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## Statewide availability of acute stroke treatment, services, and programs: A survey of North Carolina Hospitals

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## ABSTRACT

**Introduction:** We conducted a statewide assessment of the availability of stroke treatment, services, and programs in North Carolina (NC) hospitals. We also examined differences in stroke care capabilities between urban, suburban, and rural hospitals and trends over the past 2 decades.

**Methods:** An electronic survey was distributed to all 111 licensed hospitals in NC. Survey questions asked about stroke center certification status (i.e., standardized levels of stroke care capabilities), diagnostic testing, acute treatments and protocols, and post-acute management. Responses were collected from October 2020–April 2021. Select characteristics were compared to those from prior NC surveys in 1998, 2003, and 2008.

**Results:** All 111 hospitals responded to the survey (100% response rate). Among 108 hospitals providing acute stroke care, 12 (11%) were Comprehensive Stroke Centers or Thrombectomy-Capable Stroke Centers, which were all located in urban or suburban areas. While 38% of urban/suburban hospitals were non-certified, 48% of rural hospitals were non-certified. Non-contrast computed tomography (CT), CT angiography, and alteplase treatment were widely available (100%, 95%, and 99%, respectively). Endovascular thrombectomy was solely available in urban/suburban hospitals (29%). Of non-tertiary hospitals, 81% were using telestroke for treatment and transfer decisions. Compared to prior survey results, the availability of CT angiography (76% in 2008 to 95% in 2020–2021), alteplase treatment (69% in 2008 to 99% in 2020–2021), and acute stroke clinical pathways (47% in 2008 to 90% in 2020–2021) increased. However, having an in-house neurologist on staff dropped from approximately 55% in prior surveys to 21% in the current survey.

**Conclusions:** Rural NC hospitals were less likely to have advanced diagnostic imaging and treatment capabilities for acute stroke. Temporal trends in staffing with an in-house neurologist and use of telestroke services should be further examined.

### Introduction

Recent advancements in acute stroke care, such as endovascular thrombectomy, have transformed early management and significantly improved patient outcomes.<sup>1</sup> However, the availability of advanced capabilities varies widely across geographic location and hospitals depending on their resources and specialization.<sup>2–4</sup> A 2014 study estimated only about half of the United States population could reach an endovascular-capable hospital by ground within 60 minutes.<sup>5</sup> The higher stroke mortality in rural areas, compared to urban, is partially due to limited access to thrombolytic and endovascular therapies.<sup>6</sup> Further, as advanced stroke care becomes more complex and costly,

rural-urban stroke disparities could widen.<sup>6</sup> There is an immediate need to develop and implement effective and equitable stroke systems of care to ensure access to primary and secondary prevention, acute care, and post-acute management.<sup>7</sup>

Despite the increasing emphasis on establishing stroke systems of care,<sup>8</sup> evidence on stroke care capabilities among hospitals is limited. Among 5,533 emergency departments (EDs) in the United States in 2018, 44% were associated with certified stroke centers, i.e., hospitals designated as meeting standards for stroke capabilities and providing high-quality stroke care.<sup>9</sup> Although stroke center certification by accreditation agencies, like The Joint Commission, implies a minimum standard of care,<sup>10</sup> hospitals can provide stroke services beyond their

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certification level.<sup>9</sup> Further, the capabilities of non-certified hospitals are challenging to capture and thus understudied.<sup>11</sup> Prior statewide surveys in North Carolina (NC) successfully assessed the stroke care capabilities of all hospitals across a large, diverse state.<sup>2,12,13</sup> From 1998-2008, these survey results showed several notable improvements in diagnostic imaging capabilities and written acute stroke protocols.<sup>2</sup> With recent advancements in acute stroke care, current data are needed on hospital-based capabilities and their differences by community and changes over time.

We conducted a statewide assessment of NC hospitals to determine the availability of stroke treatment, services, and programs. We examined differences in stroke care capabilities between urban, suburban, and rural hospitals and temporal trends over the past two decades. These findings can inform stroke system design and planning in NC and throughout the United States.

