National Institute of Neurological Disorders and Stroke

Inequities in Access and Delivery of Acute Stroke Care

A Brain Attack Coalition Symposium Report

October 2022

Editing: National Institute of Neurological Disorders and Stroke

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Prepared by:

Office of Neuroscience Communications and Engagement

National Institute of Neurological Disorders and Stroke

National Institutes of Health

Department of Health and Human Services

For more information, please visit: www.ninds.nih.gov

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Brain Attack Coalition

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Preamble

Mark J. Alberts, M.D.
Brain Attack Coalition Chair and Symposium Steering Committee Co-Chair

Stroke is a leading cause of death and disability in the United States, affecting more than 795,000 individuals annually (Tsao et al., 2022). Additional patients have some form of cerebrovascular disease or transient ischemic attack. Each year, hospitals and healthcare systems across the country provide lifesaving stroke treatments to thousands of people, but many more do not receive timely and adequate stroke care. Hidden within these statistics are racial, ethnic, socioeconomic, and geographic inequities in stroke care that continue to impact the U.S. healthcare system, our patients, and their families. Considering the incidence and prevalence of stroke—as well as the importance of aging on stroke occurrence—these disparities will have an increasing impact on public health in the coming years and decades.

Recognizing this as a growing problem, on March 17-18, 2022, the National Institute of Neurological Disorders and Stroke (NINDS) sponsored a symposium of the Brain Attack Coalition titled *Inequities in Access and Delivery of Acute Stroke Care*. The call to action for the symposium was to leverage current knowledge, approaches, and technologies to better understand the etiologies for the various disparities. The ultimate goal was to formulate strategies and specific interventions to mitigate such inequities, thus, improving patient care and clinical outcomes for all populations.

The first goal of the symposium was to define the current scope of inequities in acute stroke care and understand their root causes and major contributors. We examined these issues through the prism of three major time epochs: prehospital care, acute care in an emergency department setting, and in-hospital or inpatient care. Other stroke care epochs such as primordial care, primary prevention, and post-stroke rehabilitation are of obvious importance but were beyond the purview of the symposium. However, these considerations were included in our formulations and recommendations whenever possible.

For all time epochs, we examined four cross-cutting themes: geography, policy and regulatory issues, economics and healthcare resources, and demographics. The importance of each theme varied depending on the time epoch and care paradigm. We further refined and focused each element based on information gathered during the symposium. Our hope is that hospitals, health systems, payors, and medical professionals will find these reports useful in service to the patient community.

Prehospital care was a key focus of the symposium because deficiencies in early recognition, triage, and transport have clear downstream implications in terms of treatment options, care venues, and clinical outcomes. Limited prehospital care and emergency medical resources are common sources of inequity in many cities and regions. Regarding the acute care epoch (both emergency and in-hospital care), sources of disparity may relate to differences in hospital capabilities, such as staffing, infrastructure, and related resources. We identified several barriers to stroke care, some of which were thought to be artificial based on the hospital, the system, and/or provider network concerns. Other barriers were state-based issues, potentially driven by state policies, rules and regulations,

and/or financial concerns. Some of these issues are largely driven or defined by insurance issues and limitations.

Socioeconomic status has often been cited as underlying many inequities in healthcare that exist today. Gaining a better understanding of the role of socioeconomic differences across the stroke care continuum (at the individual and population level) might inform us about the best approaches to address such disparities.

Further, when discussing stroke etiology, it is important to understand and acknowledge the diversity of affected populations, as well as the risk factors that lead to stroke. The heterogeneous nature of stroke mandates approaches that account for the variable impact of environmental factors, acquired risk factors, and genetic influences, all of which contribute to the development of ischemic stroke, hemorrhagic stroke, and cerebrovascular disease.

The good news is that we can resolve many of these concerns and disparities. As a first step, we could leverage tools and technologies and potentially modify stroke care policy. Some disparities may require fundamental alterations by way of reallocating resources, while others may require major alterations in the delivery of stroke care and implementation of these changes at a national level. Enhancing the diversity of stroke leadership committees who formulate policy and stroke care guidelines may help address the lack of diversity in the stroke care workforce and improve equity.

Clearly defining areas where there is a lack of diversity and equity, as well as developing a better understanding of their root causes, is a necessary process to begin to formulate timely and effective interventions to address and solve today's disparities. We understand that in some cases, a common solution or approach might be able to address multiple concerns, perhaps in multiple geographic regions or care venues. Other cases may require more specific and targeted interventions.

Stroke is too common a problem and a major public health concern—we simply must do a better job addressing disparities along the entire continuum of care for patients and families. It is important to acknowledge that inequities exist in almost all aspects of stroke care, including primary prevention, acute care, post-stroke care, and outcomes. Having said that, due to limitations in time and resources, we had to begin our efforts within a reasonable time epoch.

We believe that starting in the acute care arena provides a feasible opportunity to identify common and significant issues that, when properly addressed, will have a good chance of eliminating disparities in care that will result in improved outcomes within a relatively short time frame, while also using available resources. The reports that follow, informed by task forces of stroke experts and proceedings of the symposium, provide additional context for each time epoch, including short- and long-term actionable goals.

Executive Summary

Prior to the Brain Attack Coalition's *Inequities in Access and Delivery of Acute Stroke Care* symposium, the National Institute of Neurological Disorders and Stroke (NINDS), as a member of the Brain Attack Coalition, orchestrated a series of steering committee, task force, and subgroup meetings to begin thoughtful discussions on inequities in stroke care and possible strategies to address them.

During the meetings, task force members identified key disparities in stroke care and their root causes, potential solutions, best practices, remaining knowledge or research gaps, and tangible actions over both the short- and long-term to address inequities. Notably, each task force was composed of diverse, multidisciplinary teams of stroke and public health experts, including neurologists, emergency specialists, epidemiologists, health policy analysts, professional group representatives, and others, who voluntarily came together to formulate these recommendations on how to improve equity in stroke care.

Findings from each task force were formally presented at the public symposium, where they were cumulatively reviewed, re-evaluated, and discussed further among task force members, the steering committee, and attendees. We are grateful that individuals from different professions, medical specialties, and parts of the nation participated in the symposium, providing us with invaluable insight and feedback on our proposed reports. Although extensively detailed in the proceeding chapters, the key findings and recommendations of each task force can be summarized as follows:

Prehospital Stroke Care

In the prehospital care setting, there are many disparities in quantity, distance, and availability of emergency medical services (EMS), especially in rural areas of the country. For a variety of reasons, there are also disparities in awareness of stroke signs and symptoms among prehospital providers and the public, and underutilization of 911 and/or EMS by persons in minority and underserved populations. To better understand and address these disparities, the task force recommends:

- Regionalization of prehospital stroke systems of care would remove artificial and regulatory barriers to receiving high-quality stroke care. Nationally, the establishment of prehospital standards of care and related metrics could improve care for all populations—particularly people of color.
- Because EMS in the U.S. is largely regulated at the state and local level, leadership in the stroke field should work with their state and local regulators to assess education gaps and training needs among prehospital care providers.
- Expanding and enhancing successful culturally sensitive, sustainable stroke recognition public health campaigns could encourage broader EMS use. Also, prehospital reimbursement models should be modified to reduce costs for patients and better align with their needs.
- Diversity in the EMS workforce, including dispatchers, paramedics, and others along the chain of survival, is lacking. Establishing diversity committees and officers, networking

opportunities, recruitment/retention programs, removing financial barriers, and other efforts could enhance the diversity of EMS and the entire stroke workforce.
- Recognizing the success of telemedicine (telestroke) in the hyperacute and acute care setting, telestroke services need to expand into EMS and prehospital stroke care.

Hyperacute and Acute Stroke Care

In the hyperacute and acute care setting—the moments just before hospital arrival until definite hospital admission—there are clear inequities in access to high-level stroke centers. Many providers lack sufficient educational resources to maintain expertise and engage with diverse patient populations. There is also limited access to and inconsistent use of telemedicine, and low research study participation by hospitals and patients, particularly in rural settings. To understand and address these issues, the task force recommends:

- Developing a student loan repayment program for stroke neurologists and interventionalists could enhance employment and practice. This could ensure that lower-resourced hospitals achieve higher levels of stroke certification, thereby improving access to stroke expertise.
- Incorporating Mobile Interventional Stroke Team (MIST) models could improve access to thrombectomy and reduce hospital transfers, particularly outside of urban settings.
- Improvement, standardization, and expansion of educational resources and support to providers could ensure sufficient stroke expertise.
- Telestroke is a key component of acute stroke services, particularly in hospitals with limited access to experienced stroke physicians. There is a need for uniform licensing and national and/or state-wide guidelines, better infrastructure, and training in telemedicine adaptation.

Inpatient Stroke Care

In the inpatient setting, there are disparities in the use of validated and proven secondary stroke prevention measures and therapies. There are also disparities in the availability of rehabilitation services and other resources to help patients transition from inpatient to outpatient care. To better understand and address disparities, the task force recommends:

- Additional research is needed to better describe disparities in inpatient secondary stroke prevention measures (*e.g.*, implanted cardiac monitors, antithrombotic drugs, statins) and medication prescribing at discharge. Studies should focus on evaluating: 1) ethnicity/race and geography interaction; and 2) patient education, income levels, and health insurance coverage.
- Research is needed to determine how best to facilitate the community navigation necessary to encourage positive health outcomes for individuals transitioning back into rural and other low-resourced communities.
- Significant gaps in knowledge about disparities in inpatient care can be addressed by standardizing terminology and categories. For example, by requiring the use of NINDS Common Data Elements in research publications. There is also a need to improve the definitions of patient-level (*e.g.,* non-adherence), provider-level (*e.g.,* risk assessment/benefit), and societal-level (*e.g.,* drug costs) factors.

- Additional research is needed to assess which characteristics of rurality and other demographics are most salient to the inpatient and post-stroke care experience.

This summary serves to highlight the main findings and recommendations discussed in the following chapters. While the task force reports uncover numerous prominent disparities in acute stroke care, many remain unknown. Among other opportunities, developing a regional or national stroke registry could provide important insights into disparities across the entire stroke system of care, nationwide, eventually improving outcomes for all. The stroke community should seize these opportunities in the short- and long-term, working together to implement feasible solutions that address known inequities in access to stroke care, to the benefit of our most at-risk populations.

