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ORIGINAL RESEARCH

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An inventory of stroke centers in the United States

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Abstract

Objectives: Stroke centers are essential for the optimal care of patients with acute stroke. However, there is no universally applied standard for stroke center certification/designation and no unified list of confirmed US stroke centers. Multiple national organizations, and some state governments, certify/designate hospitals as stroke centers of various levels, but discrepancies exist between these systems. We aimed to create a unified, easily accessible, national stroke center database.

Methods: Lists of confirmed stroke centers were obtained from national certifying bodies (The Joint Commission [TJC], Det Norske Veritas, and Healthcare Facilities Accreditation Program) and each state government. Lists were reconciled to a common standard based on TJC requirements and incorporated into the 2018 National Emergency Department Inventory–USA database, which includes all emergency departments (EDs).

Results: Among 5533 US EDs, we confirmed 2446 (44%) as stroke centers, including 297 Comprehensive Stroke Centers, 14 Thrombectomy-capable Stroke Centers, 1459 Primary Stroke Centers, and 678 Acute Stroke Ready Hospitals. Compared with EDs without stroke centers, EDs with stroke centers had higher annual visit volumes, were more often academic, and were more often located in hospitals that had trauma or burn centers.

Conclusion: We report the consolidation of multiple stroke center designation groups with varying criteria into a unified list of all confirmed US stroke centers linked to a comprehensive, national ED database. This data set will be valuable for future stroke systems research and improving access to emergency stroke care for patients. These data have the potential to further optimize the emergency care of patients with stroke.

KEYWORDS
Acute Stroke Ready Hospital, Comprehensive Stroke Center, National Emergency Department Inventory–USA, Primary Stroke Center, stroke, Thrombectomy-capable Stroke Center

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1 | INTRODUCTION

1.1 | Background

Stroke is the fifth leading cause of death in the United States, accounting for ≈140,000 American deaths annually.[1] Strokes not only cost the nation $34 billion annually through healthcare costs, medications, and lost productivity, but also they are a significant cause of disability. Stroke reduces mobility in more than half of stroke survivors aged older than 65 years.[1–3]

In the late 1990s and early 2000s, the medical establishment at large recognized the need for improvement in both acute stroke care as well as preventive care for recurrent strokes in response to several large-scale research efforts. The Brain Attack Coalition (BAC), a group of professional, voluntary, and governmental organizations, was formed with the intent of setting direction, advancing knowledge, and communicating the best practices to prevent and treat stroke.[4] In 2003, the American Heart Association (AHA), the American Stroke Association (ASA), and The Joint Commission (TJC) established a certification process for stroke centers based on the recommendations of the BAC.[4]

Since then, these organizations have published recommendations for 4 tiers of stroke centers. Comprehensive Stroke Centers have the highest capabilities and most resources for treating patients with acute stroke. They have advanced neuroimaging, endovascular neurointervention, a specific volume of patients with stroke, a database for tracking complications and patient outcomes, and participation in patient-centered research. Thrombectomy-capable stroke centers can perform thrombectomies on patients with stroke, but they do not need to meet all of the requirements that Comprehensive Stroke Centers do.[5] They must have performed a specific number of mechanical thrombectomies during the past 2 years, but are not required to perform in patient-centered research. Primary Stroke Centers can quickly evaluate a patient with stroke, provide intravenous thrombolytics, and provide advanced medical management of stroke based on evidence-based guidelines for stroke care. Finally, Acute Stroke Ready Hospitals certify stroke centers that can identify and initiate care to patients with stroke but ultimately often transfer them to another facility with more advanced care.[5,6]

1.2 | Importance

Certification is associated with higher stroke quality of care and lower mortality after ischemic strokes.[4,7–12] However, to our knowledge, there has never been a unified list of all confirmed US stroke centers, and there is no unified stroke center certification system in the United States.[8] In addition to TJC, there are 2 other national certification agencies that certify stroke centers and follow similar guidelines consistent with recommendations of the AHA/ASA and the BAC in their stroke center certification processes: Det Norske Veritas and Germanischer Lloyd (DNV), an international organization, and the Healthcare Facilities Accreditation Program (HFAP). Both organizations have been formally approved by the Centers for Medicare and Medicaid Services (CMS) to certify stroke centers nationally. In addition to these national agencies, individual states also certify stroke centers.