## Methods

### Study design & setting

This statewide cross-sectional survey was conducted in partnership with the NC Stroke Advisory Council to guide the state's stroke prevention and care initiatives. This study was determined to be exempt from human subjects review by the University of North Carolina Institutional Review Board. North Carolina includes a diverse population with respect to race, ethnicity, and socioeconomic status among its 10.4 million residents. Further, approximately 20% of the NC population resides in rural areas.<sup>14</sup> North Carolina is also located in the Stroke Belt, a multi-state region in the Southeast United States with disproportionately high stroke mortality.<sup>15</sup>

### Survey development & administration

The survey instrument (see Supplemental Material) was designed to capture various aspects of care capabilities (i.e., diagnostic imaging and treatments), staffing and services, and protocols and programs spanning acute and post-acute stroke management. Questions were adapted from prior surveys<sup>2,12,13</sup> and created to cover emerging topics by a multi-institutional, inter-disciplinary work group of the NC Stroke Advisory Council (see Supplemental Material). In NC, hospitals are certified by either The Joint Commission or Det Norske Veritas–Germanischer Lloyd accreditation organizations as meeting standards to provide high-quality stroke care. Respondents were asked to report their hospital's current stroke certification status [i.e., Acute Stroke Ready Hospital (ASRH), Primary Stroke Center (PSC), Thrombectomy-Capable Primary Stroke Center (TSC), or Comprehensive Stroke Center (CSC)] in addition to any pending or planned applications. Open-ended items were incorporated to elicit barriers and challenges faced in providing acute stroke care and post-acute management.

An electronic survey was distributed to all 111 civilian acute care hospitals licensed by NC in 2020. Respondents were identified from existing contact lists of hospital administrators, ED directors, and stroke center coordinators. Primary contacts for each hospital were emailed a link to complete the survey in the online platform Formstack® (Fishers, Indiana). Respondents were informed that hospital-identifiable information and results would not be reported or shared in presentations or publications. Follow-up reminders were made by email and telephone call. Survey responses were collected from October 2020 to April 2021.

### Data analysis

Responses to survey items were summarized with numeric counts and percentages for the entire state. For urban-rural comparisons, each hospital was classified as urban, suburban, or rural based on the census tract Rural-Urban Commuting Area (RUCA) code (1, 2-3, and 4-10,

respectively).<sup>16</sup> Because of few hospitals in suburban areas, we combined urban and suburban hospitals into one group to compare to rural hospitals. We computed standardized differences to evaluate the magnitudes of differences between the two groups.<sup>17</sup> As suggested by Cohen, cutpoints of 0.2, 0.5, and 0.8 corresponded to small, medium, and large differences, respectively.<sup>18</sup> For temporal trends, percentages for select key characteristics were compared to those from prior NC surveys in 1998, 2003, and 2008.<sup>2,12,13</sup> Responses to open-ended items were reviewed and summarized by two work group members and categorized into themes by the lead author (MDP).

## Results

Responses were received from all 111 NC hospitals identified in 2020 and invited to complete the survey (100% response rate). Three responded as not currently providing acute stroke care (i.e., not adequately staffed or only providing long-term care), leaving 108 eligible hospitals. All 108 hospitals completed the survey.

Over half of hospitals (57%) had a stroke center certification: 10 (9%) CSCs, 2 (2%) TSCs, 34 (31%) PSCs, and 16 (15%) ASRHs. Of the 46 non-certified hospitals, 4 reported pending applications, and 25 reported planned applications. Seventeen non-certified hospitals reported barriers to certification, including lack of staff (stroke coordinator, neurology) and other resources. Among 52 hospitals located in rural communities, 25 (48%) were non-certified whereas only 21 (38%) of 56 urban or suburban hospitals were non-certified (Fig. 1). Moreover, all CSCs and TSCs were located in urban or suburban communities.

