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Geographic Access to Acute Stroke Care in the United States

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Abstract

Background and Purpose—Only 3% to 5% of patients with acute ischemic stroke receive intravenous recombinant tissue-type plasminogen activator (r-tPA) and <1% receive endovascular therapy. We describe access of the US population to all facilities that actually provide intravenous r-tPA or endovascular therapy for acute ischemic stroke.

Methods—We used US demographic data and intravenous r-tPA and endovascular therapy rates in the 2011 US Medicare Provider and Analysis Review data set. *International Classification of Diseases-Ninth Revision* codes 433.xx, 434.xx and 436 identified acute ischemic stroke cases. *International Classification of Diseases-Ninth Revision* code 99.10 defined intravenous r-tPA treatment and *International Classification of Diseases-Ninth Revision* code 39.74 defined endovascular therapy. We estimated ambulance response times using arc-Geographic Information System's network analyst and helicopter transport times using validated models. Population access to care was determined by summing the population contained within travel sheds that could reach capable hospitals within 60 and 120 minutes.

Results—Of 370 351 acute ischemic stroke primary diagnosis discharges, 14 926 (4%) received intravenous r-tPA and 1889 (0.5%) had endovascular therapy. By ground, 81% of the US population had access to intravenous-capable hospitals within 60 minutes and 56% had access to endovascular-capable hospitals. By air, 97% had access to intravenous-capable hospitals within 60 minutes and 85% had access to endovascular hospitals. Within 120 minutes, 99% of the population had access to both intravenous and endovascular hospitals.

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Conclusions—More than half of the US population has geographic access to hospitals that actually deliver acute stroke care but treatment rates remain low. These data provide a national perspective on acute stroke care and should inform the planning and optimization of stroke systems in the United States.

Keywords

access to health care; endovascular procedures; tissue-type plasminogen activator

Treatment approaches for acute ischemic stroke (AIS) include both intravenous and endovascular techniques. The only US Food and Drug Administration–approved therapy for improving outcomes after AIS is intravenous recombinant tissue-type plasminogen activator (r-tPA). Only 3% to 5% of patients with AIS in the United States receive intravenous r-tPA[1] and 64% of hospitals in the United States did not administer any r-tPA for AIS from 2005 to 2007.[2] Approximately 0.4% of patients with AIS received endovascular from 2004 to 2009.[3] Although recent trials did not demonstrate improved outcomes with endovascular therapy,[4–6] it remains an important treatment option for patients ineligible for r-tPA because of surgery, coagulopathy, pregnancy, etc, and multiple other clinical trials are ongoing.

Based on criteria originally proposed by the Brain Attack Coalition in 2000,[7] the American Stroke Association recommends designation of Acute Stroke Ready Hospitals, Primary Stroke Centers (PSC), and Comprehensive Stroke Centers.[8] PSC-certified hospitals are more likely to treat patients with AIS with r-tPA than noncertified hospitals,[9] and treatment at designated stroke centers has been associated with lower 30-day mortality.[10] Prior work has described access to r-tPA–capable hospitals in Canada[11] and to US PSCs.[12]

Prior work has also described access to endovascular therapy in the United States using a roster of registered interventional neuroradiologists.[13] This article seeks to describe access of the US population to all hospitals that actually deliver acute stroke care (intravenous and endovascular therapy) and the proportion of US patients with stroke who obtained care at these hospitals. We used intravenous and endovascular treatment rates in the Medicare Provider and Analysis Review (MEDPAR) data set to estimate geographic access of the US population to both intravenous and endovascular therapies for AIS.

Methods

Determination of Rates of Intravenous and Endovascular Treatment in AIS

The MEDPAR database is a claims-based data set that contains every fee-for-service Medicare-eligible hospital discharge in the United States. Fiscal year 2011 data were used. Patients potentially eligible for r-tPA treatment were identified based on primary discharge diagnosis *International Classification of Diseases-Ninth Revision* codes 433.xx (occlusion and stenosis of precerebral arteries), 434. xx (occlusion of cerebral arteries), and 436 (acute, but ill-defined, cerebrovascular disease). Among these, patients receiving intravenous thrombolysis were identified using *International Classification of Diseases-Ninth Revision* code 99.10 (thrombolytic use). Rates of endovascular treatment specific to AIS were estimated among patients with AIS identified as above using *International Classification of*

Diseases-Ninth Revision code 39.74 (endovascular removal of obstruction from head and neck vessels). We did not include codes denoting arteriography, angiography, catheterization, etc, because performance of such procedures may be for diagnostic purposes and not for acute treatment and intervention. Hospitals that gave a single dose of r-tPA during the study period were considered capable, whereas hospitals that performed a single thrombectomy procedure were considered endovascular capable. PSCs were hospitals designated as such by the Joint Commission as of 12/30/2010.