Task Force Reports
Prehospital Stroke Care

Stroke is a leading cause of death and long-term disability in the United States, reaching about 795,000 victims annually (*Centers for Disease Control and Prevention. Underlying Cause of Death, 1999-2020*, 2020). For each minute of a stroke, about 1.9 million neurons die (Saver, 2006). Acute treatments such as intravenous tissue-type plasminogen activator (IV tPA)—also called alteplase (Activase®)—and endovascular thrombectomy (EVT) may improve patient outcomes when administered early, during symptom onset (Powers et al., 2019). As a result, time-sensitive, high-quality care is needed to support patients at the earliest signs of stroke.

Over a decade ago, the National Academy of Medicine (formerly the Institute of Medicine) identified that evidence-based care was significantly more limited in the prehospital setting than it was in other areas of medicine (Institute of Medicine, 2007). A systematic review of prehospital evidence-based guidelines published prior to 2019 found that most guidelines written for prehospital care were not developed or written in a way that would be considered high quality by standards put forth by the National Academy of Medicine or by the Appraisal of Guidelines Research and Evaluation Trust (Turner et al., 2021). Subsequently, a Delphi process of experts in prehospital medicine and guideline development identified acute stroke management as a priority for evidence-based guideline development (Richards et al., 2022).

The prehospital stroke setting includes family and community members, emergency medical service (EMS) professionals, as well as the systems, structures, and policies that shape the stroke care environment. In the community, after it is recognized that a person is having a stroke, 911 should be called immediately. EMS plays a significant role in stroke chain of survival—being the first medical personnel on-scene, they stabilize the patient to quickly identify a stroke, gather information about when the patient was last known to be well, transport the patient to the hospital with the best level of care for stroke severity and timing, and pre-notify hospital teams of a stroke arrival (Acker III et al., 2007). Prenotification triggers the activation of stroke teams in the emergency department and clearance of neuroimaging machines, avoiding triage delays and decreasing wait times (Abboud et al., 2016; Abdullah et al., 2008; Ashcraft et al., 2021; Kim et al., 2009; Lin et al., 2012). Although most patients can rapidly access stroke centers on their own, about 50-60% of stroke patients arrive to the hospital by EMS (Asaithambi et al., 2021; Govindarajan et al., 2013; Tataris et al., 2014; Zachrison et al., 2022).

Time from symptom onset (*i.e.*, when the patient was last known well) to treatment is a strong predictor of return to functional independence; thus, prehospital factors that shorten time to treatment are critical to stroke survival and mitigation of long-term disability (Hacke, 2004; Jahan et al., 2019; Marler et al., 2000). It is well known that that arrival by EMS is associated with more rapid door-to-imaging times, shorter door-to-needle times, and more frequent use of IV alteplase (Abdullah et al., 2008). However, only 25-30% of acute ischemic stroke patients arrive within the recommended treatment windows, and studies have shown that patients arriving by EMS are more likely to arrive within the treatment window than those arriving by personal transport (Mochari-

Greenberger et al., 2015; Tong et al., 2012). Several sociodemographic disparities in EMS use are inversely associated with timely treatment of stroke, including female sex, being from a minority racial/ethnic group, and rurality (Ader et al., 2019; Boehme et al., 2014; Springer et al., 2017). Inpatient surveys suggest that some symptoms of stroke may go unrecognized by stroke patients and their family members, and that family members may incorrectly advise stroke victims that EMS use is not necessary (Eisenstein et al., 2018; Xirasagar et al., 2019).

Geography

Geographic disparities in prehospital stroke care include variability in quality, access, and experience with stroke dispatch, EMS infrastructure, and prehospital provider training and experience. Many of these disparities are exacerbated in rural areas of the country, but also exist in suburban and urban areas, as well as within U.S. territories and native peoples' reservations (Adeoye et al., 2019; Georgakakos et al., 2022; Harrington et al., 2020; Jauch et al., 2021; Mullen et al., 2014; Salwi et al., 2021; Yu et al., 2021). The rapid introduction of EVT has highlighted disparities in access regarding prehospital triage and interfacility transport, as well as variability in the use of large vessel occlusion (LVO) scales. Access to aeromedical transport, prehospital telemedicine, and mobile stroke units depend on the specific needs, size, and rurality of the location. Geographic disparities in prehospital stroke care also introduce logistical concerns for routing, traffic, and physical barriers to facility-based triage. Cultural differences in EMS provider groups and patient populations further contribute to disparities in access to stroke care.

Regionalization of prehospital stroke care

Geographic stroke systems of care should consider quantity, distance, and availability of ambulance agencies, fire and rescue, aeromedical, and interfacility transport. A systems-based approach to prehospital stroke care requires collaboration between state and local government policymakers, regional health systems, local hospitals, and area ambulance agencies. Critically, regionalized stroke networks must overcome market competitiveness and share the responsibility of developing regional standardization of prehospital stroke screening, routing protocols, and EMS training and education. To help support regionalization of prehospital stroke care, stroke systems should incorporate acute stroke ready, primary, thrombectomy-capable, and comprehensive stroke centers in a geographically mindful way that facilitates collaboration rather than competition in stroke triage (Jauch et al., 2021).

Mobile stroke units have been shown to reduce treatment times and improve outcomes (Ebinger et al., 2021; Grotta et al., 2021). However, longitudinal studies on cost effectiveness are needed to inform the generalizability and regional impact of mobile stroke units, particularly in rural and resource-limited settings.

Stroke recognition among prehospital providers and the public

Inherent in addressing geographic disparities in acute stroke care is ensuring that all first responders across the prehospital continuum—including dispatch, EMS practitioners, fire and rescue, and police—can accurately identify stroke, especially those in underserved areas (*e.g.*, rural, U.S. territories). In addition, other factors often driven by geographical disparities, such as

socioeconomic status, cultural differences, and local governance and policies, contribute to a diverse makeup of the prehospital provider population and differences in stroke awareness in the local community. Collectively, these factors have a significant impact on patient access to acute stroke care (Adeoye et al., 2014; Adeoye et al., 2019; Rivard et al., 2021; Salwi et al., 2021; Yu et al., 2021).

Leaders must work with state and local regulators to improve education and resources for stroke education and training among prehospital providers. Training and education should be culturally tailored and consistent with state and local stroke protocols. Additionally, statewide efforts should standardize training and application of prehospital stroke screening scales, including advocating for the standardized use of LVO scales to aid in the appropriate triage of patients to thrombectomy-capable and comprehensive stroke centers.

Telestroke in the prehospital setting

While telestroke systems are currently designed to address geographic disparities in hospital-based acute stroke care, they are also relevant to EMS and prehospital stroke care, particularly when telemedicine is used to facilitate ambulance-based assessment. Several studies have demonstrated the feasibility of using low-cost telemedicine in prehospital neurologic assessments and decision-support for acute stroke triage, which was particularly applicable in regions with longer transport times and a less experienced EMS workforce (Guzik et al., 2021; Lippman et al., 2016; Smith et al., 2016). Further, ambulance-based telestroke is essential to the potential cost utility of mobile stroke units (Southerland & Brandler, 2017; Wu et al., 2017).

Similar to advocacy for hospital-based acute stroke care, we need to work with policymakers, payers, and technology suppliers regarding reimbursement, availability of broadband, and wireless infrastructure for telestroke and other promising prehospital digital health systems. See *Appendix B: Telemedicine in Stroke Care* for more findings and recommendations regarding telestroke.

Policy and Regulation

In the U.S., EMS are largely regulated at the state and local levels. While federal entities, such as the National Highway and Transportation Safety Administration, the Federal Interagency Committee on Emergency Medical Services, and the National EMS Advisory Council, typically provide guidance and coordination among regional entities, most direct regulation occurs locally. For example, EMS practitioner and EMS agency certification and regulation occurs at the state level and medical protocols—including stroke protocols—are determined locally.

In some instances, EMS protocols are determined regionally or state-wide, but this model is much less common. The National Association of State EMS Officials, a nationwide network of state, regional, and local EMS and emergency care systems, regularly publishes model EMS clinical guidelines, but these recommendations serve as a guide and resource; there is no mandate to incorporate any of the model clinical guidelines into operational protocols at the EMS agency level (Cash et al., 2020).

Local determination of EMS protocols can be advantageous because this ensures that protocols are adaptable to local EMS system of care capabilities (*i.e.*, hospital resources, EMS provider agency

considerations, local geography, etc.), however, there is variability among EMS provider agencies, which may contribute to significant disparities in stroke care. Regarding stroke and trauma, advocacy with state legislatures and state health departments has resulted in some states adopting state-wide required components of EMS care (*e.g.*, severe stroke screening) where none previously existed; but without coordinated policies, fragmentation will continue to exist.

Modification of prehospital reimbursement models

While regulation of EMS is local, reimbursement of prehospital care falls under the Centers for Medicare and Medicaid Services (CMS) fee schedule for ambulance transport (*Ambulance Fee Schedule Public Use Files*, 2022). First, a requisite component of ambulance transport reimbursement is the transport of a patient. For most patients with suspected acute stroke, transportation is a component of care, but extensive decision-making resulting in a patient refusing ambulance transport is not reimbursable.

Next and most important, the base reimbursement level is determined by a general estimate of the complexity of care provided on scene, which is determined by whether the patient required an assessment by an advanced life support (ALS) practitioner (*i.e.*, paramedic) or not. However, this complexity of care is more reflective of a patient with hemodynamic instability, rather than acute neurological dysfunction.

For example, a lower level of reimbursement, known as ALS-1, requires an ALS assessment and one intervention that only an ALS practitioner can perform (for example, a peripheral intravenous catheter placement). The highest level of ALS reimbursement, known as ALS-2, requires the administration of three or more medications and the performance of an advanced procedure (*e.g.*, defibrillation, endotracheal intubation, cardiac pacing). These interventions are typically done for hemodynamically unstable patients but not acute stroke patients. Although the recognition and management of acute stroke is critically important to overall stroke care, acute stroke patients typically do not have the hemodynamic instability that indicates a higher level of reimbursement. Therefore, the complexity of assessment and destination decision-making involved in prehospital stroke care are not appropriately reflected in the metrics used to determine reimbursement for prehospital services.

Lastly, reimbursement is multiplied based on the mileage traveled with the patient and the rurality or urbanicity of the site of patient transport. Therefore, in acute stroke and other time sensitive conditions that require complex assessment and decision-making by EMS practitioners, reimbursement models do not reflect the complexity of care provided.

