

Drive-Time Proximity to Joint Commission Primary Stroke Centers Among North Carolina Residents Who Died of Stroke

Andrew W. Asimos, Dianne Enright, Sara L. Huston, Laurie H. Mettam

Abstract

Objective: In developing a statewide system of stroke care, understanding the relative availability of acute stroke care at designated centers for stroke care is essential. In this article, we compare the change in availability of acute stroke care in North Carolina at Joint Commission Primary Stroke Centers (JCPSCs) between 2006 and 2008 by examining the drive-time proximity of the residential address to the nearest JCPSC among people who died of stroke.

Methods: We assigned geographic coordinates to residential addresses of North Carolinians who died of stroke and to addresses of North Carolina JCPSCs. We calculated the distance within a 40-minute drive from each JCPSC and determined whether the residential addresses of patients who died of stroke were in the areas demarcated by the drive time. In a secondary analysis, we included non-JCPSCs that participate in recognized quality-improvement programs for stroke care.

Results: In 2006, 37% of geocodable residences of patients who died of stroke (3,834 of 10,469) were within a 40-minute drive from a JCPSC. By the end of 2008, this percentage increased to 56% (3,482 of 6,204). Inclusion of other hospitals that participate in recognized quality-improvement programs for acute stroke care increased the 40-minute drive-time coverage to 82% (5,095 of 6,204).

Limitations: As an index of the geographic distribution of the stroke burden, we used deaths due to stroke, rather incident strokes. We included several assumptions in our drive-time calculation.

Conclusions: For many regions of North Carolina in which the stroke burden is high, timely care at JCPSCs for acute stroke is unavailable. To develop a statewide system for acute stroke care in North Carolina, criteria beyond JCPSC certification should be considered for designating hospitals as centers for stroke care.

Keywords: ambulance; stroke; public policy

To create statewide systems for acute stroke care, several states are pursuing legislative, health department, or emergency medical services initiatives that designate hospitals as stroke centers [1-8]. These initiatives are based on data indicating that acute stroke care improves once a hospital meets criteria for designation as a center for stroke care. For example, stroke center designation in New York state was associated with shorter door-to-treatment times, greater use of intravenous tissue plasminogen activator (tPA), and fewer tPA treatment protocol violations [9], and in a community hospital in Maryland the proportion of

patients with ischemic stroke who received tPA increased after the hospital was designated as a stroke center [10]. Coupled with many of these stroke center designation initiatives are protocols for emergency medical services professionals to route patients within prespecified intervals to stroke centers, bypassing nondesignated hospitals [3, 8, 11]. Implicit in such initiatives is that patients with acute stroke will be afforded the best opportunity to receive time-sensitive treatment for acute stroke by being preferentially taken to stroke centers. Indeed, the sooner tPA is given to a patient with ischemic stroke, the greater the benefit, especially

Andrew W. Asimos, MD, director of emergency stroke care, Department of Emergency Medicine, Carolinas Medical Center. He can be reached at andrew.asimos@carolinashealthcare.org.

Dianne Enright, GISP, manager, Health and Spatial Analysis Unit, State Center for Health Statistics, Division of Public Health, NC Department of Health and Human Services.

Sara L. Huston, PhD, Heart Disease and Stroke Prevention Branch, Division of Public Health, NC Department of Health and Human Services.

Laurie H. Mettam, MEd, Tri-State Stroke Network and Heart Disease and Stroke Prevention Branch, Division of Public Health, NC Department of Health and Human Services.

when treatment is started within 90 minutes after the initial stroke [12, 13]. For hemorrhagic strokes, timely availability of emergency care is also important, since substantial early hemorrhage growth occurs in roughly a quarter of patients within 1 hour after stroke and is an independent determinant of both mortality and functional outcome [14]. As an example, treatment for anticoagulation reversal in patients with warfarin-related hemorrhagic strokes is a demonstrated time-sensitive therapeutic strategy that has the potential to limit early hemorrhage growth [15].