The Bottom Line

With increased specialization of stroke care in the US, a universal standard and list of emergency department (ED) stroke centers is needed. This manuscript consolidates all 2,446 stroke centers by location and level into a simple app *findERnow*, thereby making ED selection easier for the public and EMS.

1.3 | Goals of this investigation

With a focus on acute stroke care, the aim of the current study was to develop a unified database of confirmed stroke centers colocated with emergency departments (EDs). We then aimed to make this information easily accessible to the public to optimize access to emergency care for patients with stroke.

2 | METHODS

2.1 | Design

This is a cross-sectional study of all stroke centers colocated with EDs during the year 2018. The Mass General Brigham Human Research Committee reviewed this project and classified it as exempt.

2.2 | Stroke center data sources

We developed a unified list of confirmed stroke centers by collecting and integrating data from a number of different national-level (ie, across multiple states) and state-level sources. We only included stroke centers formally recognized by 1 of these external sources to reflect confirmation of their stroke center capabilities. Regarding national stroke lists, TJC list was downloaded (December 18, 2018) from the "TJC Quality Check" website, which publishes an up-to-date list of all TJC-certified stroke centers.[13] The DNV[14] and HFAP[15] lists were compiled into a spreadsheet from lists found on their respective websites.

Regarding state lists, we conducted online Google searches using combinations of terms, including "[state name]," department of health," "stroke center," and "emergency medical services" (EMS). To supplement online data, representatives from each state's department of

health and Washington, DC, were contacted through email, online form, or phone. We did this to either obtain a list (or updated list) of stroke centers for the year 2018 if data posted online were missing or not up to date or to confirm that data posted online were comprehensive. We compiled information from the state's sources, including source organization type and details, source download link, source of last list update when applicable, contact information for source information when applicable, and PDFs of all relevant correspondence. We incorporated these methods into a manual of procedures to facilitate the abstraction of stroke center data in future years.

2.3 | National Emergency Department Inventory–USA database

Once the stroke lists were finalized and confirmed as up to date, we matched all stroke centers by name and address to hospitals/EDs from the 2018 National Emergency Department Inventory (NEDI)–USA database from the Emergency Medicine Network at Massachusetts General Hospital.[16] We assume that all—or nearly all—stroke centers are colocated in EDs given the criteria for stroke center certification (eg, initial assessment by an emergency physician). NEDI-USA is a comprehensive database of all non-federal, non-specialty EDs in the United States open 24 hours a day, 7 days a week, 365 days per year, including freestanding EDs. The 2018 NEDI-USA database included 5533 EDs. The locations of all US EDs currently open can be found in the free smart phone application (app), *findERnow*.[17] This app is based off of NEDI-USA and uses the Global Positioning System to give the distance, directions, and driving times to all nearby EDs, anywhere in the United States.

NEDI-USA includes annual total ED visits volumes, which were categorized into the following 4 groups: <10,000, 10,000 to 19,999, 20,000 to 39,999, and ≥40,000. US Census Bureau regions were used to classify ED locations: Northeast, Midwest, South, and West. ED locations were also classified as location within or outside of a core-based statistical area.[18] Other ED characteristics incorporated into NEDI-USA and examined were academic ED status,[19] freestanding EDs[20] (broken down into subgroups of autonomous and satellite EDs), Critical Access Hospitals (CAH),[21] trauma centers,[22] and burn centers.[23]

2.4 | Stroke center definitions

As previously introduced, there are 4 different levels of acute stroke centers. From most to least advanced, these are Comprehensive Stroke Centers, Thrombectomy-capable Stroke Centers, Primary Stroke Centers, and Acute Stroke Ready Hospitals. Both national agency and state stroke system agencies have standards for each level based on recommendations of the AHA/ASA and BAC and codified by TJC. Therefore, the criteria for each stroke center category or level was standardized to that published by TJC.