Stroke capabilities and resources for NC hospitals overall and by urban/suburban and rural classification are presented in Table 1. Diagnostic imaging with non-contrast computed tomography (CT) and CT angiography was widely available although CT perfusion and diffusion-weighted MRI were less commonly available, especially in rural hospitals. While 107 (99%) hospitals provided alteplase, only 16 (15%) provided endovascular thrombectomy, solely in urban/suburban communities (standardized difference of 0.89). In-house neurology staffing was only available in 21% of hospitals, of which less than half had an in-house neurologist available 24/7. Ninety percent of non-CSCs used telestroke for the treatment and management of acute stroke patients. Further, 79% were relying on telestroke exclusively 24/7, with a marginally higher percentage among rural hospitals (standardized difference of -0.21). Majority of hospitals (81%) reported using telestroke to make transfer decisions for stroke patients requiring a higher level of care. Also, 87% of these hospitals used a transfer protocol for stroke patients although more prevalent among urban/suburban hospitals (standardized difference of 0.82). About half (49%) reported experiencing major delays in transferring patients with the main reasons being lack of beds at the receiving hospital, unavailable inter-facility transport (EMS or air medical), and weather not allowing air transport. Thirty-nine percent of hospitals reported challenges in providing acute stroke care because of the COVID-19 pandemic.

Select hospital stroke capabilities and resources were compared between our survey responses and those from prior NC surveys in 1998,

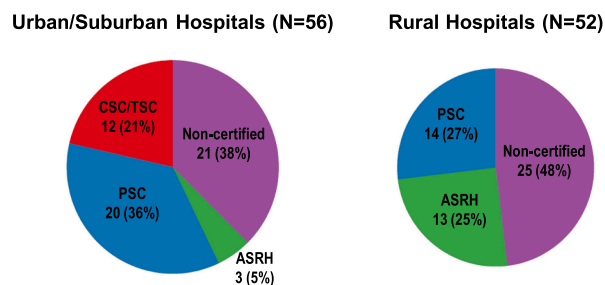


Fig. 1. Stroke Center Certification among North Carolina Hospitals by urban-rural classification, 2020-2021.

**Table 1**  
Stroke care capabilities, services, and programs among North Carolina Hospitals, 2020-2021.

	Overall (N=108)		Community Classification				Standardized Difference
			Urban/Suburban (N=56)		Rural (N=52)		
	No.	%	No.	%	No.	%	
<b>Acute Care Capabilities</b>							
<i>Diagnostic imaging</i>							
Non-contrast CT	108	100%	56	100%	52	100%	undefined
Available 24/7	88	81%	46	82%	42	81%	0.04
CT angiography	103	95%	54	96%	49	94%	0.10
Available 24/7	74	69%	41	73%	33	63%	0.21
CT perfusion	45	42%	30	54%	15	29%	0.52
Available 24/7	14	13%	11	20%	3	6%	0.43
Diffusion weighted MRI	55	51%	34	61%	21	40%	0.42
Available 24/7	34	31%	20	36%	14	27%	0.19
<i>Treatment</i>							
tPA/alteplase	107	99%	56	100%	51	98%	0.20
Endovascular thrombectomy	16	15%	16	29%	0	0%	0.89
<b>Staffing &amp; Services</b>							
In-house neurology	23	21%	18	32%	5	10%	0.58
Available 24/7	11	10%	11	20%	0	0%	0.70
Neuro-interventional services	19	18%	17	30%	2	4%	0.75
Available 24/7	17	16%	15	27%	2	4%	0.67
Telestroke*	88	90%	41	89%	47	90%	-0.04
Rely on 24/7	77	79%	34	74%	43	83%	-0.21
Transfer decisions	79	81%	38	83%	41	79%	0.10
Stroke unit	49	45%	35	63%	14	27%	0.77
Neuro-intensive care unit	16	15%	14	25%	2	4%	0.63
Inpatient rehabilitation	50	46%	27	48%	23	44%	0.08
<b>Protocols &amp; Programs</b>							
Acute stroke clinical pathway	97	90%	52	93%	45	87%	0.21
Prehospital EMS activation protocol	98	91%	50	89%	48	92%	-0.10
Pre-written stroke orders	91	84%	50	89%	41	79%	0.29
Transfer protocol*	85	87%	46	100%	39	75%	0.82
Evaluation for post-discharge rehab.	84	78%	44	79%	40	77%	0.04
Stroke quality improvement program	83	77%	47	84%	36	69%	0.35

\* Overall N=98, denominators for percentages excluded Comprehensive Stroke Centers.