In 2006, the North Carolina General Assembly ratified House Bill 1860, which established a stroke advisory council to provide guidance on the development of a statewide system of stroke care, including a system to identify primary stroke centers and disseminate information about their location [16]. Joint Commission Primary Stroke Center (JCPSC) certification is the only established and recognized program in North Carolina for designating stroke centers. Established in 2003 in response to recommendations from the Brain Attack Coalition and the American Stroke Association [17], JCPSC certification requires that hospitals demonstrate compliance with standards for stroke care, including standardized methods for delivering clinical care that are based on appropriate clinical guidelines or evidence-based practice and commitments to measuring performance and improving care. In addition to the JCPSC program, 2 other organized quality-improvement programs for stroke care exist among North Carolina hospitals: the Paul Coverdell National Acute Stroke Registry (PCNASR) and the Get With The Guidelines-Stroke (GWTG-S) program. The PCNASR is funded by the Centers for Disease Control and Prevention and collaboratively implemented by the North Carolina Heart Disease & Stroke Prevention Branch and the University of North Carolina at Chapel Hill Department of Epidemiology [18]; the GWTG-S program is managed by the American Stroke Association [19]. Participation in these programs suggests that a hospital is committed to improving all aspects of stroke care, including treatment of acute stroke, since these programs evaluate implementation of treatment guidelines by tracking performance measures identical to those tracked by JCPSCs (Table 1). Furthermore, participation in the PCNASR and the GWTG-S program is associated with improved performance in some of these areas [20-22]. However, these 2 programs are not rigorously evaluated by an independent certifying body such as the Joint Commission, which conducts on-site inspection of JCPSCs every 2 years.

Quality stroke care requires expeditious treatment, but several impediments exist. Previous studies have described delayed presentation to the hospital among patients with lack of

awareness of stroke signs and symptoms, reluctance to call emergency services (eg, 911), and absence of a bystander for acute stroke events [23-30]. Additionally, critical time can be lost after a patient has arrived at the hospital, owing to administrative delays, competing emergent events, and the overall patient volume in the emergency department [31]. The focus of this study involves another critical component in the stroke chain of survival—the potential for expeditious ground transport to hospitals capable of administering high-quality care for acute stroke [32]. It is well documented that, as the interval between the acute stroke event and arrival at a stroke center increases, the delay in receipt of time-sensitive treatments increases and the likelihood of a clinical benefit from treatment decreases [12, 13, 33, 34]. Therefore, a crucial aspect of a statewide system of stroke care involves understanding the geographic distribution of designated stroke centers relative to the location of patients with acute stroke. As an example, in Georgia, stroke mortality was 20% lower among populations living within a 20-mile radius of a stroke-ready hospital [35].

Immediately after the passage of House Bill 1860, 10 JCPSCs existed in North Carolina, whereas at the end of 2008, there were 22 JCPSCs. In this article, we compared the change in relative availability of acute stroke care in North Carolina between 2006 and 2008 by examining the drive-time proximity of residential addresses of patients who died of stroke to the nearest JCPSC. In a secondary analysis, for areas underserved by JCPSCs, we evaluated drive times to hospitals participating in the PCNASR and the GWTG-S program. These institutions represent logical additions to the network for acute stroke care because of demonstrated improvement in stroke care with participation in the PCNASR and/or the GWTG-S program.

Table 1.
Standardized Performance Measures Common Among North Carolina Hospitals Providing Stroke Care

Performance measure
Provide venous thromboembolism prophylaxis
Provide/continue antithrombotic therapy at hospital discharge
Provide anticoagulation therapy for atrial fibrillation or flutter
Provide thrombolytic therapy
Provide antithrombotic therapy by the end of day 2 of hospitalization
Provide/continue statin therapy at hospital discharge
Screen for dysphagia
Provide stroke education
Refer to a smoking-cessation program
Assess for rehabilitation needs

Note. Hospitals consist of Joint Commission Primary Stroke Centers and those in recognized quality-improvement programs for stroke care (ie, the Paul Coverdell National Acute Stroke Registry and the Get With The Guidelines-Stroke program).