2.5 | Unified stroke center classification system

Each ED in NEDI-USA was classified according to (1) whether a stroke center confirmed by 1 of the 3 national organizations or by its respective state was colocated with the ED and (2) at what level it was confirmed. In some cases, a state agency would not use the categories Comprehensive Stroke Center, Thrombectomy-capable Stroke Center, Primary Stroke Center, and Acute Stroke Ready Hospital, but would use other categories such as level 1, level 2, and level 3 or level 1+, level 1, and level 2. When this was the case, we reviewed the standards of each level either in state stroke center application materials or legislation. From this information, we reclassified each of the non-standard categories as either Comprehensive Stroke Center, Thrombectomy-capable Stroke Center, Primary Stroke Center, or Acute Stroke Ready Hospital. Given the focus on stroke centers colocated with EDs, we excluded all stroke centers coded as stroke rehabilitation centers only.

To classify a confirmed stroke center to a standardized TJC level, several methods were used. We contacted representatives from all states via phone or email about their stroke systems. In addition, state stroke center legislation was investigated online. Finally, we accessed and reviewed state stroke center application forms for similar standards as those published by TJC, such as diagnostic testing capability, staff stroke education requirements, and clinical performance measures.

Hospitals/EDs may have dual stroke center certification for different levels. If a stroke center indeed had ≥2 conflicting certification levels, we considered it to be in the more advanced stroke center level to avoid counting each stroke center more than once. For instance, if a stroke center was both a TJC-confirmed Comprehensive Stroke Center and a state-confirmed Primary Stroke Center, it was counted as a Comprehensive Stroke Center in our final database.

To address discrepancies in nomenclature, we assumed that a center "confirmed" to be a certain stroke level was the equivalent of a center "designated" or "recognized" at that level. The term *certification* is used by each of the 3 national agencies. However, state governments use a combination of "certification," "designation," and "recognition." For instance, stroke centers were often considered to be state certified if they attested to the national standards and had a site visit, and stroke centers were considered to be state designated if they attested to the national standards but did not require a site visit. From this framework, we were able to develop a nationwide count of each type of confirmed stroke center by certifying organization and state government designation.

2.6 | Analysis

Data analysis was performed using Stata 15.1 software (StataCorp, College Station, TX). Descriptive statistics are presented as frequencies with proportions. Bivariate associations between ED characteristics and stroke center classifications were tested using chi-square,

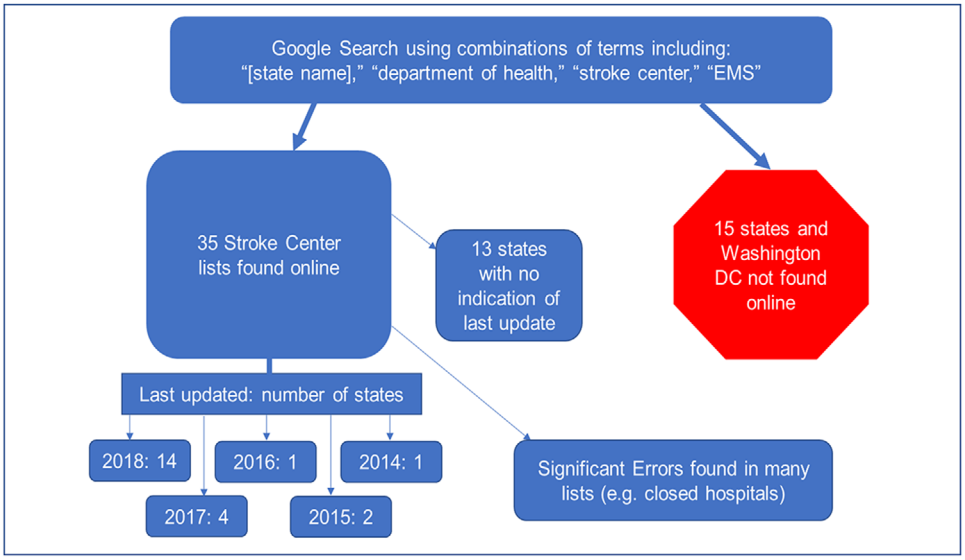

FIGURE 1 Online stroke center algorithm. Initial search algorithm used for collecting online stroke center information. This yielded significant outdated and incomplete information and was supplemented by calls and emails to each state government representatives. EMS, emergency medical services

Fisher's exact, and Kruskal-Wallis tests as appropriate. All *P* values were 2-tailed, with $P < 0.05$ considered statistically significant.