Abbreviations: CT computed tomography, MRI magnetic resonance imaging, tPA tissue plasminogen activator.

2003, and 2008 (Table S1).<sup>2,12,13</sup> The total number of NC hospitals overall declined across surveys: 125 in 1998, 128 in 2003, 111 in 2008, and 108 in 2020-2021. The availability of non-contrast CT imaging (87% in 1998 and 100% in 2020-2021) and CT angiography (35% in 1998 and 95% in 2020-2021) increased over time (Fig. 2, panel a). Since the last survey in 2008, the percent of hospitals with a stroke unit increased from 23% to 45%. Neuro-interventional staffing and in-patient rehabilitation services remained similar over time (Fig. 2, panel b). However, the availability of in-house neurology dropped from about 55% in prior surveys to only 21% in this survey. The availability of an acute stroke clinical pathway, pre-written stroke orders, and a stroke quality improvement program improved similarly over time (Fig. 2, panel c)

## Discussion

This study provides a comprehensive assessment of stroke care capabilities among all NC hospitals in 2020-2021. Survey responses revealed gaps in advanced diagnostic imaging and treatment capabilities for acute stroke especially among rural hospitals. While the majority of both rural and non-rural hospitals had pre-written stroke orders, an inter-facility transfer protocol, and a stroke quality improvement program, our findings suggest some room for improvement in the availability of these organizational resources. We also found telestroke was widely used for both stroke treatment and transfer decisions throughout the state. Only one-fifth of hospitals were staffed with in-house neurology, which is a notable decline since a 2008 survey that found about half of NC hospitals had a neurologist on staff. Over the past 20 years, there have been substantial improvements in the statewide availability of basic diagnostic imaging, alteplase treatment, and an acute stroke clinical pathway, which coincide with large population

growth in NC. Since 2000, approximately 2.6 million people were added to the population with the 65 and older age group experiencing the most growth.<sup>19</sup>

Our findings on stroke center certification status were comparable with prior studies. In a national study by Boggs, et al., 44% of EDs were associated with a stroke center;<sup>9</sup> and in our study, 57% of hospitals were stroke centers. We found non-certified hospitals were more prevalent in rural areas. In open-ended survey responses, non-certified hospitals reported the lack of staffing with a neurologist and stroke coordinator as a major barrier to obtaining certification. Moreover, endovascular-capable stroke centers were only located in urban or suburban areas. Four out of 34 PSCs reported having endovascular thrombectomy, which highlights the importance of hospital surveys to assess regional stroke care capabilities instead of relying on certification levels. Further, our study addresses the dearth of evidence on stroke care capabilities in rural hospitals, many of which are non-certified.

The rural-urban gap in access to acute stroke care is well documented. Recently, Hammond, et al. showed lower rates of intravenous thrombolysis and endovascular thrombectomy among rural patients in nationwide data.<sup>6</sup> Rural hospital- and community-based quality improvement programs have been shown to improve stroke care and patient outcomes through investments in education, staffing, and organizational tools such as treatment pathways and protocols.<sup>20-22</sup> A statewide program in Montana in 2004 to address stroke care capabilities in rural hospitals significantly improved CT availability and ED stroke protocols.<sup>22</sup> More recent data from our survey show relatively high availability of CT imaging, alteplase treatment, and clinical pathways and protocols among rural NC hospitals. However, we found these hospitals were less likely to have advanced diagnostic imaging (i.e., CT perfusion, diffusion-weighted MRI), and endovascular thrombectomy capabilities. Because of the resources and specialization required, it may