Population Data

Population data, including block group centroid locations, came from the 2010 Neilsen Claritas Census Estimations, which rely on a regularly refined projection methodology based on the most recent decennial Census data.[14,15] Estimations were derived from the 2000 US Census data.

Access Calculations

Details of our access calculations have been published previously.[12,15–18] Block groups, which are subdivisions within Census tracts consisting of 600 to 3000 people, were used as the primary geographic unit for analysis. A population-weighted center point (centroid) was assigned within each block group. Using the Network Analyst functionality in ESRI ArcMap 10.1, the shortest road distance was determined between each block group centroid (Neilson Claritas data) and each hospital type. Distances were then converted to total prehospital ambulance transport times. Travel times were computed based on posted speed limits for the roads in each path. Key intervals were added to the drive times to estimate total prehospital travel time. Using times derived from trauma care and previously applied to stroke, we estimated the time from 911 activation to ambulance dispatch as 1.4, 1.4, and 2.9 minutes for urban, suburban, and rural areas, respectively. The time from ambulance dispatch until arrival at the scene was determined by multiplying the drive time from the scene to the hospital (as described above) by 1.6, 1.5, and 1.4 minutes for urban, suburban, and rural drives, respectively, based on previously derived and validated faster ambulance drive times in rural versus urban settings.[19] Finally, 13.5, 13.5, and 15.1 minutes were added to account for time spent by emergency medical services on the scene before transport.[19] We allowed for crossing of state lines in our access calculations. Average helicopter ambulance times were response time 23.25 minutes, on-scene time 20.43 minutes, and transport time 29.80 minutes. These time estimates and ground ambulance and helicopter response, on-scene, and transport times were based on a previous meta-analysis of published prehospital transport times for 155 179 trauma patients during a 30-year period in the United States.[19]

Air Ambulance Data and Transport Times

We used the 2010 Atlas and Database of Air Medical Services[20] to obtain the locations of all civilian air medical depots. These data include location, type, and air speed of rotary aircraft housed at the base station that respond to emergency calls in the United States. The maximum speeds of those specific helicopters, as well as estimates of average warm up and on-scene times were used to determine total prehospital time for a patient transported by air. The time to scene and time from scene to hospital were calculated using Euclidian distances.

Results

Of 370 351 AIS primary diagnosis discharges during the study period, 14 926 (4%) received intravenous r-tPA and 1889 (0.5%) received endovascular therapy. Of 4583 acute care hospitals in the MEDPAR database in fiscal year 2011, 2895 (63%) did not give any doses of intravenous r-tPA, whereas 4252 (93%) did not perform any thrombectomy procedures for stroke; 327 (7%) hospitals gave ≥1 dose of intravenous r-tPA and performed ≥1 thrombectomy procedure for stroke. Of these hospitals, 278 (85%) were PSCs. Four hundred fifty-five hospitals (9.9%) gave intravenous r-tPA >10× during the year.

Geographic access was calculated and by ground, 81% of the US population had 60-minute access to intravenous r-tPA–capable hospitals, 66% had access to PSCs, and 56% had access to endovascular-capable hospitals. The Table depicts 60-minute ground and air access by region and state. By air, 97% had 60-minute access to intravenous-capable hospitals, 91% had access to PSCs, and 85% had access to endovascular-capable hospitals. Figure 1 depicts access by ground or air to intravenous r-tPA–capable hospitals and Figure 2 shows access to endovascular-capable hospitals; 60-minute access is shown in yellow and population density is shown in blue. Within 120 minutes, 99% of the population had access to both intravenous and endovascular hospitals by ground or air. We conducted sensitivity analyses estimating access with an additional 15 minutes of helicopter dispatch time after the request for the helicopter and found that access to intravenous r-tPA within 60 minutes decreased from 97% to 88%; access to endovascular therapy for the same dispatch times decreased from 85% to 69%.