3 | RESULTS

3.1 | State lists

A total of 35 state stroke center lists were found online with varying dates of last updates (Figure 1). In 13 states where a list could be found online, there was no indication of the last update. No stroke center lists could be found for 15 states and Washington, DC, after online search and contact with state departments of health. While matching confirmed stroke centers with EDs in NEDI-USA, significant errors were found in many of the state lists (eg, closed hospitals), and many hospital names were not up to date. After additional contacts with state departments of health, we confirmed that the actual stroke center certifications used in this database were up to date as of December 2018. We plan to continue to update this stroke list annually each December, implementing the aforementioned methods. Going forward, the updated lists will be made available in *findERnow* as soon as they are collected and will be later incorporated into the corresponding NEDI-USA database for that year. If EDs gain or lose stroke center certification before the annual update, they may request that we immediately update their information in *findERnow* by writing to us at emnet@partners.org.

3.2 | State and national agency comparison

All 50 states and Washington, DC, contain stroke centers certified by national agencies. A total of 28 states and Washington, DC, have Comprehensive Stroke Centers, Primary Stroke Centers, and Acute Stroke Ready Hospitals certified by national agencies with no state certification, designation, or recognition. The remaining 23 states had various ways of confirming their own stroke centers. A total of 3 states (Nebraska, Rhode Island, and West Virginia) have Comprehensive Stroke Centers, Primary Stroke Centers, and Acute Stroke Ready Hospitals certified by national agencies and designated by the state with an attestation that they are certified by a national agency. Two states (Minnesota and North Dakota) have Comprehensive Stroke Centers, Primary Stroke Centers, and Acute Stroke Ready Hospitals certified by national agencies and designated by the state with an attestation. Acute Stroke Ready Hospitals are also designated by these states, with a site visit required.

A total of 2 states, New York and Massachusetts, have unique but similar systems. In New York, although many stroke centers are certified by national agencies, that certification is not recognized by the state, and there is a separate process to become designated as a stroke center. The designation system is binary with no tiered levels. New York "stroke centers" have similar standards to nationally certified Primary Stroke Centers and require a site visit. Massachusetts designates stroke centers as "Primary Stroke Service Centers" without a required site visit. The designation of "Primary Stroke Service Center" has been confused with "Primary Stroke Center" when in reality the designation standards are instead functionally closer to those of an Acute Stroke Ready Hospital.[24,25] The 15 remaining states have distinct certification systems (Online Supplement, Table S1).

3.3 | Characteristics of US stroke centers

Overall, there were 1371 confirmed stroke centers certified by TJC, 191 by DNV, 60 by HFAP, and 1427 by state governments (Table 1). When excluding overlap (eg, those certified by multiple organizations

TABLE 1 Nationwide counts of each type of stroke center by certifying organization and state government designation, n = 2446

Type of stroke center	TJC	DNV	HFAP	State	Total excluding overlap
CSC	174	69	5	134	297
TSC	15	0	0	0	12
PSC	1112	116	47	647	1459
ASRH	70	6	8	646	678

Abbreviations: ASRH, Acute Stroke Ready Hospital; CSC, Comprehensive Stroke Center; DNV, Det Norske Veritas; HFAP, Healthcare Facilities Accreditation Program; PSC, Primary Stroke Center; TJC, The Joint Commission; TSC, Thrombectomy-capable Stroke Center.