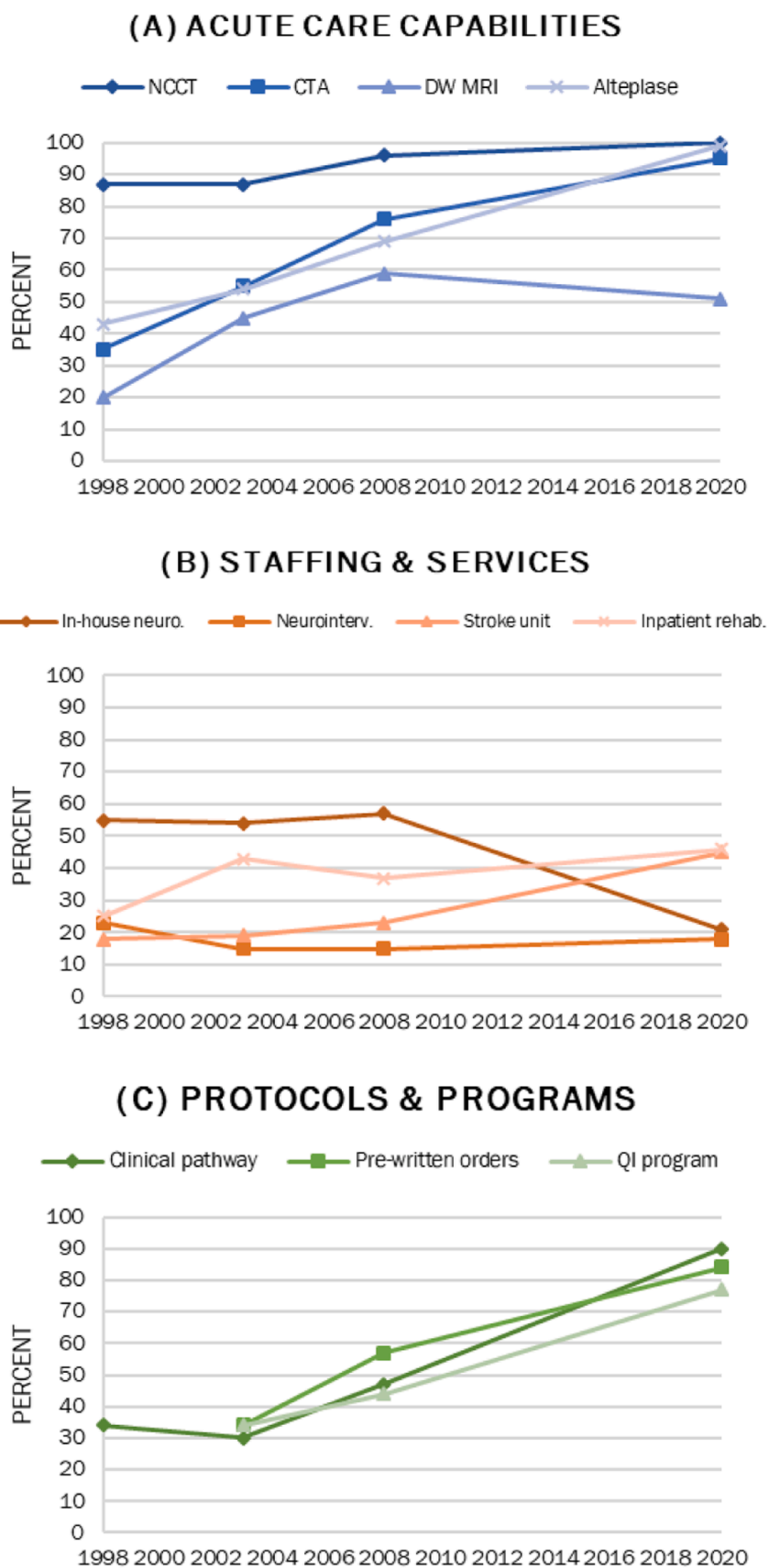


Fig. 2. Trends in select hospital-based stroke capabilities and resources in North Carolina based on 1998, 2003, 2008, and 2020-2021 Surveys.

