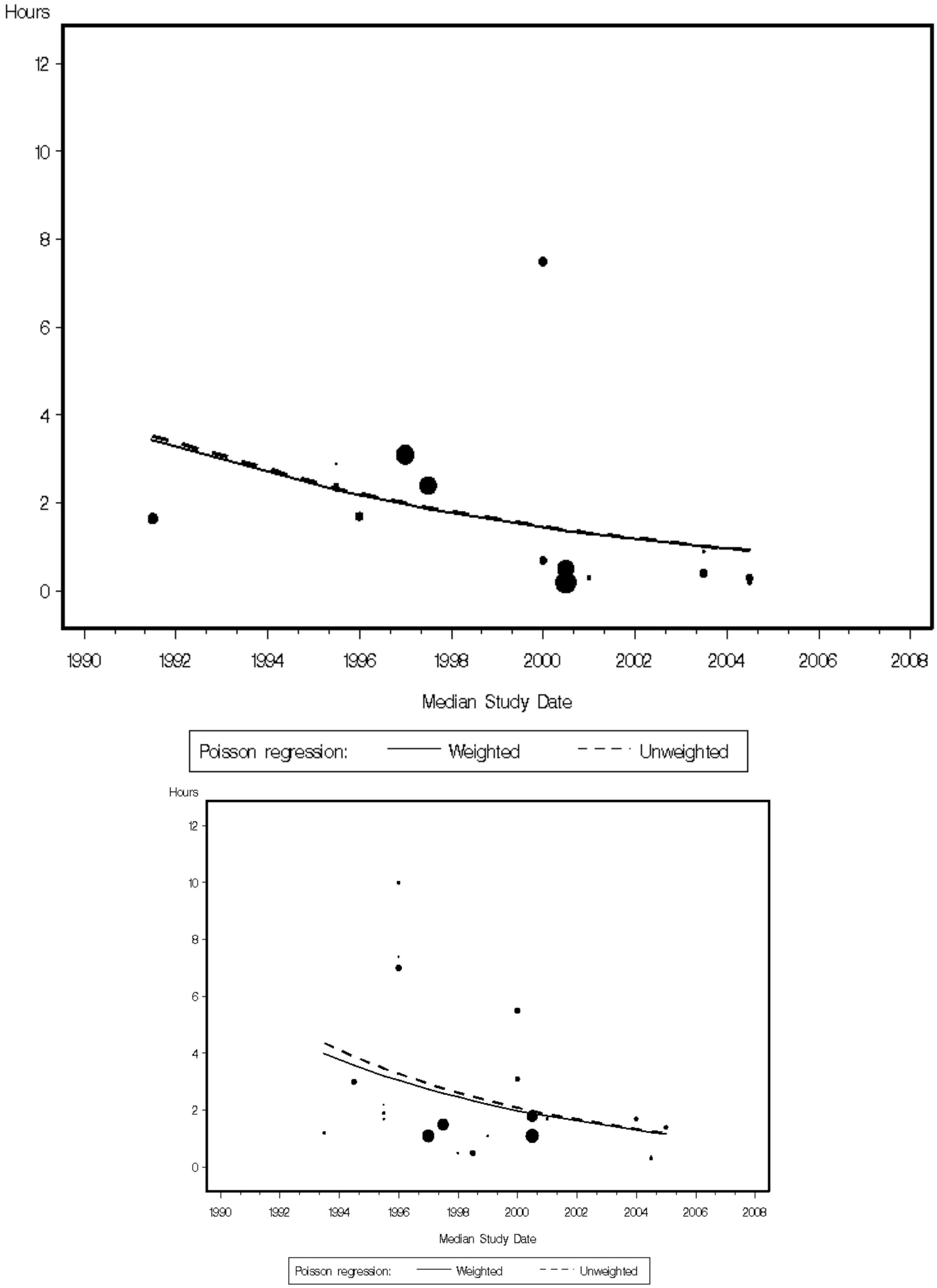

Hours
12
10
8
6
4
2
0
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
Median Study Date
Poisson regression: Weighted Unweighted
Hours
12
10
8
6
4
2
0
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
Median Study Date
Poisson regression: Weighted Unweighted

Figure 2.

Median in-hospital delay for stroke evaluation and care over time, with each study represented by a circle weighted for sample size.

a. Arrival to emergency physician evaluation

b: Arrival to neurology notification or evaluation

c: Arrival to initiation of computed tomography scan

Studies are plotted from either Table 2 of this paper or Table 2 from (6) if the study provided a median delay time.