Methods

We conducted a drive-time analysis to stroke centers for 2006 and 2008. We used ArcGIS 9.2 software (Esri) to assign geographic coordinates to the residential addresses of patients who died of stroke and the address of JCPSCs, using various sources of local and state Department of Transportation street centerline data. We defined North Carolina deaths due to stroke as those for which the underlying cause of death on the death certificate was coded with any of the following *International Classification of Diseases, Tenth Revision* codes: I61 (ie, intracerebral hemorrhage), I63 (ie, cerebral infarction), and I64 (ie, stroke, not specified as hemorrhage or infarction) [36]. We chose residential addresses of patients who died of stroke because these data provide a precise geographic representation of one index of the stroke burden across the state. Although we recognize that use of the number of incident strokes during the periods studied would have been preferable, such data can only be geocoded at the county level. For the 2006 analysis, we geocoded the residential addresses of people in North Carolina who died of stroke during 2003-2005, along with the addresses of the 10 JCPSCs that, according to the Joint Commission [36], were in North Carolina during 2006. For the 2008 analysis, we geocoded the residential addresses of people in North Carolina who died of stroke during 2006-2007, along with the addresses of the 22 North Carolina JCPSCs that, according to the Joint Commission [36], were in North Carolina at the end of 2008. We did not require institutional review board approval for use of the data in this study because deaths are in the public record in North Carolina and because the addresses of JCPSCs and of hospitals in the PCNASR and/or the GWTG-S program were made available to us by the agencies sponsoring those programs.

We calculated the distance within 40-minute drives from hospitals of interest, using ArcGIS Network Analyst and North Carolina Department of Transportation Integrated Statewide Road Network (ISRN) source data. ISRN data are attributed with one-way streets, numbers of lanes, and speed limits. By using network analysis, drive-time estimates can be accurately computed. For example, a greater distance can be traveled along an interstate highway at a speed of 65 miles/hour than on a neighborhood road at a speed of 35 miles/hour. We created 40-minute drive-time polygons around each JCPSC. We chose a 40-minute drive time for our analysis because of limitations in the methods we used to calculate drive times, as well as practical considerations. Our goal was to consider a 30-minute

drive time based on ambulance-response speeds. However, because our software assumed that ambulances traveled at the speed limit and that each left-hand turn added 5 seconds to the drive time, we extended the drive time to 40 minutes to adjust for these limitations. Although it is difficult to calculate a definitive adjustment in drive time to account for the speed traveled by ambulances (which is 10-15 miles/hour greater than the speed limit), our adjustment represents an acceptable modification. We chose the

Table 2.
Characteristics of Patients With Geocodable Residences Who Died of Stroke

Variable	Patients, no. (%), by year of death ^a	
	2003-2005 (N = 10,469)	2006-2007 (N = 6,204)
Stroke type ^b		
Ischemic	1,060 (10)	489 (8)
Hemorrhagic	1,906 (18)	1,141 (18)
Unspecified	7,503 (72)	4,574 (74)
Age, years		
<40	86 (1)	55 (1)
40-49	274 (3)	146 (2)
50-64	1,012 (10)	667 (11)
≥65	9,097 (87)	5,336 (86)
Sex ^c		
Female	6,395 (61)	3,731 (60)
Male	4,074 (39)	2,472 (40)
Race		
African American	2,365 (23)	1,393 (22)
White	7,971 (76)	4,727 (76)
Other	133 (1)	84 (1)
Education level ^d		
Less than high school	5,005 (48)	2,688 (43)
High school graduate	2,812 (27)	1,816 (29)
More than high school	2,652 (25)	1,560 (25)

Note. A total of 10,689 patients died of stroke during 2003-2005, and 6,393 died of stroke during 2006-2007.

^aData for 2003-2005 were used in analysis of the 2006 study period involving 10 Joint Commission Primary Stroke Centers (JCPSCs), and data for 2006-2007 were used in analysis of the 2008 study period involving 22 JCPSCs.

^bDefined on the basis of *International Classification of Diseases, Tenth Revision* codes for ischemic stroke (I63), hemorrhagic stroke (I61), and stroke, not specified as hemorrhage or infarction (I64).

^cThe sex of 1 patient who died during 2006-2007 was unavailable.