Of all 821 PSCs, 93% administered ≥1 dose of intravenous r-tPA, whereas 23% of non-PSCs administered ≥1 dose of intravenous r-tPA. Thirty-three percent of PSCs performed ≥1 thrombectomy, whereas 1.5% of non-PSCs performed ≥1 thrombectomy procedure. The 327 hospitals that gave ≥1 dose of r-tPA and performed 1 thrombectomy procedure discharged ≈28% of all patients with AIS in the MEDPAR database in fiscal year 2011; hospitals that did not give any doses of intravenous r-tPA discharged 17% of all AIS cases.

Discussion

During the study period, most of the US population had geographic access to hospitals capable of delivering intravenous r-tPA by ground or air, whereas about half the country had 60-minute ground access and 85% had 60-minute air access to endovascular therapy. Within 120 minutes, close to 100% of the US population had access to both intravenous and endovascular therapy by ground or air. Despite this, treatment rates were extremely low, with intravenous r-tPA administered to 4% and endovascular therapy to 0.5% of all discharged patients with AIS.

Prior work using GIS has described access to intravenous r-tPA in Canada.[11] Our access estimates for the United States may be more accurate than that report because we used actual r-tPA and endovascular treatment rates determined by *International Classification of Diseases-Ninth Revision* codes. The report by Scott et al[11] defined hospitals capable of delivering intravenous r-tPA as those with a computed tomographic scanner and a

neurologist and emergency medicine specialist on the medical staff. It is noteworthy that 7% of PSCs in our study did not administer any r-tPA. Thus, using PSC certification instead of actual treatments would have overestimated access.

A report on US access to endovascular therapy estimated that 82% of the US population had ground or air access within 2 hours, whereas 99% had access within 5 hours.[13] We found greater access to endovascular therapy within 2 hours (99%) in this report, likely because of increased access to endovascular care between study periods. It is also possible that access was underestimated in that prior report because only those interventional neuroradiologists registered with the American Society of Interventional and Therapeutic Neuroradiology were used to estimate access.[13] The use of billed procedures for acute stroke endovascular intervention in our study may represent a better estimate of actual access.

We have reported previously that 55% of the US population has ground access and 79% have air access to PSCs within 60 minutes.[12] In that study of the 2008 US population, 520 PSCs were designated by the Joint Commission. In this report, we found an improvement in access of the population to PSCs, likely mediated by an increased number of PSCs (n=821) in 2011 compared with 2008. The 58% increase in the number of PSCs and the corresponding 47% increase in population ground access to PSCs within 60 minutes in this compared with the prior study suggest that US PSCs primarily developed in regions without prior population access. No data are available on the impact of Comprehensive Stroke Center designation on acute stroke treatment and it is not currently possible to identify Acute Stroke Ready Hospitals reliably on a national level. Future studies should examine the impact of these designations on acute stroke treatment.

Using the model of rapid access used in US trauma care,[21] we focused our access calculations at 60 minutes. In population-based studies, only about a quarter to a third of patients with AIS arrived in the Emergency Department within 3 hours of symptom onset, [21,22] whereas a study at urban US academic centers found that 38% arrived within 2 hours of onset.[22] Faster onset to treatment times have been associated with reduced mortality, reduced symptomatic intracranial hemorrhage, and increased poststroke independence with both intravenous r-tPA[23] and endovascular therapy.[24] As such, although access approached 100% within 120 minutes, faster access to stroke care is critical for minimizing morbidity and mortality because of stroke, and considerable effort to minimize delays in presentation is required.

We found that 17% of all AIS discharges in fiscal year 2011 were from hospitals that did not give any r-tPA during that year, whereas 28% were from hospitals capable of delivering both intravenous and endovascular therapy. These findings are critical evidence of room for improvement in the current US system.

We recognize that our study has limitations. Our calculations reflect potential access and not true access. Geographic access does not assure that patients will receive proper treatment. Barriers to seeking and obtaining care quickly after symptom onset in AIS warrant further study. Another limitation is the use of an administrative data set to estimate r-tPA and endovascular treatment rates. Single center studies are prone to referral bias, and population-

based studies may not be generalizable to the whole nation. Self-reported data from hospitals with an expressed interest in high-quality stroke care who are incentivized to meet predefined process measures (such as Get With The Guidelines) are also prone to referral bias and are not generalizable to hospitals not participating in such initiatives. Thus, administrative data sets remain useful for estimating national practice. Proficiency demonstrated by a minimum number of treatments or appropriate treatment of eligible patients may be a better metric for access to care than a single treatment as we used for our analysis. However, only ≈10% of US hospitals gave intravenous r-tPA >10× during the study period, emphasizing the challenge of achieving true access to experienced centers.