For graph a, one study with missing enrollment dates was not graphed.(27) For graph c, the Cassidy et al study (52) was not graphed because the delay represented an outlier (48 hours).

NIH-PA Author Manuscript
NIH-PA Author Manuscript

Table 1

Mean and median prehospital stroke delay (symptom onset to emergency department arrival) and percent arriving in 3, 6, and 24 hours, in reverse publication year order, 2000-2007

Study dates	Location	Population Reported On	Delay in Hours:		Percent Arriving In:			Truncated Times in Hours	Reference
			Mean	Median	3 hours	6 hours	24 hours		
2004-2005	Sydney, Australia	100 S			40				Batmanian, 2007 (41)
3 mo period	Netherlands	263 S	6.1	2.6					Boode, 2007 (27)
2001	Italy	4,936 I, H unit 6,636 I, H ward				39 36		48 hrs	Candelise, 2007 (14)
1981-1982 1991-1992 2001-2002	Auckland, New Zealand	1,030 S 1,305 S 1,423 S			42 47 59				Carter, 2007 (77)
2004-2005	Southern Taiwan	I29 I, TIA		1.2	92			4 hrs	Chen, 2007 (10)
2005	Pisa, Italy	258 S			40				Chiti, 2007 (78)
2004	Singapore	100 CI		16.1	12	27	64		De Silva, 2007 (25)
1999-2005	Germany	26,319 S, ICH women			25				Foerch, 2007 (79)
		27,095 S, ICH men			26				
2005-2006	142 hospitals in 4 US states	7,901 S, TIA		2.0	48% in 2 hrs				Frankel, 2007 (80)
1997-1998	10 European countries	1,721 S				43			Heidrich, 2007 (81)
1993-1994 1999	Cincinnati, Ohio	1,757 I 1,963 I			23 26				Kleindorfer, 2007 (82)
2003-2006	Warsaw, Poland	733 I			18% in 2 hrs				Kobayashi, 2007 (83)
2000-2004	Boston, Massachusetts	106 I		1.1		70		24 hrs	Konstantopoulos, 2007 (11)
2000-2005	Southeast Texas	2,257 I			33	46	75		Majersik, 2007 (84)
2003-2004	Munich and Regensburg, Germany	23 BAO direct 16 BAO transfer	2.1 1.5	1.3 1.0					Müller, 2007 (85)
2000-2006	Switzerland	876 I			53	81		24 hrs	Nedeltchev, 2007 (12)
2002-2005	Szczecin, Poland	1,015 I, H		6.0	33				Nowacki, 2007 (86)
1999	Münster, Germany	102 I			35% in				Ritter, 2007 (87)

NIH-PA Author Manuscript
NIH-PA Author Manuscript

Study dates	Location	Population Reported On	Delay in Hours:		Percent Arriving In:			Truncated Times in Hours	Reference
			Mean	Median	3 hours	6 hours	24 hours		
					2 hrs				
2000-2001	Chicago and Urbana/ Champaign, IL	38 I	27.7	16.0	34% in 2 hrs				Zerwic, 2007 (88)
2000-03	Bern, Switzerland	615 I, TIA	6.3	3.0	51	62		48	Agyeman, 2006 (15)
1998-2000	Australia	150 SS		4.5	41		86		Barr, 2006 (89)
2002-03	Oxfordshire, UK	241 TIA					56		Giles, 2006 (90)
2004	Kurashiki, Japan	130 I, CH		7.5	(30 in 2 hrs)				Iguchi, 2006 (91)
2000-01	4 hospitals in Berlin, Germany	588 I, H, TIA	2.5					168	Jungehulsing, 2006 (21) Rossnagel, 2004 (92)
2003	Norway	88 I			23	31			Owe, 2006 (53)
1998-2004	Perugia, Italy	2213 I, H, S	Yr 2000 Yr 2001 Yr 2002 Yr 2003	6.1 5.9 5.7 5.6		61			Silvestrelli, 2006 (93)
2001-02	98 hospitals in 4 US states	6867 I, ICH, SAH, TIA		GA (n=1450) MA (n=1206) MI (n=2566) OH (n=1608)	21 27 19 23	34 41 33 35	61 68 53 61		Coverdell, 2005 (71)
1999-2002	Southwestern Ontario, Canada	179 S LHS (n=109) RHS (n=70)	1.2 1.2						Di Legge, 2005 (45)
2001-02	Canadian Stroke Registry	990 HS LHS (n=458) RHS (n=473)	25 24	5.8 6.2	40 34				
1995-98	20 Portuguese hospitals	90 CVT	4 days				25		Ferro, 2005 (94)
1997-98	Melbourne, Australia	566 I, H, S=undetermined		3.9	34	45	59		Gilligan, 2005 (95)
2003	Charleston, West Virginia	64 S	14.3	4.1	(34 in 2 hrs)				John, 2005 (96)
2003-04	Istanbul, Turkey	229 I, H		1.5	49			48	Keskin, 2005 (16)
1998-99	Kaohsiung, Taiwan	197 S, ICH		5.3				48	Li, 2005 (97); Chang, 2004 (17); Tan, 2002 (98) (median time taken from Li 2005 study)
2000-02	Israel	209 I	15.3	4.2					Mandelzweig, 2005 (99)
2000-01	Berlin, Germany	42 I; female with arrhythmia 154 I; female without		1.4 3.3					Nolte, 2005 (100)