be unreasonable to expect rural hospitals to improve in these capabilities. Further, rural hospitals in NC, as across much of the United States, are at higher risk of reducing services and closing due to financial problems.<sup>23</sup> Rather, reducing persistent rural-urban disparities in stroke morbidity and mortality may need to focus on improving regionalized stroke care that accounts for geographic differences in hospital certification (e.g., drip-and-ship and mothership models).<sup>24</sup> Because almost half of surveyed hospitals reported major delays in transferring patients, regional stroke systems should streamline and optimize inter-facility transfer workflows with data-driven process improvement.<sup>8</sup> Moreover, since transfer delays can be due to unavailable transport resources, expanding access to critical care transport services might also be a viable option for rural communities.

Among NC hospitals, we found 90% used telestroke, of which the majority were relying on it 24/7 to make treatment and transfer decisions for acute stroke patients. Our survey results show a substantially greater use of telemedicine services for stroke compared to 58% of EDs found to use telemedicine, for any clinical application, in a 2017 national survey.<sup>25</sup> Compared to 90% telestroke use in 2020-2021 found in our survey, another study reported 61% of NC hospitals had a telestroke program in 2015.<sup>26</sup> These findings suggest telestroke use in NC has grown rapidly since the first telestroke network in the state was established in 2009.<sup>27</sup> While the immediate expansion of telehealth services during the COVID-19 pandemic has likely played a role in recent changes,<sup>28,29</sup> there may be other secular trends that influenced the current widespread use of telestroke. For example, we found the availability of in-house neurology substantially decreased since 2008, suggesting telestroke services may have replaced in-house neurologists in many of these hospitals, including certified stroke centers. Recently, the lack of neurologists among rural NC hospitals was identified as a major motivator to implementing a telestroke program.<sup>30</sup> Our survey findings support future qualitative research on the facilitators and barriers to telestroke use and its role in stroke systems of care.<sup>31,32</sup>

This study has some notable limitations. First, findings of this NC hospital survey on urban-rural differences and temporal trends may not be fully generalizable to other states. As a part of the Stroke Belt, NC experiences higher stroke incidence and mortality, potentially motivating hospitals to address stroke care capabilities. We found a higher prevalence of stroke center certification and telestroke use compared to published national estimates, suggesting our findings on hospital-based stroke care capabilities may be more favorable than in other states. Nonetheless, our 100% response rate from civilian acute care hospitals across a large and diverse state provides rigorous evidence on urban-rural differences. Moreover, this work demonstrates the feasibility and importance of conducting similar surveys in other states. Second, the survey questions were not validated although they were informed by subject matter experts and adapted from prior surveys to allow comparisons over time. Third, even though we were able to compare surveys over 20 years, prior surveys did not report results by urban and rural hospitals, so we could not evaluate temporal changes by rurality and comment on trends towards centralization of acute stroke care. Fourth, the survey responses were self-reported and subject to error. To minimize inaccurate and missing data, respondents were allowed to share the unique survey link with colleagues and encouraged to complete the survey collaboratively as needed. Lastly, this survey was distributed during the COVID-19 pandemic; therefore, responses, especially those on treatment and transfer delays, may have been influenced by the pandemic effects on in-hospital care and community health.<sup>33,34</sup>

## Conclusions

This statewide survey of NC hospitals found widespread availability of basic diagnostic imaging and alteplase treatment for acute stroke. However, rural hospitals were less likely to have advanced diagnostic imaging and endovascular thrombectomy capabilities. Temporal trends in staffing with in-house neurology and use of telestroke services should

be further examined. Stroke system design and planning need to take into account geographic differences and temporal changes in hospital-based stroke care capabilities.

## Disclosures

None

## Declaration of Competing Interest

None

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## Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jstrokecerebrovasdis.2023.107323.

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