The designation of PSCs is a continually evolving process. We recognize that there are limitations associated with using these data and that we may have underestimated access to PSCs. Although we likely captured these additional PSCs in the intravenous-capable hospitals, we cannot be certain. In addition, our access calculations include presumption of access to ground and air transport, presumption of stroke occurring where people reside, empirical derivation of estimated transport times from trauma data, and restriction of PSC designation to those by the Joint Commission only (ie, no state designated stroke centers were included). We acknowledge the possibility of underestimating rural access because of not accounting for drip-and-ship cases. However, great regional variability exists in the use of the V code, and reported rates of drip-and-ship cases among r-tPA–treated patients in the United States have ranged from 17% to 69%.[25–28] If hospitals do not use the V code, administrative data sets cannot track these cases individually and would risk double-counting r-tPA treats. Thus, for calculating access to care, use of the V code to estimate drip-and-ship rates would lead to over or underestimation of regional access in ways that are difficult to estimate. As such, we decided to eliminate these cases from our analysis.

Finally, use of the MEDPAR database means patients <65 years (except transplant and permanently disabled patients) were not adequately represented in our study.

In this report of access of the US population to both intravenous and endovascular acute stroke care, we present evidence of continued low treatment rates of AIS,[1,29] treatment of a substantial number of patients with stroke (17%) at hospitals without documented intravenous or endovascular treatment during the study year and significant population access to hospitals capable of delivering acute stroke care. These data provide a national perspective on acute stroke care and should inform the planning and optimization of stroke systems in the United States.

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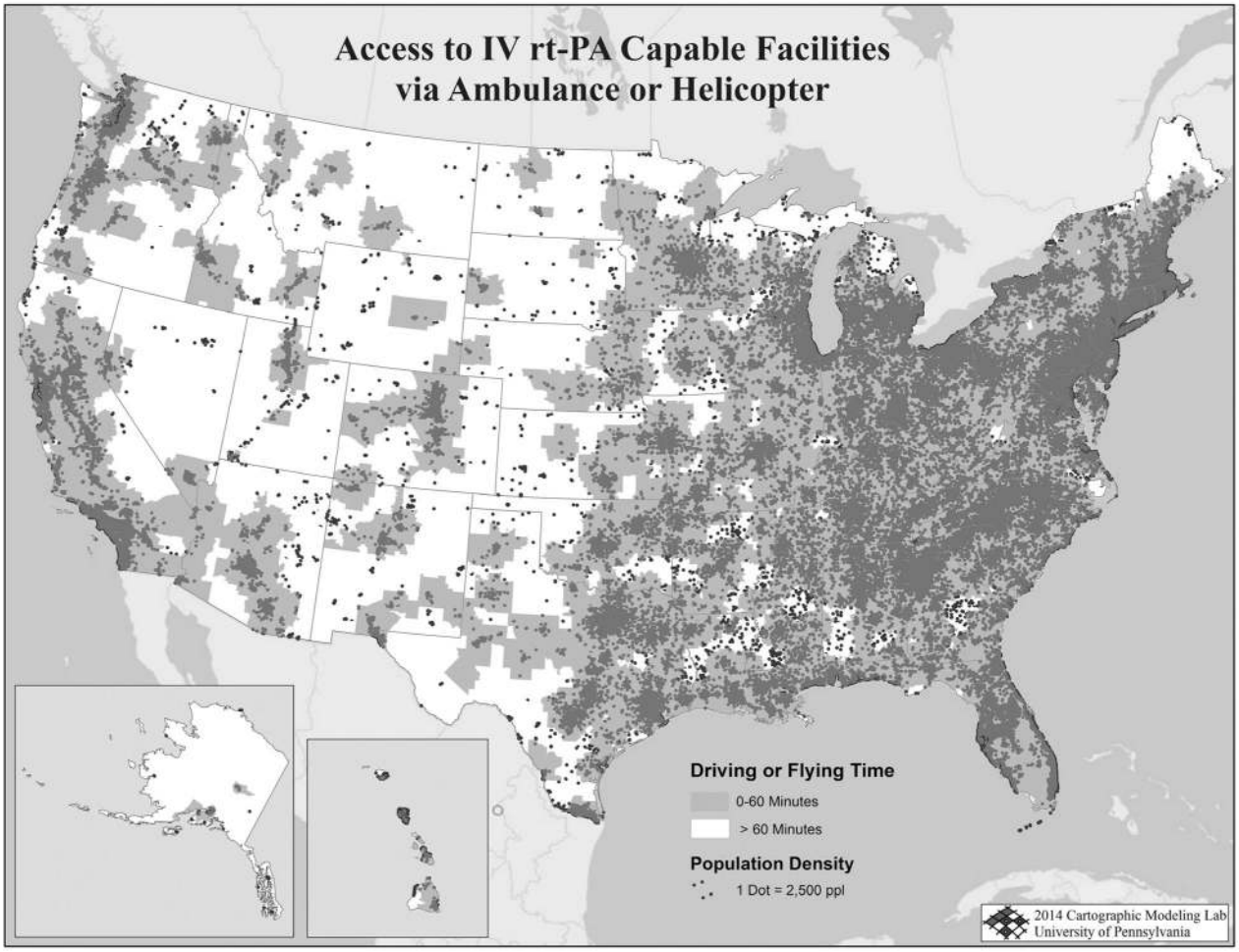