Study dates	Location	Population Reported On	Delay in Hours: Mean	Delay in Hours: Median	Percent Arriving In: 3 hours	Percent Arriving In: 6 hours	Percent Arriving In: 24 hours	Truncated Times in Hours	Reference
		arrhythmia 37 I; male with arrhythmia 221 I; male without arrhythmia		2.5 2.6					
2000	11 hospitals in Western New York	1590 I			21	32	51		Qureshi, 2005 (101)
2002-03	Hong Kong	173 I, S 189 I, S		9.7 8.4	30 32				Chow, 2004 (68)
1999-2000	Cleveland, Ohio	1635 I			15				Katzan, 2004 (102)
1999-2000	156 hospitals in Japan	16922 I, TIA			37	50	73	168	Kimura, 2004 (22)
2000-02	Thessaloniki, Greece	100 I, ICH, SAH, TIA		3.2	45	71			Koutlas, 2004 (38)
not known	2 hospitals, Midwest US	50 I, H, TIA	5.5	5.0	29				Maze, 2004 (103)
2003-04	7 hospitals in rural Georgia	62 I	1.2	0.8					Wang, 2004 (39)
2001	Hartford, Connecticut	64 I		3.9	42	58			Bohannon, 2003 (104)
2000	Newcastle on Tyne, UK	356 CI, ICH, SAH			49				Harbison, 2003 (105)
2000-01	14 hospitals in Ohio	604 I, H, TIA, S	4.0	1.9	66	84		>6 optional	Katzan, 2003 (24)
1998-99	Sao Paulo, Brazil	59 I, TIA, H	18.8		29	32	53		Leopoldino, 2003 (40)
2000-02	Bern, Switzerland	597 I Bern Non-Bern−CT Non-Bern+CT	1.7 2.1 3.5	1.4 2.3 3.5					Nedeltchev, 2003 (106)
1997-98	Dublin, Ireland	117 I	16.0		33	56	87		Pittock, 2003 (107)
1997-2000	Rural Florida and Georgia	111 I helicopter transported			71				Silliman, 2003 (108)
1999-2000	6 hospitals in Houston, Texas	359 SS	3.8	1.6	(59 in 2 hrs)				Wojner, 2003 (109)
6 weeks, year not provided	Heidelberg, Germany	47 I, TIA (pre)	5.2	2.3					Behrens, 2002 (46)
		71 I, TIA (post)	3.3	1.4					
1998-99	Lyon, France	164 I, ICH, SAH	5.2	4.1	29	75			Derex, 2002 (110)
2000	22 hospitals in UK	729 SS		6.0	37	50			Harraf, 2002 (28)