Current models of reimbursable patient-centered care

In 2020, the CMS launched the Emergency Triage, Treat, and Transport (ET3) Model pilot program to expand reimbursable patient-centered care (Goldman et al., 2020). The goal of this pilot is to explore alternate models of prehospital care, including transport to non-hospital destinations, such as primary care offices and community mental health centers. The program also aims to explore reimbursement of extensive on-scene evaluation that would obviate a potential ambulance transport (*i.e.*, through telehealth). The primary goal of the ET3 model is to reduce the cost of healthcare by reducing EMS transport of patients to hospital emergency departments.

Additionally, the National EMS Quality Alliance strives to codify quality metrics for prehospital care that reflect how well care is provided instead of relying on procedure-based and transport distance compensation. For acute stroke patients, current metrics are modest and report the rate of stroke screens performed on suspected stroke patients and the recording of glucose readings.

Unfortunately, rather than rewarding the complex care that acute stroke patients need, current EMS models focus on avoiding costly services. New initiatives are starting to acknowledge the complex care that can be provided by EMS practitioners before hospital arrival. However, given the pilot and limited nature of both initiatives, acute stroke patient care cannot improve without further development. For example, performing an advanced stroke severity screen to determine transport to a higher-level stroke center is not captured in current models as a critical prehospital intervention.

Linking prehospital care and patient outcomes

Historically, in acute stroke, the link between the care provided in the prehospital setting and patient outcomes during hospitalization and beyond remains unclear. A critically important logistical barrier is the lack of integration between prehospital patient care and hospital patient care reports. From a hospital's point of view, all care provided prior to hospital arrival is often a "black box", even if the patient received significantly important assessments and interventions (Mears, Pratt, et al., 2010; Mears, Rosamond, et al., 2010; Powers, 2015). Similarly, for EMS practitioners, the eventual outcome of the patient's course in the hospital is difficult or impossible to routinely ascertain or track, which means that quality improvement initiatives are largely informed by operational metrics and not by patient-oriented outcomes (Cash et al., 2017).

Several initiatives have begun to link prehospital records to hospital records. For example, in recent years, the Paul Coverdell National Acute Stroke Program (Coverdell Program) has facilitated these record linkages, with a focus on acute stroke. In the private sector, the patient care software company ESO Solutions, Inc. hosts the ESO Data Collaborative, one of the largest prehospital research databases in the country. This comprehensive database links EMS records to hospital-based records and patient outcomes (Crowe et al., 2021; Fernandez et al., 2020; Jarvis et al., 2020; Walter et al., 2021).

Lastly, there are several research programs dedicated to determining how prehospital care contributes to overall patient outcomes (Audebert et al., 2017; Helwig et al., 2019; Itrat et al., 2016). While these initial programs have improved communication between prehospital and hospital stages of care of acute stroke patients, routine and universal linkage is far from a reality. Although substantial opportunity exists to align payment through the CMS with the National EMS Information System (NEMSIS), current NEMSIS data are de-identified and not connected to claims or hospital data.

Economics and Healthcare Resources

The intersection of economic and healthcare resources in prehospital stroke care is complex. EMS regulation typically occurs at the state, territory, or local level, whereas stroke standards of care are created by professional organizations, and payment is driven by state (*i.e.*, Medicaid), federal (*i.e.*,

Medicare), and private (*i.e.*, the insurance industry) sources. Prehospital and hospital-based stroke care systems are highly interdependent and reflect the communities that they serve. Although exceptions exist where legacy referral hospitals, often academic medical centers, thrive in economically challenged communities, a community's economy often determines the quality of healthcare resources available (Merwin et al., 2006). Disparities in health outcomes are associated with variability in regional resource availability. These disparities primarily impact racial and ethnic minority groups, people living in rural areas, and those with who are economically disadvantaged.

Stroke and the broader emergency critical care system

Prehospital care is a central touchpoint between the community and the healthcare system for patients with acute stroke and other emergency conditions. To date, however, efforts to improve out-of-hospital care for patients with stroke are not part of efforts focused on other conditions, including trauma, ST-elevation myocardial infarction (STEMI), and out-of-hospital cardiac arrest. The National Quality Forum (NQF) recently described the importance of using multidisciplinary coordination to improve outcomes for critical illness and injury (National Quality Forum, 2021). By developing a model that allows for shared accountability for health outcomes (attribution) at the community level, key stakeholders including hospitals, health departments, and prehospital providers, would have aligned incentives to work together to improve access to care and optimize outcomes for the communities that they serve.

While most prehospital care is organized at the community level, healthcare is primarily focused on individual patient care. The geographic and community approach of this report represents a framing that is gaining traction around healthcare planning, which includes trauma, STEMI, regional preparedness, cardiac arrest care, and stroke. This framework, now captured in the NQF's work described above, lays the foundation for a connection between population-based planning and population-based payment or incentive structures. National legislation could create a pathway from measurement to implementation of best practices, mandate public reporting of variability in regional resources (especially in healthcare deserts), create guidance on how to risk adjust health outcomes based on regional healthcare resources, and direct an investment in delivery system science focused on improving our understanding of how the underlying economic drivers of healthcare resource allocation impact disparities in health outcomes.

Developing a national stroke registry

The lack of a national stroke registry not only limits our ability to inform clinical practice, but also introduces economic bias into stroke care research. This is because more highly resourced stroke and referral centers are more inclined to participate in voluntary registries. Research on the availability and quality of healthcare resources are particularly lacking for minority populations, including in U.S. territories and Native American populations. The lack of representative data limits the ability to develop meaningful metrics to inform national policies and standards around value-based reimbursement, EMS protocols, patient transport, stroke center performance, mobile stroke unit access, telestroke utilization, and the regionalization of prehospital stroke care across states and territories. Establishment of a national stroke registry would provide real time data on the care

delivered to stroke patients and enable shared visibility of the costs, reimbursements, management, and outcomes of stroke care before and after acute treatment.

Demographics

Among other disparities, it is well known that racial, ethnic, and sex differences exist regarding the utilization of EMS transport among hospitalized stroke patients (Mochari-Greenberger et al., 2015). Derived from multiple community and other prehospital related factors, there is a downstream effect contributing to the observed demographic disparities seen in stroke treatment rates related to sex/gender, race, ethnicity, socioeconomic status, and insurance status, with certain populations having lower acute phase treatment rates compared to baseline (Hsia et al., 2011; Schwamm et al., 2010).

Priority areas of focus to reduce health disparities in the prehospital stroke setting include: (1) the development of a high-quality, systematic and comprehensive national data collection, which may be used at the community level to expand the current evidence base and provide the information necessary for potential targeted interventions; (2) an expansion of programs, practices, and procedures to enhance public education about stroke identification and acute management, especially for populations and/or regions in which disparities exist; and (3) to broadly expand, where necessary, requisite EMS systems health equity training and workforce diversity.

Collecting high-quality, systemic national data

For stroke systems of care, the collection of high-quality, systematic, comprehensive and measurable data, at both a community and national level, is essential to evaluate current performance, identify areas of improvement, and to examine the effects of continuous quality improvement programs (Rudd et al., 2020). Such data can have an integral role in identifying and evaluating demographical health disparities of key prehospital variables, such as the identification of stroke symptoms by bystanders and EMS, 911 utilization rates, EMS dispatch effectiveness, on-scene time, accessibility to care, and linking such items to national averages, as well as hospital-based outcomes including treatment rates, overall morbidity and mortality. In turn, analyzing registry data, at a regional or statewide level, may lead to the identification of demographical disparities, providing opportunities for targeted interventions aimed at standardizing care outcomes for all.

Today, several platforms exist, and software designed to connect prehospital and health system data is being developed. At a state level, the Centers for Disease Control and Prevention (CDC) has supported the development of stroke registries (Group, 2005; Wattigney et al., 2003), but they are not uniformly existent in most states. The American Heart Association and other nonprofit organizations have created national databases, currently accounting for the most robust national level prehospital demographical stroke database (*i.e.*, the Get With The Guidelines Stroke Program) (Schwamm, Fonarow, et al., 2009). However, these "super-user" type platforms designed to collect, collate, and analyze state and community level data are only utilized at participating stroke centers and at a limited number of state health departments.

Proposed solutions include:

- Advocate for the more widespread creation of state and/or regional stroke registries, which may complement and enhance existing national registries.
- Advocate for state health departments to devote funding, resources, and staff to collecting and interpreting state level stroke registry data.
- Support further enhancement of gathering key prehospital metrics and link them to demographical variables and health center outcome data.
- Enhance collection and utilization of high-quality data to provide the basis-of-understanding necessary to inform targeted interventions aimed at reducing demographical disparities in prehospital care.

Public education about stroke

Age, sex and gender, and racial/ethnic disparities exist in the placement of 911 calls and subsequent EMS utilization. Demographical differences also occur in the prehospital identification of stroke, both by bystanders and EMS providers (Govindarajan et al., 2015). The reasons behind these disparities are difficult to elucidate, but may be associated with health literacy, stroke recognition, access to care, socioeconomic status, patient mistrust, and provider bias (Boden-Albala et al., 2014). Communication elements, such as the use of vague words to describe stroke signs and symptoms during 911 calls, may also play a role (Richards et al., 2017). Recent patient surveys have shown that in some populations, up to 75% of hospitalized stoke patients may be unaware of the connection between EMS use and favorable health outcomes after stroke (Xirasagar et al., 2019). Public awareness and educational initiatives have conventionally been regarded as integral for the early identification of stroke and early activation of the prehospital stroke system. While such interventions may increase stroke knowledge, limitations exist in the linkage to behavioral change in large, medically underserved populations (Boden-Albala et al., 2014; Prabhakaran et al., 2020). Further, targeted interventions may be necessary to increase individuals' understanding of and trust in prehospital stroke care (Eisenstein et al., 2018).

Proposed solutions include:

- Form local, state, and national policies to prioritize, comprehensively investigate, and work to create strategies for implementing sustainable community and health system-based interventions aimed at reducing disparities.
- Create partnerships with local representative focus groups, which may explore the stroke knowledge base, attitudes, beliefs, and barriers regarding stroke treatment, as well as identify potential strategies for overcoming obstacles.
- Conduct more research and exploratory analyses aimed at fortifying linkages between educational initiatives and behavioral changes in large, medically underserved communities.
- Identify strategies to augment engagement of local stakeholders and key community leaders.