^dData are for patients aged ≥25 years. The education level was unavailable for 140 patients who died during 2006-2007 (13 patients were aged <25 years, and 127 patients had an unknown education level).

Figure 1.
Proximity of Patients Who Died of Stroke to
Hospitals Confirmed to Be Joint Commission
Primary Stroke Centers (JCPSCs) in 2006

This figure is available in its entirety in the
online edition of the *NCMJ*.

Note. Triangles denote geocoded residential addresses of
patients who died during 2003-2005. Color-shaded areas denote
40-minute drive-time service areas of JCPSCs.

30-minute threshold because other states have incorporated this value into their destination-bypass protocols [8] and because it is practical. For example, it has been demonstrated that patients who arrive at the hospital within 60 minutes after symptom onset receive thrombolytic therapy earlier and more frequently than those who arrived later [34], and a 30-minute drive time allows an additional 30 minutes for recognition of stroke symptoms and activation of the 911 system. Furthermore, it is impractical to expect that personal vehicles or ambulances will, after a 30-minute drive, continue bypassing hospitals in favor of a JCPSC, and that drive times exceeding 30 minutes will not yield delays in tPA initiation that might counterbalance this treatment's beneficial effect.

To estimate how many patients died of stroke within and beyond a 40-minute drive from JCPSCs in the state, we used point-in-polygon (PIP) analysis. PIP analysis is a geospatial tool commonly used and well suited for our drive-time investigation [37, 38]. The analysis involves an overlay of points and an area or polygon that defines the distance within the given drive time from the destination of interest. In our primary analysis, the points denote the residential addresses of patients who died of stroke, and the polygons define the distance within 40-minute drives from JCPSCs. By using PIP analysis (also known as a "spatial join"), the number of residential addresses in the 40-minute drive-time service area can be calculated. For both study periods, we compared the percentage of patients who resided within a 40-minute drive and died of stroke. In a secondary analysis involving regions of North Carolina outside the 2008 40-minute drive-time polygons, we geocoded addresses of hospitals that were not certified as JCPSCs (as of the end of 2008) but participated in the PCNASR or GWTG-S quality-improvement programs for stroke care. We calculated the additional potential access to acute stroke care provided by these hospitals, using the same methods described above.

Results

For the 2006 analysis, we identified 10,689 patients who died of stroke during 2003-2005, and residential addresses for 98% (10,469) could be geocoded. In the 2008 analysis, residential addresses for 6,204 (97%) of 6,393 patients who died of stroke during 2006-2007 could be geocoded.

As demonstrated in Table 2, patient characteristics between the 2 periods were similar. Figures 1 and 2, available only in the online edition of the *NCMJ*, depict the locations of the JCPSCs, the drive-time service areas, and the residences of patients who died of stroke. Table 3 lists the percentages of death due to stroke that occurred among patients who resided within the 40-minute drive-time service areas for both study periods. In 2006, geocodable addresses for 37% of patients who died of stroke were within a 40-minute drive from a JCPSC, whereas by the end of 2008, 56% were within a 40-minute drive (Table 3 and Figures 1 and 2). In 2006, 19% of patients who died of stroke (1,941 of 10,469) lived within a 40-minute drive from more than 1 JCPSC, whereas by the end of 2008 that percentage had doubled to 38% (2,357 of 6,204). Figure 3, available only in the online edition of the *NCMJ*, shows the additional drive-time coverage afforded by including hospitals from the PCNASR and the GWTG-S program in the network for acute stroke care that was in place at the end 2008. Of the geocodable residences of patients who died of stroke during 2006-2007, a total of 82% (5,095 of 6,204) were within a 40-minute drive from JCPSCs or hospitals in the PCNASR or the GWTG-S program.