Study dates	Location	Population Reported On	Delay in Hours:		Percent Arriving In:			Truncated Times in Hours	Reference
			Mean	Median	3 hours	6 hours	24 hours		
	and Dublin, Ireland								
2000	104 hospitals in Germany	13440 I			25				Heuschmann, 2003 (72)
1998-2000	5 hospitals in Texas	206 TIA, I, ICH, SAH 365 TIA, I, ICH, SAH		8.4 3.7	(21 in 2 hrs) (30 in 2 hrs)				Morgenstern, 2002 (57); Morgenstern, 2003 (61)
1999	Edinburgh, Scotland	42 SS			10				Quaba, 2002 (47)
2000	Quezon City, Philippines	259 I, ICH, SAH		2.0	59	73	89	48	Yu, 2002 (18)
1996-99	4 hospitals in Calgary, Canada	1168 I			27				Barber, 2001 (111)
1994-95	Germany	222 IS			25		48		Becker, 2001 (56)
1997	Hong Kong	71 I, TIA, ICH	20.6	4.0		56			Cheung, 2001 (112)
1997-98	3 locations in US	559 SS			47			48	Evenson, 2001 (19) Schroeder, 2000 (29)
1998-99	Durham, North Carolina	506 I		1998 1999	~17 ~6	~33 ~17	~63 ~56		Goldstein, 2001 (113)
1999	42 ED in US	511 I		Whites: 3.3 Blacks: 4.9	43				Johnston, 2001 (114)
1996-97	10 ED in New Jersey	553 SS			46	61			Lacy, 2001 (115)
1996-97	28 Indonesian hospitals	2065 SAH, ICH, I	98.8	~24	21	33	50		Misbach, 2001 (26)
1997-98	New Delhi, India	110 S		7.7	25	49	87	72	Srivastava, 2001 (20)
1998-99	Himeji, Japan	254 I, TIA, IS			32	40	70	168	Yoneda, 2001 (23)
1997	48 ED in US	721 SS	5.4	2.6	56			24	Morris, 2000 (13)
1997-99	Germany	64 I	2.2	1.6					Schellinger, 2000 (49)
22 months, year not provided	Milan, Italy	1068 S, TIA	9.0	2.6	53				Villa, 2000 (116) (update from Villa 1999 (117) on prior review)
1997	Taipei, Taiwan	842 S, CH, SAH, TIA			38				Yip, 2000 (118)
1996-97	Mobile, Alabama	152 S			36				Zweifler, 1998 (9)
1994-95	4 hospitals in Bejing,	833 I, ICH/SAH, CE, TIA Ischemic (n=591)			24 18 37	35 28 54	61 54 77		de Wang, 1997 (8)

Study dates	Location	Population Reported On	Delay in Hours:		Percent Arriving In:			Truncated Times in Hours	Reference
			Mean	Median	3 hours	6 hours	24 hours		
	China	ICH/SAH (n=242)							

Abbreviations:

BAO = basilar arterial occulsion, CE = cerebral embolism, CH = cerebral hemorrhage, CI = cortical infarcts, CT = computed tomography, CVT = cerebral vein and dural sinus thrombosis, ED = emergency department, H = hemorrhagic stroke, I = ischemic, ICH = intracerebral hemorrhage, IS = in-hospital stroke, L/R HS = left/right hemispheric stroke, n = number of patients, S = stroke, SAH = subarachnoid hemorrhage, SS = stroke-like symptoms, TIA = transient ischemic attack

Pre and post indicates before and after an intervention.

Please see methods section of paper for details on data abstraction.

Table 2

Mean and median in-hospital stroke delay in reverse publication year order, 2000-2007

Study Dates	Location	Population Reported On	Time in Hours: Mean	Time in Hours: Median	Truncated Times in Hours	Reference
Emergency Department Arrival to Emergency Physician Evaluation						
3 month period	Netherlands	263 S	4.4	1.0		Boode, 2007 (27)
2000-01	14 hospitals in Ohio	692 I, H, TIA, S		0.2	>6 optional	Katzan, 2003 (24)
2000	22 hospitals in UK and Dublin, Ireland	736 SS		0.6		Harraf, 2002 (28)
1997-98	3 locations in US	559 SS		0.3	48	Schroeder, 2000 (29)
Emergency Department Arrival to Neurology Notification or Evaluation						
2004-05	Southern Taiwan	129 I, TIA		0.2	4 hrs	Chen, 2007 (10)
2004-05	Melbourne, Australia	187 I, TIA, ICH		0.3		Mosley, 2007 (36)
2000-01	4 hospitals in Berlin, Germany	558 I, H, TIA		0.5	168	Jungehulsing, 2006 (21)
2000	Melbourne, Australia	212 I, TIA (pre)		0.7		Bray, 2005 (37)
		210 I, TIA (post)		0.4		
2003-04	Istanbul, Turkey	229 I, H		0.4	48	Keskin, 2005 (16)
2000-02	Thessaloniki, Greece	100 I, ICH, SAH, TIA		0.3		Koultas, 2004 (38)
2003-04	7 hospitals in rural Georgia	64 I	1.0	0.9		Wang, 2004 (39)
2000-01	14 hospitals in Ohio	692 I, H, TIA, S		0.2	>6 optional	Katzan, 2003 (24)
1998-99	Sao Paulo, Brazil	59 I, TIA, H	1.5			Leopoldino, 2003 (40)
2000	Quezon City, Phillippines	254 I, ICH, SAH		7.5	48	Yu, 2002 (18)
1997	48 ED in US	615 SS		3.1		Morris, 2000 (13)
1997-98	3 locations in US	559 SS		2.4	48	Schroeder, 2000 (29)
Emergency Department Arrival to Initiation of CT Scan						