EMS workforce diversity

Another perceived contributor to prehospital disparities in care is the ethnic/racial composition and diversity of EMS professionals, dispatchers, and other related personnel, which in some regions

has been cited to not be representative of the population they serve. In some reports, Hispanics and African Americans have been underrepresented in the EMS profession (Crowe et al., 2016). Additionally, a large survey of over 146,000 EMS providers who were nationally certified between 2017-2019 identified female sex and minority underrepresentation. The survey revealed that EMS professionals were primarily male (76%) and white (85%). By race/ethnicity, 85% were white, 5% were Hispanic/Latino, 5% were Black/African American, 2% were American Indian/Alaskan Native, 2% were Asian and 1% were Native Hawaiian/Pacific Islander (Rivard et al., 2021). Having a diverse workforce has been associated with improved access to healthcare for those in racial and ethnic minority communities, with greater patient choice and satisfaction, an overall improvement in the reported quality of care (Harker, 2016), and presumptive increased trust in the system.

Proposed solutions include:

- Diversity initiatives at health professional schools, including the removal of financial barriers for minorities, and inclusive policies for underserved and foreign-born candidates.
- Minority hiring programs in partnership with local civic and community groups.
- Sponsorship, support, and backing of EMT academies providing scholarships or other aid to minority students.
- Regional EMS diversity committees, with community and minority representation, to create recommendations for ongoing EMS diversity education.
- National advocacy organization level guidance for EMS diversity optimization strategies and/or development of local/state policies to encourage EMS diversity initiatives.

Hyperacute and Acute Stroke Care

Prior to 1995, acute stroke treatment consisted primarily of supportive care during the immediate phase followed by rehabilitation and prevention of recurrent episodes. The introduction of intravenous tissue-type plasminogen activator (IV tPA) as a treatment for acute ischemic stroke revolutionized the stroke treatment paradigm. As a result, acute care shifted to immediate identification of potential stroke patients, rapid clinical and radiographic evaluation to confirm treatment eligibility, and drug administration within three hours of symptom onset. Stroke became a treatable disease (Grotta, 2021).

Over the ensuing 22 years, advanced imaging techniques such as computed tomographic (CT), or magnetic resonance angiography (MRA) and perfusion imaging (CTP, MRP), along with the development of mechanical revascularization devices, have dramatically increased the pool of individuals who could benefit from emergent treatments. With the rapid identification of a vascular occlusion and significant salvageable brain tissue, patients could be treated within 24 hours from symptom onset with excellent clinical outcomes.

Despite these advances, several barriers remain to rapid stroke identification and treatment of patients in the acute phase. Individuals who are potential candidates for intravenous and/or intra-arterial therapy need to be identified quickly so they can be taken to hospitals capable of providing treatment. Geographic location, availability of telemedicine, communication and coordination services, and limited access to stroke expertise have all been cited as potential roadblocks to obtaining high level stroke care.

Stroke telemedicine (telestroke) has emerged as an effective way to reach stroke patients in emergency departments where vascular neurology expertise is required for decision-making. However, low-resourced hospitals in rural areas often lack access to broadband or telemedicine equipment needed for remote consultation. Other barriers include lack of financial and technological support, and misalignment of regulations and policy at the local, state/territory, and national levels (see *Appendix B: Telemedicine in Stroke Care*).

Competing health systems with overlapping "hub-and-spoke" territories may lead to patients bypassing the closest hospital in favor of one that is within the system. There are also disparities in physician licensing laws and competing insurance programs—particularly in areas where patients are transported across state lines.

The acute stroke care workforce does not reflect the diverse population it serves, despite healthcare workforce diversity being shown to improve trainee experience, patient outcomes, and the quality of research. Another gap in our current knowledge is the potential benefit of more diverse healthcare professionals to patients' well-being and medical knowledge.

Geography

Geographical inequities in access and delivery of acute stroke care include maldistribution of higher-level stroke hospitals and stroke expertise, nonuniform access to telemedicine, limited opportunities for continuing education for providers and patient communities, and low research

participation by hospitals and patients in rural areas. Timely dissemination of impactful research findings (*i.e.*, what thought leaders consider representative of "standard-of-care") is also impacted by geography.

Higher-level stroke hospitals, those designated as primary stroke centers (PSCs), thrombectomy-capable stroke centers (TSCs), and comprehensive stroke centers (CSCs), are generally clustered in areas of high population density near academic institutions where stroke experts typically choose to work. Telemedicine is often employed to gain access to patients who require higher-level services, but telemedicine services are not always used in centers with a low volume and/or geographically isolated from higher-level stroke centers, which may be due to limited access to reliable broadband internet.

Educational opportunities and support for leave from work for continuing medical education conferences are likely less robust in rural areas. Community education events focused on stroke are generally spearheaded by an individual or organization dedicated to the stroke mission through structured efforts. Personnel dedicated to this effort, and knowledge of the differences in how rural communities learn best, are needed to overcome disparities in stroke awareness.

Access to stroke centers

Several recent studies have mapped the distribution of PSCs and CSCs in the U.S. (Boggs et al., 2022; Schieb et al., 2015). Technology is available to facilitate the determination of distance, and even time, between where populations live and the closest appropriate hospital. But maintaining a comprehensive map of stroke resources is burdened by the rapid, continuous evolution of certifying hospitals (Boggs et al., 2022).

Therefore, this issue needs to be revisited with frequency. The larger challenge is determining the most effective way to fill the gaps in access to quality PSCs, TSCs, and CSCs for definitive care and reduce the geographical disparity. Routing by state-funded "communication centers" can facilitate identification of the closest appropriate hospital based on patient location, clinical large vessel occlusion (LVO) screening, and time from symptom detection and/or last known well. This could ensure that patients with suspected stroke get to the right place at the right time and receive access to appropriate care. Additionally, initial destination protocols should be in place in all states and communication centers should have real-time recommendations for the closest appropriate hospital. A mechanism for crossing state lines to access closer emergency care and time-sensitive treatment should be provided. Lastly, ongoing education for implementation of protocols, clinical LVO screening in the field, and how to access communication centers is needed for prehospital providers.

Telemedicine can help fill the gaps in access to neurological expertise needed for making emergency treatment decisions. However, telemedicine cannot convert a non-thrombectomy center into a thrombectomy center. Further, there are gaps in access to advanced neuroimaging, which may result in triaging patients to TSCs and CSCs far away from rural critical access hospitals. Expanding access to advanced neuroimaging can help rule out LVO or eligibility for recanalization therapy, saving time and allowing triage to closer PSC certified hospitals. Moreover, significant financial resources are necessary to advance from one level of certification to another. Existing

routing protocols create a self-fulfilling prophecy of feasibility to advance; if a center doesn't get the patients, the center cannot demonstrate mastery, and investment may be futile.

Access to stroke expertise

While the majority (98%) of Americans live within 60 minutes of an emergency department (ED) (71% within 30 minutes), access to teaching hospital EDs is far more limited, particularly in rural states (Carr et al., 2009). Access to certified stroke centers is also a moving target, due to the evolution of hospitals through escalating certification programs. Eighty-one percent of Americans have access to intravenous-capable hospitals within 60 minutes and 56% have access to endovascular-capable hospitals, improving to 97% and 85%, respectively, if air ambulance is utilized (Adeoye et al., 2014). Stroke expertise is required for certification, which impacts some routing protocols. Hospitals without certification have less access to patients with acute stroke, and therefore have less opportunity to establish efficiency and proficiency without externalizing stroke expertise through telemedicine. In fact, studies have shown that over a two-year period from 2005-2007, 64% of hospitals in the MEDPAR database had no reported treatments with IV tPA for acute ischemic stroke. Bed size, rural or underserved, stroke center designation, and population density were associated with reported tPA treatment rates (Kleindorfer et al., 2009).

Emergency medicine (EM) residency programs lack standardization for exposure to managing stroke patients; many do not require residents to rotate on a neurology service (only 2% required stroke service exposure) nor to log stroke-related procedures, such as administration of tPA. There are also no stroke-specific ongoing education requirements for EM physicians. EM physicians who have been in practice for decades may have limited exposure to new, practice-changing clinical trial results, rendering deficiencies in identifying candidates for recanalization therapies. Access to trained stroke experts and vascular neurologists is limited. The ratio of the number of strokes per vascular neurologist in the U.S. is 717:1 (Charles Callison & Leira, 2008). Fellowship training of neurologists has kept pace with expansion of stroke centers, which particularly influences rural and underserved urban areas. The maldistribution of stroke interventionalists is even greater since a case load is necessary to maintain skills, which is particularly relevant for recent graduates of training programs. Even radiologists specializing in neurology may be deficient in some rural areas, placing greater responsibility on the neurologist.

To resolve the geographical disparities in access to stroke expertise, we need to increase the number of vascular neurologists and incentivize them to work in areas of shortage. We also need to motivate interventionalists to work in areas which will close the gaps in access to thrombectomy which may require modifications to credentialing requirements. Training and post-graduate education for EM physicians can improve proficiency in identifying and treating candidates for recanalization therapies. Accessing neuroradiologists or provision of automated intelligence technology to facilitate timely interpretation of computed tomography angiography (CTA) to identify LVO may improve the secondary transfer efficiency for thrombectomy candidates.

Continuing education opportunities for providers and communities

Knowledge of stroke signs and symptoms is lower among adults in rural areas, where there is a higher prevalence of key stroke risk factors (*i.e.*, hypertension, diabetes, and tobacco use)

(Swanoski et al., 2012). Physicians in rural areas may have lower confidence in treating stroke acutely, perhaps due to a limited understanding of risks and benefits, and the knowledge and means to counsel patients on risk. Lower education, poverty and other macrolevel inequities likely contribute to participation, comprehension, and retention of such educational efforts.

Research participation and dissemination of research findings

Literature on geographic disparities in medical research participation, particularly stroke research, is sparse. However, there is a consensus that small rural hospitals and clinics are less likely to be involved in stroke research and, similarly, people in underserved geographic regions are less likely to participate in research studies. Clinical trial and study sites in the U.S. are highly clustered around urban areas with healthcare/social service facilities (Seidler et al., 2014). One common exclusion criterion for participation in a clinical trial is if the patient is unlikely to be able to complete all timepoints of measurement of outcomes, which is less feasible for patients who were "shipped" to a higher-level stroke center from a remote, rural region. Additionally, studies show that clinical trial leadership is clustered in urban, largely academic, centers in the U.S. and Western Europe (Hoekman et al., 2012).