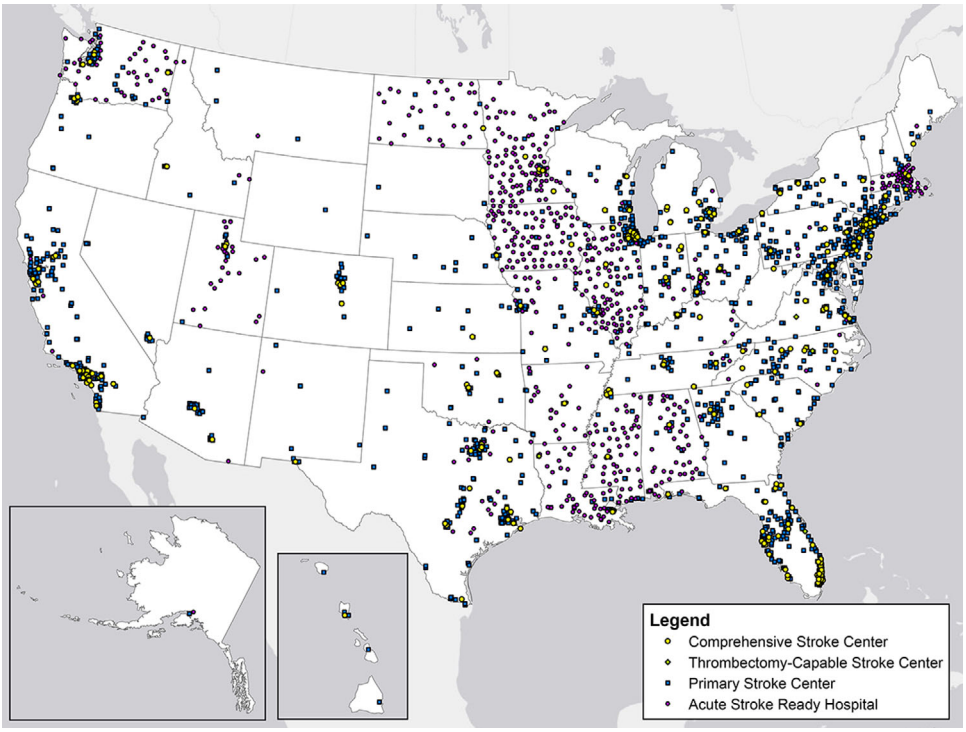

FIGURE 2 Locations of all US stroke centers, 2018. All US Comprehensive Stroke Centers, Thrombectomy-capable Stroke Centers, Primary Stroke Centers, and Acute Stroke Ready Hospitals in 2018 are shown

and at multiple levels), the final stroke data set included 2446 stroke centers: 297 Comprehensive Stroke Centers, 12 Thrombectomy-capable Stroke Centers, 1459 Primary Stroke Centers, and 678 Acute Stroke Ready Hospitals. The locations of all stroke centers are shown in Figure 2, and state-specific counts of certified stroke centers are shown in the Online Supplement (Table S2). Of US Eds, 44% were located in a facility with a confirmed stroke center; there were 3087 (56%) US EDs without a confirmed stroke center.

Compared with EDs without confirmed stroke centers, EDs with confirmed stroke centers more frequently had total annual ED visit volumes of ≥40,000 (50% vs 10%, respectively), were academic (8% vs 1%), and had a trauma center (32% vs 4%) and a burn center (2% vs 0.1%, all $P < 0.001$; Table 2). The Northeast had more confirmed stroke centers (17%), whereas the South had a lower percentage of hospitals with confirmed stroke centers (7%, $P < 0.001$). Stroke centers were less frequently located outside of core-based statistical areas or CAHs.

The characteristics of US EDs by confirmed stroke center type are shown in Table 3. Comprehensive Stroke Centers and Primary Stroke Centers more frequently had a total annual ED visit volume ≥40,000 compared with Acute Stroke Ready Hospitals (92%, 61%, and 10%, respectively). Comprehensive Stroke Centers and Primary Stroke Centers, compared with Acute Stroke Ready Hospitals, more frequently were located in the Northeast (17%, 20%, and 10%), had trauma centers (68%, 35%, and 8%), and were less frequently located outside of core-based statistical areas (0.3%, 1%, and 35%, all $P < 0.001$). No Comprehensive Stroke Centers and only 1% of the Primary Stroke Centers were designated as CAHs, whereas 48% of Acute Stroke Ready Hospitals were Critical Access Hospitals ($P < 0.001$). No Acute Stroke Ready Hospitals were located in hospitals with burn centers. Thrombectomy-capable Stroke Centers had similar characteristics to Comprehensive Stroke Centers and Primary Stroke Centers. For example, 67% of Thrombectomy-capable Stroke Centers had a total annual ED visit volume ≥40,000, and none were designated as CAHs.