Figure 1.

Access by ground or air to intravenous recombinant tissue-type plasminogen activator (IV r-tPA)–capable hospitals within 60 minutes.

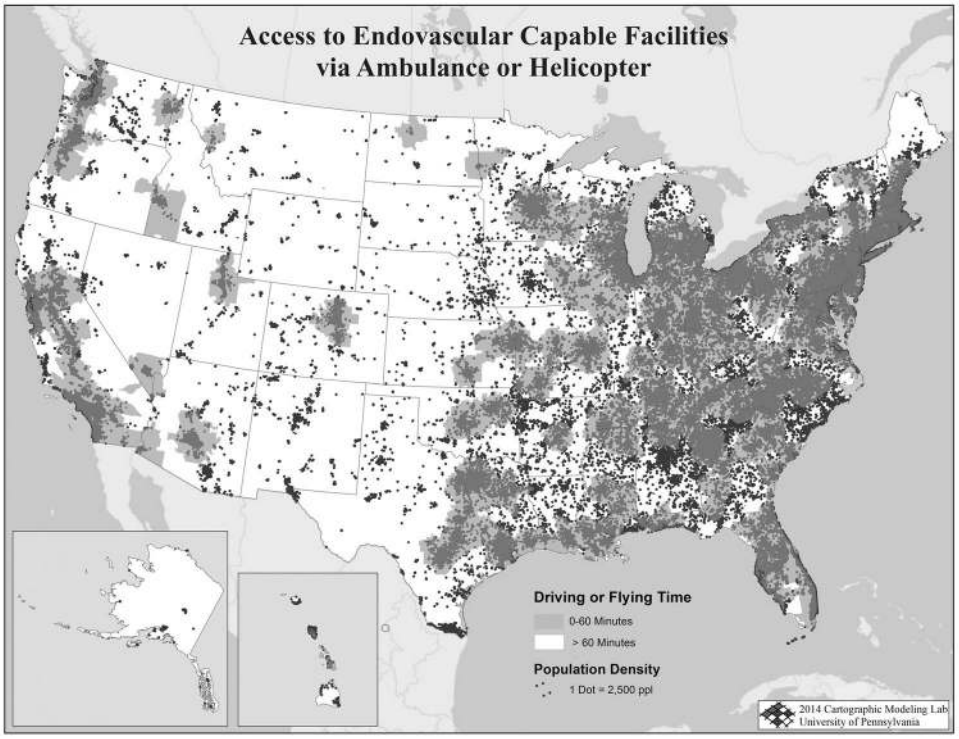

Figure 2.
Access by ground or air to endovascular-capable hospitals within 60 minutes.