There is lack of investment in existing research infrastructure and technologies in rural communities with less patients, who are already hesitate to participate in clinical trials. This is a barrier to providing research opportunities to underrepresented populations, which is critically needed to generalize clinical trial findings. Rural hospitals also may be less likely to fund clinicians or support time away from practice to attend national conferences, during which they learn about late-breaking, practice-changing trial results, making the effort to do so less appealing.

Policy and Regulation

Improving hub-and-spoke models

Following evidence-based guidelines for time-sensitive recanalization therapy, starting with intravenous thrombolytic therapy, hospitals struggled to provide a new "standard-of-care" (Schwamm, Holloway, et al., 2009). Hospitals lacking on-site stroke expertise used to rely on emergency medicine physicians, who often have limited education and experience in the evaluation and treatment of high-risk procedures. Formal transfer protocols to off-load treated patients by transferring to higher-level stroke centers have successfully facilitated treatment in centers without on-site neurological expertise. The establishment of hub-and-spoke models, particularly as telemedicine technologies evolved, has brought more experienced neurologists to hospitals in need of experts.

Over time, individual hospitals have partnered with hospital systems for financial and management advantages, increasing the radius between hub and spoke hospitals, and creating overlapping systems within states. Consequently, patients often go directly to the "mothership" and bypass closer facilities, leading to a delay in definitive care when endovascular therapy is warranted and sometimes rendering patients as poor candidates for intervention. The physical separation impedes family and caregivers from being present during hospitalization and post-stroke rehabilitation, leading to added burden and stress for patients and their family.

Policy and legislation are needed to allow smaller hospitals to gain access to the closest appropriate hospital, potentially utilizing a neurological expert from a different hospital system. A centralized stroke command center could be used at the local level to help triage patients to the closest appropriate facility and determine the mode of secondary transfer (air vs. ground ambulance). This can be done using artificial intelligence, incorporating time from last seen normal, time from symptom detection, odds of harboring LVO, GPS data, road conditions, weather conditions, and location of all appropriate hospitals.

The key to efficiency in hub-and-spoke models is rapid, safe inter-facility transfer. Appropriate policies are needed to accommodate transfers to ensure all patients continue to receive quality stroke care during transportation and transfers. The spoke hospital is responsible for monitoring the patient and responding to a neurological deterioration while the patient is physically in the spoke facility. The hub hospital provides education for these activities and responds, when notified, of a clinical change. During the transfer, however, who owns the responsibility for managing the patient is more ambiguous. The Joint Commission considers it the responsibility of the certified center to establish expectations for monitoring the post-lytic patient before and during transfer, yet the legal responsibility for the patient may fall to the sending physician or to a "med control" authority under the umbrella of the EMS agency. Unless the hub hospital formally assumes this role, hub physicians may not be aware of potentially serious clinical changes.

Standardization of education and materials for management and clinical documentation during secondary transfer could promote patient safety during this high-risk period, during which the stroke specialist is disconnected from the patient. Quality improvement efforts should be in place to troubleshoot avoidable adverse outcomes.

State stroke care policies and regulations

Based on a survey of stroke care policies and regulations across states, there is wide variability in rigor and robustness. A recent study examined stroke care laws and identified challenges for hospitals to comply with prescriptive standards (Centers for Disease Control and Prevention, Division for Heart Disease and Stroke Prevention, 2018). State registries/data repositories are needed to track patient outcomes but linking prehospital EMS and hospital data has logistical challenges. Smaller hospitals with limited personnel resources may find participating in a stroke registry a burden, yet inclusion of data from these hospitals is necessary to avoid bias in the data. Moreover, some states certify stroke programs whereas others only recognize an external certifying entity (*i.e.*, the Joint Commission, Det Norse Veritas, Healthcare Facilities Accreditation Program).

Economics and Healthcare Resources

Infrastructure and access to stroke expertise

Socioeconomic disparities in low-income neighborhoods substantially impact stroke care. This is likely due to the lack of telestroke services and stroke neurologists in rural and underserved areas. As per the MEDPAR database, 64% of the hospitals in the U.S. did not use IV tPA for acute stroke in the last two-year period. The direct cost of stroke, around $35 billion annually, is only the tip of the iceberg; the indirect costs like premature death, unemployment, and missed workdays increase the

costs to $68.5 billion, bringing the total cost of stroke to $103.5 billion per year (Girotra et al., 2020). Economic disparities contribute to even more costs. The issue varies by state and U.S. territory. For example, Medicare pays less in Puerto Rico than the U.S. mainland, and this impacts where recent graduates choose to start their careers. Studies have shown that when medical students graduate, they are three times more likely to take a job in a U.S. state than a U.S. territory (Beaton-Comulada et al., 2022). Such limited access to neurologists and stroke specialists, especially in rural areas and U.S. territories, significantly impedes stroke care.

Resources for continuing education

Stroke management is changing quickly. There are limited educational resources in the low economic areas and rural hospitals to keep providers stay up-to-date on stroke guidelines. Education in stroke management may also help hospitals treat patients better. Knowledge regarding stroke symptomatology and the importance of going to the hospital quickly is lower in the rural communities (Swanoski et al., 2012). A lack of appropriate, current education may lead to mismanagement of patients; providers could miss early symptoms and send patients home, which could lead to patients returning later with a major stroke.

Demographics

Stroke workforce diversity

Having a diverse healthcare workforce is critically important to reducing health disparities. Maintaining a diverse healthcare workforce has been shown to 1) improve the learning experience of diverse students and medical trainees; 2) improve patient care and health outcomes; and 3) improve the quality of healthcare research (Johnson et al., 2021; Sandset et al., 2019).

Unfortunately, the current racial and ethnic diversity among the stroke, neurology, and neurosurgery workforce does not reflect the diversity of the U.S. population (Hamilton, 2016). A lack of diversity is a problem across the board in medicine (Lett et al., 2018; Salsberg et al., 2021), and stroke is no exception. Another concerning disparity is the lack of gender diversity in academic stroke medicine, especially in leadership positions (Cordonnier et al., 2019; Pikula et al., 2020). In addition to the academic faculty workforce, there is also a lack of racial/ethnic diversity among neurology and neurosurgery trainees (including vascular neurology) (Das et al., 2021; *Diversity in Medicine: Facts and Figures 2019. Figure 13: Percentage of U.S. medical school graduates by race/ethnicity, academic year 2018-2019.*, 2019; Hamilton, 2016; Kim et al., 2021; Salsberg et al., 2021). In addition to having a low proportion of faculty and trainees from minoritized groups, individuals from minoritized groups who are part of the medical workforce face particular challenges in career advancement (Campbell et al., 2020). Challenges include the "minority tax," "gratitude tax," "loyalty tax," "distance traveled," "power distance," and imposter syndrome.

Although we still lack knowledge as to whether increasing diversity of the stroke workforce will reduce population health disparities, as well as which strategies would be most effective, there is some evidence for possible strategies to enhance diversity in the academic stroke workforce.

Potential solutions to the lack of diversity in the stroke workforce:

- Track and measure diversity within the stroke workforce using targeted tools such as a Diversity Index (Salsberg et al., 2021).
- Develop the role of diversity officers and Diversity, Equity, and Inclusion (DEI) committees within academic neurology departments, particularly regarding residency, fellowship and faculty recruitment. Formalize training in DEI by using certification programs (Bank et al., 2017; Harpe et al., 2021; Mohile et al., 2021).
- Make use of social media to increase networking and mentorship opportunities for diverse trainees and junior faculty (Corsini et al., 2021; Stamp et al., 2019).
- Create multipronged and continuous "diversity pipelines" to help recruit and retain trainees to vascular neurology. Look to other specialties for successful examples of similar programs, such as emergency medicine (Clayborne et al., 2021), radiology (Mcintosh-Clarke et al., 2019), general multispecialty (Muppala & Prakash, 2021), and gastroenterology (Carethers et al., 2019).
- Incentivize increased diversity in training and research programs through targeted funding opportunities (Campbell et al., 2020).

Educating underserved and "at-risk" populations about stroke

Another priority that is critical to the reduction of disparities in acute stroke care is the need for improved outreach to underserved communities and to individuals at risk for inadequate stroke care. It has been well documented that race, ethnicity, urban/rural status, socioeconomic status, and other social determinants of health impact access to acute stroke care (*e.g.*, thrombolysis, mechanical thrombectomy) (Attenello et al., 2014; Brinjikji, Rabinstein, et al., 2014; Hsia et al., 2011; Messé et al., 2016; Mullen et al., 2014). Although the reasons for these disparities are multifactorial, patient and community related factors likely play a substantial role. For example, there is lower knowledge of stroke signs and symptoms among stroke survivors who are at risk for disparate treatment and outcomes—those who are Black, Hispanic, Spanish-speaking, those with lower income, low education, and those living in rural areas (DuBard et al., 2006; Jackson et al., 2020; Patel et al., 2019; Swanoski et al., 2012). Adding to these disparities, educational acronyms (FAST/BE-FAST) for stroke signs and symptoms are primarily available in English. However, new Spanish language tools are being developed and studied (AHORA/RAPIDO).

Overall, the literature suggests differences in arrival time based on various sociodemographic factors, but the reasons for delays to hospital arrival are not well understood. Such reasons may include factors related to patient knowledge, community knowledge, self-efficacy, concerns about cost, prior experiences of racism/discrimination in the healthcare system, EMS provider knowledge and implicit bias, concerns about immigration status, and lack of trust in the local healthcare system. Community-based educational initiatives may be the best approach to increasing stroke knowledge in populations at highest risk for disparities in care.

There are several strategies with the potential to improve our understanding of delayed arrivals among those from minoritized groups. First, high quality studies evaluating the reasons for delays to hospital presentation are needed. Such studies should include data from stroke survivors, caregivers, and community members to help understand barriers to seeking immediate stroke care. Further, future interventions must not only address improving patient knowledge of stroke warning signs but must address barriers to self-efficacy for patients from underrepresented groups. In addition, hospitals should be incentivized to engage with patients and community leaders to identify strategies (*e.g.*, public education campaigns) aimed at decreasing delays to arrival. Disparities in stroke treatment must also be a funding priority for federal organizations to further incentivize investigators in this field.