TABLE 2 Characteristics of US emergency departments with any stroke center[a] versus those without any type of stoke center

ED characteristics	Any stroke center (n = 2446)	No stroke center (n = 3087)	*P* value
Annual total ED visits			<0.001
<10,000	311 (13)	1380 (45)	
10,000–19,999	238 (10)	802 (26)	
20,000–39,999	662 (27)	608 (20)	
≥40,000	1235 (50)	297 (10)	
Region			<0.001
Northeast	407 (17)	225 (7)	
Midwest	717 (29)	791 (26)	
South	878 (36)	1491 (48)	
West	444 (18)	580 (19)	
Rural	252 (10)	857 (28)	<0.001
Academic ED	206 (8)	21 (1)	<0.001
Freestanding ED	19 (1)	726 (24)	<0.001
Autonomous ED	0 (0)	270 (9)	<0.001
Satellite ED	19 (1)	456 (15)	<0.001
Critical access hospital	333 (14)	1018 (33)	<0.001
Trauma center	777 (32)	128 (4)	<0.001
Burn center	54 (2)	3 (0.1)	<0.001

Note: Results are reported as n (%).
Abbreviation: ED, emergency department.
[a]Includes hospitals/EDs certified as a Comprehensive Stroke Center, Thrombectomy-capable Stroke Center, Primary Stroke Center, or Acute Stroke Ready Hospital.

TABLE 3 Characteristics of US emergency departments by stroke center type

ED characteristics	CSC (n = 297)	PSC (n = 1459)	ASRH (n = 678)	*P* value
Annual total ED visits				<0.001
<10,000	2 (1)	12 (1)	297 (44)	
10,000–19,999	3 (1)	67 (5)	168 (25)	
20,000–39,999	20 (7)	496 (34)	142 (21)	
≥40,000	272 (92)	884 (61)	71 (10)	
Region				<0.001
Northeast	51 (17)	288 (20)	67 (10)	
Midwest	64 (22)	331 (23)	320 (47)	
South	129 (43)	540 (37)	204 (30)	
West	53 (18)	300 (21)	87 (13)	
Rural	1 (0.3)	14 (1)	237 (35)	<0.001
Academic ED	115 (39)	86 (6)	2 (0.3)	<0.001
Freestanding ED	0	6 (0.4)	13 (2)	<0.001
Autonomous ED	0	0	0	–
Satellite ED	0	6 (0.4)	13 (2)	<0.001
Critical access hospital	0	10 (1)	323 (48)	<0.001
Trauma center	202 (68)	515 (35)	55 (8)	<0.001
Burn center	35 (12)	19 (1)	0 (0)	<0.001

Note: Results are reported as n (%). Thrombectomy-capable stroke centers (n = 12) were excluded from these results.
Abbreviations: ASRH, Acute Stroke Ready Hospital; CSC, Comprehensive Stroke Center; ED, emergency department; PSC, Primary Stroke Center.

4 | LIMITATIONS

Our study had several potential limitations. First, we primarily relied on data published online. However, the variation in availability of information online was mitigated by directly contacting state officials and by reviewing legislation posted online. Another limitation is that hospitals or EDs may perform procedures or follow guidelines that would qualify it for a stroke center designation or certification but still may not have obtained that designation. For instance, one third of TJC Primary Stroke Centers perform thrombectomy even though this is beyond the requirement for Primary Stroke Center certification.[5] Furthermore, there may be EDs that have some capabilities to treat strokes (eg, via telestroke) that are not formally certified, designated, or recognized by a national agency nor by their state. We decided not to include stoke centers without external confirmation in our database given that having an external confirmation suggests that the sites consistently meet standards set forth by the certifying, designating, or recognizing organization. Also, this analysis reflects stroke center availability and ED characteristics for the year 2018. Although these results provide a baseline for these characteristics in the pre-COVID-19 era, it is likely that there have been meaningful changes since the onset of COVID-19. We encourage future work to characterize these changes.

5 | DISCUSSION

Given that access to timely and specialized care are 2 areas of the utmost importance when providing emergency care for a patient with stroke, the compilation of a national, unified database of confirmed stroke centers is an important endeavor. Although national agencies (TJC, DNV, HFAP) have unique lists of stroke centers available online, and many states have certification systems, there has not previously been a combined, up-to-date, easily accessible list of all >2000 EDs with stroke centers. With this list, we confirmed distinctions between EDs that were part of confirmed stroke centers versus those that were not.