Discussion

Intravenous tPA is currently approved by the US Food and Drug Administration for use within 3 hours after onset of stroke symptoms. However, it is well-known that the sooner tPA is given to patients with stroke, the greater the benefit, especially if treatment is started within 90 minutes after symptom onset [12, 13, 33]. For acute ischemic strokes, the benefit of thrombolytic therapy is highly dependent on the time at which it is initiated, with every 10-minute delay in tPA delivery resulting in 1 fewer patient realizing an improved outcome [33]. Furthermore, a recent study concluded that patients who arrived at the hospital within 60 minutes after symptom onset received thrombolytic therapy earlier and more frequently than did those who arrived later [34]. Unfortunately, the same investigators found that only 12% of patients with ischemic stroke presented to the hospital within 1 hour after the documented time of stroke onset [34]. Similarly, for warfarin-related hemorrhagic strokes, every 30-minute delay in administering the first dose of fresh-frozen plasma is associated with a

Figure 2.
Proximity of Patients Who Died of Stroke to
Hospitals Confirmed to Be Joint Commission
Primary Stroke Centers (JCPSCs) in 2008

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online edition of the *NCMJ*.

Note. Triangles denote geocoded residential addresses of
patients who died during 2006-2007. Color-shaded areas denote
40-minute drive-time service areas of JCPSCs.

20% decrease in the odds of international normalized ratio reversal within 24 hours. Although public education efforts may increase the percentage of patients who seek medical care promptly after stroke symptom onset, a critical component of obtaining acute stroke care involves timely transport to a stroke center or hospital otherwise capable of managing acute stroke in accordance with the latest established guidelines.

Our analysis found that although the number of JCPSCs in North Carolina more than doubled between 2005 and 2008, a considerable percentage of patients who died of stroke during 2008 resided outside of the 40-minute drive-time polygons of JCPSCs. This is largely because the majority of JCPSCs were added in the center of the state, which is not necessarily surprising because market forces and a hospital's interest, rather than geographic need, are among the driving forces for seeking JCPSC certification. It is important to note, however, that our results should not be interpreted to imply that the locations of JCPSCs directly contributed to stroke mortality, because deaths from stroke were only used as an index of the geographic distribution of the stroke burden across the state. Our work does suggest that North Carolina cannot rely on a statewide system of acute stroke care exclusively designed around the use of JCPSCs as the destination for patients with presumed acute stroke. Indeed, several other states have reached this same conclusion and have implemented processes in addition to JCPSC certification for designating centers for stroke care [3, 5-8]. Establishment of an additional "acute stroke center" designation on the basis of evidence-based criteria that complement the existing JCPSC criteria would enhance acute stroke care in North Carolina by recognizing the vital role played by smaller hospitals in treating patients with acute stroke, especially in rural areas. Such criteria were recom-

Figure 3. Proximity of Patients Who Died of Stroke to Hospitals Confirmed to Provide Stroke Care in 2008

This figure is available in its entirety in the online edition of the *NCMJ*.

Note. Triangles denote geocoded residential addresses of patients who died of stroke during 2006-2007. Color-shaded areas denote 40-minute drive-time service areas of hospitals. GWTG-S, Get With The Guidelines-Stroke; JCPSC, Joint Commission Primary Stroke Center; PCNASR, Paul Coverdell National Acute Stroke Registry.

mended in 2008 by the American Stroke Association and are listed in Table 4 [39]. Our analysis suggests that non-JCPSCs participating in the PCNASR and the GWTG-S program are relatively well dispersed geographically across the state and are logical first targets for such criteria, especially because data demonstrate that participation in the PCNASR and the GWTG-S program is associated with improvements in important measures of stroke care [20-22]. However, it should be emphasized that criteria fulfillment would likely be best verified by an onsite inspection process because use of remote survey techniques for self-reporting stroke treatment capability may be unreliable [40].