Hospital resources and U.S. territories

Disparities in hospital resources are another contributor to disparities in the care of patients from minoritized groups, and hospitals located in U.S. territories are no exception. One of the challenges that U.S. territories face is their distance from the continental U.S. The distance of U.S. territories from the rest of the U.S. creates an urgency to improve systems of care and hospital resources. Expanding telemedicine and increasing the number of medical professionals working in U.S. territories could help to address some of the disparities. Mentoring and education are also essential tools needed to improve the care of stroke patients living in U.S. territories. There is a need for new preventive medicine initiatives that help to decrease stroke risk and other chronic diseases that lead to increased risk of stroke.

A major gap in the current knowledge of stroke care and outcomes in U.S. territories is due to the lack of a comprehensive national registry with stroke data from all the U.S. territories and Native American Nations. As part of our work for this task force, Dr. Rodriguez Mercado compiled data from the CDC on stroke care in Puerto Rico (PR) (from the Puerto Rican Stroke Registry, the largest stroke registry conducted among Hispanic individuals). Although not representative of all U.S. territories, the data from PR reveal multiple factors which may contribute to disparities in stroke care and outcomes—high prevalence rates of stroke risk factors, long arrival times and low rates of ambulance arrivals, and low rates of secondary prevention measures (see Table 1).

Compared to data from the U.S. mainland, these findings are striking. For example, in this dataset, the median arrival time to the emergency room (from symptom onset) is over five hours, which is more than double the median arrival time reported in a similar study conducted in Worcester, Massachusetts (2 hours) (Goldberg et al., 2000), and much higher than arrival times from a registry in Stockholm, Sweden where median arrival time is 20 minutes (Ekelund et al., 2011; Members et al., 2009). Consistent with long delays in hospital arrival times, only one in five patients in the PR registry arrived by ambulance, compared to 45% in the U.S. mainland. Additional data from the PR stroke registry are listed below in Table 1.

Table 1: Demographics, Risk Factors, and Secondary Prevention Strategies in Stroke Patients in the Puerto Rican Stroke Registry

Demographics	Sex: 52% female Age (mean): 74 years, female; 69 years, male
Risk Factors	Hypertension: 86% Diabetes: 52% Hyperlipidemia: 27% Current smokers: 10%
Stroke Subtype	Ischemic: 74.4% Hemorrhagic: 18.2%
Hospital Arrival Metrics	Time to hospital arrival (from symptom onset): 5 hours, 30 minutes (median) Ambulance arrival: 21%
Secondary Prevention Measures	Activity recommendation: 17% DVT prophylaxis at 2nd day: 41% Stroke education: 31% Lipid lowering agent: 72% Stroke discharge checklist: 13% Smoking cessation in smokers: 15% All secondary measures met: 31%

Details of registry: Data abstracted from medical chart review (ICD-9 codes 430-438, TIAs excluded), January 1, 2007-December 31, 2009, from 21 participating hospitals in Puerto Rico. Study includes all patients hospitalized with an acute stroke in all hospitals with acute care capability in Puerto Rico. Total n = 3,999.

Acknowledgements: The collection of these data was funded by Puerto Rican resources, and data were collected in collaboration with the University of Massachusetts and the University of Miami.

Inpatient Stroke Care

Inpatient stroke care typically begins after acute therapies have been delivered and continues through inpatient rehabilitation. During this phase, stroke patients undergo diagnostic studies to determine the mechanism of stroke, are treated for potential complications, started on secondary prevention treatments, and assessed for rehabilitation needs. Remarkably, there is very little in the literature on inequities in access to or utilization of evidence-based approaches during this period.

For diagnostic studies, the report considers computed tomography (CT) and CTA magnetic resonance imaging (MRI) and MR angiography, carotid duplex and transcranial Doppler ultrasound, conventional cerebral angiography, echocardiography, cardiac rhythm monitoring, and standard blood tests (*i.e.*, hemoglobin A1c, lipid panel). We also discuss several secondary stroke prevention interventions, including antithrombotic and statin therapies, carotid revascularization, closure of patient foramen ovale, and risk factor modification consultation.

We predicted that low-resourced regions of the U.S. would have fewer services, delayed implementation, and poorer patient outcomes. We also postulated that socioeconomic status impacts medical decisions. Financial factors may play a role in patients' willingness to undergo inpatient testing or comply with treatment recommendations. Further, there may be implicit bias in determining which patients receive specific tests or referrals for interventions. Currently, the strongest evidence for this bias is gender-based.

Although data in the inpatient setting are scarce, evidence suggests that there are disparities in the management of patients with acute stroke. Identifying the factors that contribute to these inequities is critical for improving stroke outcomes and quality of life. Another challenge is a lack of data element standardization, which makes it difficult to interpret current research findings. The overall dearth of information related to inpatient diagnostic and interventional utilization highlights the critical need for future investigation.

Geography

Despite a lack of data on disparities in the delivery of inpatient care in the U.S., international data suggests that regions with depressed economies have fewer high resource facilities, and as a result, may not offer the same range of testing and interventions (Addo et al., 2012; Brinjikji, El-Sayed, et al., 2014; Langagergaard et al., 2011). In contrast, urban areas with a greater number of academic medical and comprehensive stroke centers may be able to provide a broad array of services, better meeting the needs of higher acuity stroke patients. However, this assumption may be flawed if socioeconomic factors interact with geography and impact decision-making during the inpatient period.

Several publications have explored the role of rurality on post-stroke care. Patients with complex conditions, including stroke, were shown to have reduced access to specialized support services, lack of coordinated care, experiences with providers with limited healthcare knowledge regarding their complex needs, and an increased risk of secondary complications. Studies have shown that a lack of continuity of care following transition back to the rural community results in increased

emergency department visits and re-hospitalization within six months of discharge (Danzl et al., 2016; Kitzman et al., 2017). Home-based and telehealth tools were found to be helpful in alleviating patient barriers to post-stroke care. Also, robotic therapies were found to reduce cost and increase access in a rural setting focused on veteran stroke survivors (Custodio et al., 2009; Housley et al., 2016; Morrell et al., 2017).

Gap areas and research opportunities

- The characteristics of rural and urban hospitals that contribute to inequities in delivery of in hospital and post-stroke care should be further studied.
- The influence of geographic location of hospitals and availability of the most up to date equipment, protocols, and expertise should be explored in relation to the effect on stroke outcomes.
- The role of technologies (such as telemedicine and robotics) in reducing disparities should be investigated in the inpatient and post-stroke rehabilitation setting.

Policy and Regulation

In 1985, the U.S. Department of Health and Human Services released the Secretary's Task Force on Black and Minority Health (the Heckler Report). As one of the first federal documents to highlight healthcare disparities between majority and racial and ethnic minority populations, it is important to note the emphasis that this document placed on advances in health information technology (HIT) in the necessary reforms. The report also emphasized systems development over individual patient care. There was also an emphasis on systems development over individual patient care. Since the start of the COVID-19 pandemic in March 2020, the progress in remote care has been unprecedented.

In August 2021, Duncan et al. appropriately asked, "Has the time come for telerehabilitation?" In this commentary, the authors note that the very systems in need of better HIT integration (*e.g.*, prisons, rural healthcare, etc.) were the early adopters. Telerehabilitation has been shown to be non-inferior to inpatient care to improve stroke impairments and quality of life in both the patient and the caregiver (Cramer et al., 2019). While disparities to telerehabilitation appear to overlap with both socioeconomic status and geography creating a digital divide, strategies to improve technology access may help to limit their effect as well (Caughlin et al., 2020; Custodio et al., 2009; Duncan & Bernhardt, 2021; Strowd et al., 2021).

Gap areas and research opportunities

- Insurance coverage is often a barrier and a driver of disparities. The U.S. Department of Veterans Affairs (VA) has direct appropriation from Congress, and therefore, can decide what it supports. From an equity standpoint, this is a positive approach. More data on the impact of insurance is needed.
- Hospital certifying agencies could consider policies designed to eliminate barriers to equitable delivery of care.

- There is potential value in distributing protocols from CSCs, representing a bundle for in-hospital stroke care, to all hospitals across a network to promote standardized practices, which should also promote more equitable care.

Economics and Healthcare Resources

It is difficult to tease out the combined effects of geography, socioeconomic status, and race/ethnicity on equitable delivery of inpatient care. An analysis of the National Inpatient Sample identified several factors associated with reduced utilization of inpatient implantable cardiac monitor (ICM) placement for detection of paroxysmal atrial fibrillation. Multivariate analysis revealed that hospital region [Midwest (OR 0.74 95% CI 0.61 - 0.90, p = 0.002), South (OR 0.68 95% CI 0.57 - 0.81, p < 0.001), and West (OR 0.37 95% CI 0.29 - 0.45, p < 0.001)], hospital bed size [small (OR 0.38 95% CI 0.39-0.46, p < 0.001) and medium hospital bed size (OR 0.73 95% CI 0.63 - 0.84, p < 0.001)], insurance status [Medicaid (OR 0.86 95% CI 0.76 - 0.98, p = 0.02) and self-pay (OR 0.51 95% CI 0.41 - 0.62, p < 0.001)], and non-teaching hospital (OR 0.52 95% CI 0.47 - 0.60, p < 0.001) were associated with a lower likelihood of having an ICM placed (Yaghi et al., 2022).

Evidence of the association between racial/ethnic health disparities and socioeconomic differences is very consistent across chronic illnesses and health care services. We found several publications evaluating the influence of neighborhood socioeconomic status (nSES) on post-stroke recovery. Higher nSES was associated with better function, biopsychosocial health, physical health-related quality of life, and fewer depressive symptoms when compared to lower nSES. In addition, mortality after stroke was significantly higher among residents from lower nSES (Brown et al., 2013; Elfassy et al., 2019; Stulberg et al., 2021; Twardzik et al., 2019).