Study Dates	Location	Population Reported On	Time in Hours: Mean	Time in Hours: Median	Truncated Times in Hours	Reference
2004-05	Sydney, Australia	15 IS		0.4		Batmanian, 2007 (41)
2004-05	Southern Taiwan	129 I, TIA		0.3*	4 hrs	Chen, 2007 (10)
2004 2005	Melbourne, Australia	172 I, ICH, TIA (pre) 180 I, ICH, TIA (post)		1.7 1.4		Hamidon, 2007 (42)
2004	Philadelphia, Pennsylvania	171 SS		1.7		Chen, 2006 (43)
2000-01	4 hospitals in Berlin, Germany	558 I, H, TIA		1.8	168	Jungehulsing, 2006 (21)
2004	Helsinki, Finland	100 S	0.1			Lindsberg, 2006 (44)
2000	Melbourne, Australia	212 I, TIA (pre)		3.1		Bray, 2005 (37)
		210 I, TIA (post)		2.1		
1999-02	Southwestern Ontario, Canada	179 S LHS (n=109) RHS (n=70)	0.9 0.8			Di Legge, 2005 (45)
2000-02	Thessaloniki, Greece	100 I, ICH, SAH, TIA		1.7		Koutlas, 2004 (38)
2000-01	14 hospitals in Ohio	671 I, H, S		1.1	>6 optional	Katzan, 2003 (24)
1998-99	Sao Paulo, Brazil	59 I, TIA, H	5.3			Leopoldino, 2003 (40)
1999	Heidelberg, Germany	47 I, TIA (pre)	1.3	1.1		Behrens, 2002 (46)
		71 I, TIA (post)	1.2	1.1		
1999	Edinburgh, Scotland	57 SS	2.2 days			Quaba, 2002 (47)
2000	Quezon City, Philippines	259 I, ICH, SAH		5.5	48	Yu, 2002 (18)
			36% in 3 hr 53% in 6 hr			
1999-2000	Southeastern Ontario, Canada	42 I	0.4			Riopelle, 2001 (48)
1998-99	Himeji, Japan	254 I, TIA, IS		0.5	168	Yoneda, 2001 (23)
1997	48 ED in US	615 SS	1.9	1.1	24	Morris, 2000 (13)
1997-99	Germany	64 I	0.6	0.5		Schellinger, 2000 (49)

Study Dates	Location	Population Reported On	Time in Hours: Mean	Time in Hours: Median	Truncated Times in Hours	Reference
1997-98	3 locations in US	559 SS		1.5	48	Schroeder, 2000 (29)
Emergency Department Arrival to Expert CT Interpretation						
2000-01	14 hospitals in Ohio	379 I, H, S		1.7	>6 optional	Katzan, 2003 (24)
Emergency Department Arrival to tPA Administration						
2004-05	Sydney, Australia	15 IS		1.5		Batmanian, 2007 (41)
2004	Helsinki, Finland	100 S	0.8			Lindsberg, 2006 (44)
3 month period, year not provided	Norway	88 I		1.3		Owe, 2006 (53)
1999-2002	Southwestern Ontario, Canada	179 S				Di Legge, 2005 (45)
		LHS (n=109)	1.4			
		RHS (n=70)	1.4			

Pre and post indicates before and after an intervention, respectively.

Please see methods section of paper for details on data abstraction.

Abbreviations: CT = computed tomography, CVD = cerebrovascular disease, H = hemorrhagic stroke, I = ischemic, ICH = intracerebral hemorrhage, IS = in-hospital stroke, L/R HS = left/right hemispheric stroke, n = number of patients, S = stroke, SAH = subarachnoid hemorrhage, SS = stroke-like symptoms, TIA = transient ischemic attack, tPA = tissue plasminogen activator

* to completion of scan