Our analysis has several limitations. First, the correlation between the residential address of patients who died of stroke and the location of the stroke event is unknown. As an alternative, the proportion of the population living within 40-minute drives could have been analyzed, but this does not allow for precise geocoding and relies on aerial interpolation to estimate the total population residing within the drive time. Of note, we participated in such an analysis, which involved the tristate region of North Carolina, South Carolina, and Georgia [41]. That work found that only 49% of the population in the tristate region resides within a 30-minute drive to a JCPSC, which is similar to the results of this analysis. Second, the overall validity of the underlying cause of death specified on death certificates was unknown for our study population. We recognize that only modest agreement was observed in a study comparing underlying causes of death coded as stroke by an experienced nosologist, who did not rely on supplemental information, and those adjudicated as stroke by a study committee, which used medical records and other supplemental information [42]. Third, although we increased the drive time to adjust for some limitations, the drive-time model did not consider the possible influence of time of year or time of day. We realize that these variables can impact

Table 3.
Patients Who Died of Stroke and Had a Geocodable Residence Within a 40-Minute Drive From a Joint Commission Primary Stroke Center (JCPSC)

Stroke type ^a	Patients, proportion (%), by study period ^b	
	2006	2008
Ischemic	407/1,060 (38)	301/489 (62)
Hemorrhagic	710/1,906 (37)	644/1,141 (56)
Unspecified	2,717/7,503 (36)	2,537/4,574 (55)
Any	3,834/10,469 (37)	3,482/6,204 (56)

Note. Data are no. of patients who resided within the drive time/total no. who died (%). There were 10 JCPSCs in North Carolina during 2006 and 22 during 2008. For all comparisons, $P < .05$ by the χ^2 test.

^aDefined on the basis of *International Classification of Diseases, Tenth Revision* codes for ischemic stroke (I63), hemorrhagic stroke (I61), and stroke, not specified as hemorrhage or infarction (I64).

^bData for 2006 involve patients who died during 2003-2005, and data for 2008 involve patients who died during 2006-2007.

Table 4.
American Stroke Association Acute Stroke Designation Advisory Committee Recommendations for Classifying Facilities as Acute Stroke Care Capable Hospitals

Recommendations

These hospitals should fulfill all of the following requirements outlined for the emergency evaluation and treatment of patients with acute stroke as indicated for JCPSCs. Hospitals may achieve these criteria through a drip and ship model or telemedicine if local staffing is inadequate:

Acute stroke team & availability 24/7

Written care protocols

Emergency medical services integration

Emergency department

Commitment & support of medical organization; a stroke center director

Neuroimaging services 24/7

Laboratory services 24/7

Outcome and quality improvement activities that includes tracking of all patients seen with acute stroke and appropriate use of thrombolytic therapy

These capabilities, including collection of relevant performance measures, must be verifiable.

These hospitals may not have all of the non-acute care capabilities required of JCPSCs.

These hospitals or facilities should be encouraged to pursue formal JCPSC certification.

These hospitals should have a plan for transfer of patients to a JCPSC as appropriate based on clinical and other factors.

Note. Recommendations are for hospitals that are not Joint Commission Primary Stroke Centers (JCPSCs) [39].

the overall drive time experienced by patients. Fourth, it is important to emphasize that any statewide system of stroke care that relies on emergency responders to accurately identify patients with acute stroke in order to make appropriate destination decisions must have a prehospital stroke screen in place that has adequate specificity. Unfortunately, a study conducted in North Carolina found that one commonly used scale to screen for stroke was only 52% specific in identifying stroke victims [43]. Clearly, as the authors of that work concluded, if prehospital screening is to be used for transport diversion, the specificity of the screening scale must improve beyond 52%. Fifth, we did not consider telestroke support or the use of a field-to-stroke center helicopter transport, both of which have the ability to enhance statewide access to experts in acute stroke care. Finally, we did not consider JCPSC resources in border states, but our tristate analysis indicated no added drive-time accessibility to JCPSCs when stroke-care resources in bordering states were considered [41].

Our work indicates that non-JCPSCs currently engaged in quality-improvement initiatives for stroke care are well-placed geographically to provide much needed acute stroke treatment. This supports the opportunity to strengthen the system of stroke care in North Carolina by expanding the role of some hospitals that have not obtained designation as a JCPSC but likely have the potential to provide evidence-based acute stroke care. North Carolina should establish an additional set of evidence-based criteria for designating centers of acute stroke care that complements the JCPSC program. States considering criteria for stroke center designation that go beyond those of the Joint Commission will benefit from using GIS modeling to identify whether such designated centers adequately enhance the statewide system of acute stroke care in their state. **NCMJ**

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