Stroke rehabilitation referral patterns

Referral patterns also affect the provision of post-stoke care. The literature suggests that women were less likely to receive inpatient rehabilitation compared to men. Similarly, higher socioeconomic groups, patients from urban areas, and patients from geographic areas close to regional rehabilitation hospitals were more likely to go to an inpatient rehabilitation facility. Underinsurance is a likely barrier to rehabilitation services. Referral patterns also affect the provision of post-stoke care. The literature suggests that women were less likely to have inpatient rehabilitation than men. Similarly, higher socioeconomic groups, patients from urban areas and from geographic areas close to the regional rehabilitation hospitals were more likely to go to an inpatient rehabilitation facility. Referrals to home health services were more often provided to racial minorities, females, older individuals, and those with lower incomes. Conversely, uninsured individual and rural residents were less likely to receive home health services. Blacks, females, older individuals, uninsured individuals and those with lower incomes were less likely to use skilled nursing facilities rather than acute inpatient rehabilitation hospitals (Freburger et al., 2011; Sandel et al., 2009).

Based on these findings, further research is needed to evaluate the structural and social characteristics of neighborhoods that may contribute to post-stroke recovery and mortality. Evaluating referral patterns and the use of community care coordinators within regions of lower nSES maybe a useful adjunct to care following acute stroke admissions.

Gap areas and research opportunities

- Telemedicine can provide some opportunities not available in traditional in-person visits. This may include (but is not limited to) joint discussions with family members who are geographically dispersed. Reimbursement for telehealth has been robust during the COVID-19 pandemic, but whether insurers will continue to cover telehealth remains uncertain.
- Many patients don't have access to a smartphone or internet connectivity to support telemedicine video interactions. The VA recently addressed some of these issues by loaning patients a tablet with a data plan, which provides cost benefits when compared to not providing care. However, this approach would be difficult to apply to the general population and more research is needed on its effectiveness. Although preliminary, the VA also recently developed local community pods with tech support to bring telehealth to underserved areas (see *Appendix B: Telemedicine in Stroke Care* for more details on telestroke).
    - Secondary stroke prevention usage declines with age, despite the risk of stroke increasing with age. Possible explanations include comorbidities and other risk factors preventing use of certain medications or limitations due to cost. More research is needed on this pattern. It is also important to examine what causes medication noncompliance at certain timepoints after discharge (*e.g.*, 30, 60 days, etc.).
    - More research is needed on how different types of post-discharge care affect patient outcomes (*e.g.*, primary care physician [PCP], community-based health clinics).

Demographics

Secondary stroke prevention measures

In the previously referenced analysis of ICM inpatient placement, from the National Inpatient Sample, Black race was associated with decreased utilization (OR 0.76 95% CI 0.68 - 0.84, $p < 0.001$) (Yaghi et al., 2022). Compared to younger patients, those aged 65 years and older in the REGARDS study were less likely to be prescribed a statin at discharge (OR 0.75, 95% CI 0.57, 0.99), but there was no significant difference by sex, race, education, income, or residence (Albright et al., 2017). Hispanics in Puerto Rico had lower odds of being prescribed a statin (adjusted OR 0.23, 95% CI 0.12, 0.47) compared to non-Hispanic whites (Sacco et al., 2017). In the same cohort, patients aged 65 years and older were no less likely to be prescribed antithrombotic therapy at discharge based on race/ethnicity (Sacco et al., 2017). Based on data from the Get with the Guidelines (GWTG) program, Asian Americans had a higher odds of being prescribed a statin compared to Whites (adjusted OR 1.25, 95% CI 1.16, 1.35 than Whites) (Song et al., 2019).

Guidelines recommend antithrombotic administration within two days of hospitalization. In the GWTG Florida and Puerto Rico cohort, compared to Whites, Hispanics from Puerto Rico had lower odds of receiving an antithrombotic by end of hospital day two (adjusted OR 0.24, 95% CI 0.10, 0.55). However, in patients aged 65 years and older, there was no significant difference by race/ethnicity for antithrombotic use by end of hospital day two. In GWTG, compared to Whites,

Asian Americans had higher odds of receiving an antithrombotic within 24 hours of hospital admission (adjusted OR 1.10, 95% CI 0.99-1.21) (Sacco et al., 2017).

Antiplatelet prescribing at the time of stroke discharge was also evaluated in these populations. In the GWTG Florida and Puerto Rico cohorts, Hispanics from Puerto Rico had lower odds of being discharged on an antithrombotic (adjusted OR 0.29, 95% CI 0.12–0.74) compared to whites. In patients with atrial fibrillation, Hispanics from Puerto Rico were less frequently discharged on aspirin (Blacks 43.6% vs. 42.2% White, 35.5% FL-Hispanic, 11.1% PR-Hispanic) (Sacco et al., 2017). In addition, in patients aged 65 years and older, there was no significant difference by race/ethnicity for antithrombotic prescribed at discharge (Sacco et al., 2017). In symptomatic carotid endarterectomy patients, women were less frequently discharged on an antiplatelet compared to men (women 95.9% vs. men 96.6%, P = 0.007) (Dansey et al., 2020).

Multiple U.S. studies have found that women and non-white individuals are less likely to receive secondary stroke prevention therapies, including antiplatelet and anticoagulation medications. In symptomatic carotid endarterectomy patients, women were less frequently discharged on an antiplatelet than men (women 95.9% vs. men 96.6%) (Dansey et al., 2020). Interestingly at least one study found that non-White subjects, women, and those with lower education were less likely to see a cardiologist, which is important as multiple studies have shown that seeing a cardiologist is more likely to be associated with guideline-based care for atrial fibrillation.

Access to post-stroke rehabilitation services

Blacks, females, older individuals, uninsured individuals and people with lower incomes were less likely to use skilled nursing facilities compared to acute inpatient rehabilitation hospitals (Freburger et al., 2011; Sandel et al., 2009). Despite data revealing no clinically significant racial difference in rehabilitation therapy utilization or intensity, there are considerable differences in functional outcomes. Blacks were less likely to achieve comparable functional improvement following rehabilitation. A pertinent factor noted was that Black patients underwent more frequent post-stroke transitions. Therefore, racial differences in discontinuous care and suboptimal transitions between settings may play a role in patient outcomes (Ellis et al., 2015; Ellis et al., 2014; Skolarus et al., 2017). Based on these findings, further research is needed to evaluate the consequence of care transitions in patients with stroke and strategies to optimize or decrease transitions are needed.

Gap areas and research opportunities

- Further studies are needed to address demographic inequities in the utilization of inpatient procedures, such as carotid interventions and patent foramen oval closure.
- Demographic variations in diagnostic procedures and prescribing secondary stroke prevention medications during hospitalization requires further study.
- The impact of demographic inequities in the use of secondary stroke prevention measures and post-discharge disposition on stroke outcomes should be investigated.

Action Opportunities

The section below serves to summarize tangible actions and potential solutions gleaned from the task force reports and the March 2022 *Inequities in Access and Delivery of Acute Stroke Care* symposium. Formulated by thoughtful discussions, the steering committee and task forces agreed that the following recommendations represent a path forward to resolving disparities in stroke care.

Prehospital Stroke Care

As mentioned prior, prehospital care emerged as a primary focus of the symposium because deficiencies in early recognition, triage, and transport have clear downstream impacts on treatment options, care venues, and clinical outcomes. To better convey potential action opportunities in this care epoch, the task force presented their recommendations in three categories.

Education and training

1. Enhance education and training in stroke recognition among emergency medical services (EMS) professionals, throughout the chain of survival (*i.e.*, dispatch, fire and rescue, police, paramedics, and others), especially in rural areas and U.S. territories.
2. Implement statewide policies to promote the use of nationally validated prehospital large vessel occlusion (LVO) stroke scales as they evolve.

Stroke systems of care

3. Encourage research to further optimize adaptive, 'real time' prehospital routing algorithms based on location, patient characteristics, local resources, and transport times.
4. Enhance access to prehospital stroke research across geographic barriers and promote prehospital triage programs for U.S. territories and native peoples' communities/reservations.
5. Standardize prehospital communications within stroke systems of care to ensure universal prenotification in acute stroke triage.
6. Incorporate community paramedicine and local partnerships into stroke systems of care.
7. Establish linkages between prehospital and hospital patient care records to enable real-time patient care and quality improvement activities.

Government and regulatory

8. Pass legislation to promote standard EMS protocols and regionalization of prehospital stroke care across and within states and U.S. territories.
9. Advocate for policies, legislation, and resources to support the creation of state or community-level stroke registries with the capacity to link prehospital data to health system outcomes and serve as a basis for policy development and continuing quality improvement initiatives.

10. Enlist panels of community stakeholders and local and regional stroke care advisory groups.
11. Develop financial aid and loan repayment programs for EMS professionals and support paramedic stroke training specific to rural and resource-limited settings.
12. Partner with commercial telecommunication providers and emergency services to enhance cellular and broadband capability for rural ambulance agencies.
13. Pilot prehospital telemedicine services (telestroke) to support LVO scale validation, assessment, and triage.
14. Provide guidance to states regarding minimum elements required for prehospital stroke systems of care, including the role of stroke advisory committees.
15. Support Centers for Medicaid and Medicare reimbursement guidelines that promote reimbursement for prehospital care commiserate with the level and complexity of care (*e.g.*, value-based reimbursement, reimbursement of non-transports and alternative destination transports, mobile stroke units and telestroke consultation, and "code stroke" billing modeled from trauma activation billing).

Hyperacute and Acute Stroke Care

During discussions about acute care in the emergency department setting, access to high-level stroke centers and expertise emerged as a ubiquitous disparity. The task force focused their recommendations on potential short- (1-3) and long-term (4-6) solutions to expand stroke expertise to where it's needed, improve hospital infrastructure and resources, and remove policy and regulatory barriers to receiving high-quality stroke care.

1. Develop a student loan repayment program for stroke neurologists and interventionalists to enhance employment and practice. This could ensure that lower-resourced hospitals achieve higher levels of stroke certification, thereby improving access to stroke expertise.
2. Seek out National Institutes of Health (NIH) funding (via NIH StrokeNet) to support research and education for rural stroke coordinators who work with smaller hospitals and remove barriers to participation, including the lack of research infrastructure.
3. Provide community-based stroke educational opportunities to the public and stroke care professionals, especially in rural and low-income areas.
4. Develop a Mobile Intervention Stroke Team (MIST) model to improve regional access to thrombectomy and reduce extended transfers, which contribute to disparities in the ability of families to support patients, understand post-stroke dependency, and obtain adequate stroke education. These issues are exacerbated by disparities in socioeconomic status.
5. Develop strategies to encourage telestroke adaptation at appropriate hospitals.
6. Stroke care professionals should work at the local, state/territory, and national level to coordinate stroke care.