These results are consistent with those of prior studies investigating stroke center certification. For example, it is suggested that hospitals in urban areas and with higher patient volumes are more likely to have better patient outcomes and cost savings among patients with stroke.[4] Although the current study does not explore patient outcomes, we indeed found that EDs that were part of confirmed stroke centers were larger and tended to be located in urban areas. Conversely, our results suggest that locations outside of core-based statistical areas (ie, more rural areas) may lack access to confirmed stroke centers. We encourage future research and policy work to investigate barriers to stroke center certification in those areas as well as exploring alternative methods for the improvement of the care of patients with stroke (eg, telehealth use).[26]

There have been recent attempts to create a unified list of confirmed stroke centers, most notably by Shen et al.[27] Although this resource is valuable, it is likely to be incomplete because the authors relied on the American Hospital Association Database to identify EDs. The American Hospital Association does not list hundreds of the EDs included in NEDI-USA (4546 vs 5479 EDs in 2017, respectively).[28] Indeed, the authors identified 1689 hospitals/EDs with stroke centers in 2017 versus the 2446 we identified in 2018. In addition, Shen et al.[27] obtained a list of stroke centers certified by their state per online sources only. We contacted individuals from state departments of health to confirm that their lists were up to date to supplement data identified in online lists and repositories. We believe that this additional confirmation has yielded the most complete list of confirmed stroke centers available today. Furthermore, this is the only list that will be made easily available to other researchers. Instructions for requesting this list for a specific project can be found at https://findernow.massgeneral.org/methods/stroke-data/.

We hope that this list of confirmed stroke centers will be used to help inform health services research about stroke care, including research about differences in stroke quality of care and patient outcomes between states. Currently, the website for the National Stroke Association simply directs visitors to TJC webpage where one can find a downloadable list of TJC-certified hospitals without any indication of other national certifying bodies. State governments have implemented their own stroke system guidelines and requirements, further complicating the ability to access a unified list of confirmed stroke centers. In studies that include all 3 national certifying organizations, their analyses do not include exclusively state-designated or state-recognized stroke centers.[8,25,29] To facilitate greater transparency in the stroke capabilities of hospitals/EDs, we encourage states with stroke center certification, designation, and recognition systems to make their stroke center requirements and updated lists of stroke centers publicly available online. This new unified, confirmed stroke list, linked with the NEDI-USA database, allows for the analysis of stroke center data and provides a more complete picture of the capabilities of US EDs in a way that was previously impossible.

As described previously, we are incorporating the unified stroke center list into *findERnow*.[25] EMS personnel and emergency physicians might use this app to help patients identify nearby stroke centers if they are planning to travel. In addition, EMS can use the app to identify nearby stroke centers if they are on a long transport in an unfamiliar area.

As described previously, Comprehensive Stroke Centers, Thrombectomy-capable Stroke Centers, and Primary Stroke Centers are certified as being capable of providing more advanced stroke care when compared with Acute Stroke Ready Hospitals.[5,6] Given the differences in characteristics between Comprehensive Stroke Centers and Primary Stroke Centers compared with Acute Stroke Ready Hospitals, as confirmed by our data, the app distinguishes between "advanced" (ie, Comprehensive Stroke Center, Thrombectomy-capable Stroke Center, Primary Stroke Center) and "basic" (ie, Acute Stroke Ready Hospital) stroke centers.

In conclusion, creating an up-to-date list of confirmed stroke centers by combining all certified by national agencies as well as state agencies into 1 unified list will serve several purposes. By incorporating the data into a free smartphone app (*findERnow*), it will allow EMS as well as the general public to quickly and easily find a stroke center. In addition, linking these data with other databases will allow future researchers a

more complete and accurate way of studying the outcomes at stroke centers in a way that has not been possible before.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Krislyn M. Boggs, Brian T. Vogel, Ashley F. Sullivan, and Carlos A. Camargo conceived and designed the study. Krislyn M. Boggs, Brian T. Vogel, Kori S. Zachrison, and Ashley F. Sullivan collected the data. Janice A. Espinola provided statistical advice and Mohammad K. Faridi analyzed the data. Rebecca E. Cash created the map. Krislyn M. Boggs and Brian T. Vogel drafted the manuscript, and all authors contributed substantially to its revision. Carlos A. Camargo, Jr. takes responsibility for the article as a whole.

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SUPPORTING INFORMATION

Additional supporting information may be found in the online version of the article at the publisher's website.

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