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Table

Percentage of Americans With 60-Minute Access r-tPA–Capable Hospitals, Endovascular-Capable Hospitals, and Primary Stroke Centers by Ground and Air Ambulance, Allowing for Crossing State Lines

	60-min Ground Access			60-min Air Access		
	r-tPA Capable, %	Endovascular Capable, %	PSC, %	r-tPA Capable, %	Endovascular Capable, %	PSC, %
Northeast						
New England						
CT	95.6	63.8	89.4	100.0	100.0	100.0
ME	54.5	21.3	31.7	90.0	60.5	88.7
MA	96.3	63.4	9.3	100.0	97.6	96.9
NH	77.1	0.0	0.0	99.6	81.9	74.7
RI	97.5	83.7	96.5	100.0	100.0	100.0
VT	37.1	25.1	25.1	90.7	66.4	66.3
Middle Atlantic						
NJ	98.4	87.0	95.1	100.0	100.0	100.0
NY	91.9	77.4	72.3	99.8	96.0	94.2
PA	85.5	57.8	73.5	100.0	97.5	99.7
Midwest						
East North Central						
IN	75.0	43.6	55.7	99.0	95.8	93.2
IL	86.2	69.7	82.8	99.4	92.4	98.0
MI	83.3	61.1	72.5	94.4	88.7	91.4
OH	82.9	58.7	70.6	100.0	98.2	98.5
WI	69.8	42.3	62.8	95.2	90.7	92.5
West North Central						
IA	56.6	11.9	44.8	88.5	36.2	80.1
KS	64.8	51.8	52.8	86.9	74.8	74.9
MN	70.2	54.7	56.9	96.1	78.9	81.4
MO	67.3	55.4	59.1	97.7	85.5	91.8
NE	69.8	0.0	56.2	88.7	0.0	68.6
ND	54.6	29.6	36.8	44.8	34.8	24.7

	60-min Ground Access			60-min Air Access		
	r-tPA Capable, %	Endovascular Capable, %	PSC, %	r-tPA Capable, %	Endovascular Capable, %	PSC, %
SD	45.0	0.0	37.5	61.1	0.0	52.9
South						
South Atlantic						
DE	97.7	61.8	77.3	100.0	100.0	100.0
DC	100.0	100.0	100.0	100.0	100.0	100.0
FL	90.7	65.4	82.4	99.7	95.9	99.5
GA	77.7	41.8	64.8	97.9	85.8	89.9
MD	91.8	67.8	75.6	100.0	99.9	100.0
NC	71.9	43.9	55.7	99.3	84.0	91.1
SC	76.9	28.7	36.3	99.8	77.3	82.0
VA	83.0	55.3	73.0	99.9	92.5	98.1
WV	54.5	12.8	27.3	99.6	80.9	91.8
East South Central						
AL	61.5	6.8	11.4	95.9	35.1	47.8
KY	54.0	38.8	47.1	100.0	87.2	94.2
MS	50.1	25.6	29.0	89.3	64.3	66.9
TN	66.4	46.3	52.4	99.8	96.9	93.2
AR	59.2	17.4	25.1	90.7	37.1	64.9
LA	76.0	43.6	30.2	91.0	75.0	83.6
OK	60.6	47.2	52.5	93.3	71.3	83.6
TX	81.0	53.4	71.6	97.1	76.6	91.9
West						
Mountain						
AZ	82.1	56.2	72.3	95.4	73.8	88.0
CO	82.6	47.7	58.6	94.0	80.4	85.3
ID	62.1	37.1	37.1	87.9	54.8	54.7
NM	63.4	0.0	37.9	82.0	0.0	64.4
MT	55.3	9.1	22.9	57.9	14.5	31.7
UT	79.4	74.0	74.0	85.8	85.8	85.8
NV	82.2	67.6	82.1	94.3	72.9	94.2

	60-min Ground Access			60-min Air Access		
	r-tPA Capable, %	Endovascular Capable, %	PSC, %	r-tPA Capable, %	Endovascular Capable, %	PSC, %
WY	32.8	0.0	13.3	33.0	0.0	15.8
Pacific						
AK	50.9	0.0	39.2	71.7	0.0	57.9
CA	94.0	71.8	82.7	99.2	95.3	97.8
HI	81.4	70.6	61.7	21.3	11.7	0.0
OR	76.6	50.4	55.7	93.3	76.1	83.8
WA	84.5	61.6	65.8	95.4	84.1	84.5

PSC indicates Primary Stroke Center; and r-tPA, recombinant tissue-type plasminogen activator.