Inpatient Stroke Care

Patient outcomes were a common theme in this care epoch because the quality of inpatient stroke care often has major impacts on patient recovery, post-stroke disability, and long-term health outcomes. Additionally, recognizing the lack of literature on inequities in access to inpatient stroke treatments and services, the task force recommendations focused on ways to enhance research on inpatient and post-stroke care.

1. Social determinants of health play major roles in patient outcomes (*e.g.*, medication usage, follow-ups). Therefore, there is a need for more community health needs assessments to improve medication compliance and post-hospitalization outcomes.
2. Stroke nurse navigators can help guide the transition from inpatient to outpatient care, including outpatient follow-up and ensuring consistent medication usage. We should support and diversify the stroke nurse navigator workforce.
3. To reduce costs and optimize patient outcomes, there is a need for more research on how the duration of inpatient rehabilitation affects patient outcomes.
4. Evaluate ethnicity/race, geography, patient education, income, and health insurance interaction to accurately describe existing disparities in inpatient medication prescribing (*i.e.*, early antithrombotic administration) and discharge prescribing of secondary stroke prevention medications.
5. Establish and adopt standardized categories and terminology, potentially by requiring researchers to use NINDS Common Data Elements in publications. There is also a need to improve the definitions of patient-level (*e.g.*, non-adherence), provider-level (*e.g.*, risk assessment/benefit), and societal-level (*e.g.*, drug costs) factors.
6. Additional research is needed to determine how best to facilitate the community navigation necessary to encourage positive health outcomes for individuals transitioning back into low-resourced rural communities.
7. Assess which characteristics of rurality and other demographics are most salient to the inpatient and post-stroke care experience.

Conclusion

Mark J. Alberts, M.D.
Brain Attack Coalition Chair and Symposium Steering Committee Co-Chair

Combined with knowledge gained from the symposium, the findings from the expert task forces revealed several common and overlapping causes and associations that appear to directly impact disparities in stroke care, potentially leading to poor health outcomes. Fortunately, several themes emerged that might provide opportunities to address these disparities comprehensively and efficiently. Below we summarize some areas that might be easy to address in a short-term time frame (1-2 years) and others that might require more long-term efforts (3-5 years) due to their high complexity or need for major funding or policy changes. We acknowledge that important initiatives, such as primary prevention programs, are very useful but will require high-cost investments lasting 10-20 years, which is beyond the scope of this work.

The development of a regional and/or national stroke registry would benefit patients from all backgrounds in every area of the country. A registry would provide transparency about the efficiency and effectiveness of care nationwide and provide important insights into key associations that would track with disparities of care in all care epochs and locations. To the extent that some registries currently exist in various states, and implementation of these registries typically does not require major advances in technology or infrastructure, regional or national efforts could be implemented in a relatively short time. Such registries might be highly impactful in terms of refining care for high-risk populations.

A lack of knowledge about stroke risk factors, poor recognition of stroke symptoms, and an underutilization of 911 remains a vexing problem for many high-risk populations, including persons in minority and underserved groups. There is robust literature about the effectiveness of culturally sensitive approaches to public education, as well as the need for stroke awareness programs to frequently update messaging and dissemination strategies. For example, Mind Your Risks®—a public health campaign designed to raise awareness about the link between high blood pressure, stroke, and dementia—was recently updated to focus on Black men between the ages of 28-45, a group most at-risk for hypertension. Building on their prior success, programs using the FAST or BE-FAST mnemonic should be relaunched in the current era of highly effective mechanical thrombectomy. Reviving them now may further promote rapid and accurate stroke recognition.

Emergency medicine emerged as a key venue for improvement in care for all populations, especially people of color. We identified several potential short-term solutions, including establishing national prehospital standards of care and related metrics and creating adaptive emergency medical services (EMS) routing algorithms. Long-term solutions include increasing the use of telestroke in the field and developing a more diverse workforce. EMS officials should partner with local groups, especially those that represent minority areas and populations, for public health education and related initiatives. EMS officials might also consider partnering with federal agencies (*e.g.*, the Centers for Disease Control and Prevention), state-health offices, advocacy groups, and others.

In the acute care space, expanding telestroke services to underserved areas (especially rural facilities and hospitals) could alleviate some identified disparities relatively quickly. Over the next several years, increasing the availability and use of mobile stroke units might be cost-effective, depending on the density of high-risk populations and distances between various levels of hospitals. The "triage and treatment paradigm" used to ensure timely and efficient transfer of specific types of patients with myriad emergency conditions could be implemented in stroke care within a short time frame. This is also an example of how state or regional policymakers can work together to remove barriers to access to stroke care (*i.e.*, insurance rules).

The quality of inpatient care and post-discharge care often has major impacts on patient recovery, post-stroke disability, and risk of subsequent cerebrovascular and cardiovascular events. We identified significant disparities in the use of validated and proven secondary prevention modalities (*e.g.*, medications, surgery, and endovascular therapy), availability of acute rehabilitation services, and other special services such as mental health support. Regarding secondary prevention, treatments are widely available, and programs exist to enhance compliance with national standards. In the short term, novel, focused incentives for diverse providers and patients should support the adoption of the national standards for secondary stroke prevention, while also addressing concerns about treatment side effects, affordability, and other patient concerns or barriers in a culturally sensitive manner.

Though not in the original scope of this effort, all three time epochs of acute stroke care noted access to rehabilitation and mental health services as a point of disparity. This is further complicated due to the existence of pervasive barriers, including financial support, lack of facilities near acute care hospitals as well as where patients live, and a paucity of mental health resources in areas with high-risk populations. Fortunately, the use of telehealth technologies, such as telerehabilitation and telepsychology, offers one approach to address these disparities in the long term. The thoughtful use of advanced practice providers and other modalities of home-based care might be another, partial solution to these challenging issues.

Disparities and inequities exist within all levels of stroke care. Although the root causes of these differences are as diverse as the populations impacted, several common themes have emerged that may offer pathways forward to address some of these concerns in a sensitive and thoughtful manner. There are options with both short- and long-term horizons. No matter the action, the sooner that stakeholders and relevant organizations can formulate and implement solutions, the sooner people at high risk will benefit.

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Appendix A: Brain Attack Coalition Symposium Agenda and Recordings

Inequities in Access and Delivery of Acute Stroke Care

March 17-18, 2022

This day and a half event brought together Brain Attack Coalition organizations and task force members with stakeholders and providers to share findings and identify opportunities for synergy in the identification of equity issues, their known and/or unknown causes or obstacles, and establishing best practices or possible solutions concerning stroke care across three time epochs: prehospital, hyperacute and acute, and inpatient care. Participants examined inequities across four cross-cutting themes: geography, policy and regulatory issues, economics and healthcare resources, and demographics.

Symposium goals:

The long-term goals of the symposium include improving stroke systems of care, providing more efficient and effective treatments, increasing equity in access and care, and improving outcomes for all affected populations.

Video recordings are available on NIH videocast (watch Day 1 and Day 2).

Agenda

Day 1
Thursday, March 17, 2022 (all times Eastern Standard Time)
Master of Ceremonies: Samantha White, Ph.D., National Institute of Neurological Disorders and Stroke (NINDS)

10:15am	**Welcome** *Mark Alberts, M.D., Hartford Hospital, University of Connecticut* *Richard Benson, M.D., Ph.D., NINDS*
10:30-11:15am	**Keynote Address** *David Satcher, M.D., Ph.D., Founding Director and Senior Advisor of the Satcher Health Leadership Institute*
11:15-12:30pm	**Prehospital Care Report Out with Breakout Discussions by Cross-Cutting Theme** ***Moderator:*** *Mark Alberts, M.D., Hartford Hospital, University of Connecticut*

	Todd Crocco, M.D., University of Maryland *Erika Odom, Ph.D., Centers for Disease Control and Prevention* 11:15am – Presentation 11:30am – Moderated Q&A Session 12:00pm – Breakout Discussions
12:30-1:15pm	**Lunch Break**
1:15-2:30pm	**Hyperacute and Acute Care Report Out with Breakout Discussions by Cross-Cutting Theme** ***Moderator:*** *Mary (Lee) Jensen, M.D. University of Virginia* *Ameer Hassan, D.O., University of Texas Rio Grande Valley* *Mary (Lee) Jensen, M.D., University of Virginia* 1:15pm – Presentation 1:30pm – Moderated Q&A Session 2:00pm – Breakout Discussions
	Inpatient Care Report Out with Breakout Discussions by Cross-Cutting Theme ***Moderator:*** *Mark Alberts, M.D., Hartford Hospital, University of Connecticut* *Karen Furie, M.D., Brown University* *Lawrence Wechsler, M.D., University of Pennsylvania* 2:30pm – Presentation 2:45pm – Moderated Q&A Session 3:15pm – Breakout Discussions
3:45pm	**Break**
4:15-4:50pm	**Breakout Discussion Summary and Wrap Up** ***Moderator:*** *Mark Alberts, M.D., Hartford Hospital, University of Connecticut*
4:50-5:00pm	**Closing Remarks** *Walter Koroshetz, M.D., Director of NINDS*
5:00pm	**Adjourn**

Day 2 Friday, March 18, 2022 (all times Eastern Standard Time) *Master of Ceremonies: Samantha White, Ph.D., NINDS*	
11:00am-12:30pm	**Synthesis and Discussion of Day 1 Dialogues: Confirmations, Corrections, and New Ideas** ***Moderator:*** *Mark Alberts, M.D., Hartford Hospital, University of Connecticut* ***Moderator:*** *Richard Benson, M.D., Ph.D., NINDS* **Prehospital Care Synthesis** *Charles (Chas) Wira, M.D., Yale University* **Hyperacute and Acute Care Synthesis** *Mary (Lee) Jensen, M.D., University of Virginia* **Inpatient Care Synthesis** *Karen Furie, M.D., M.P.H., Brown University* *Lawrence Wechsler, M.D., University of Pennsylvania*
12:30-1:00pm	**Symposium Wrap Up** *Mark Alberts, M.D., Hartford Hospital, University of Connecticut* *Richard Benson, M.D., Ph.D., NINDS*
1:00pm	**Adjourn**

Appendix B: Telemedicine in Stroke Care

Telestroke is one of the most successful applications of telemedicine, bringing stroke experts to hospitals where they are most needed. Telestroke systems of care were designed to address disparities in access to neurologic expertise (Demaerschalk et al., 2012; Schwamm, Holloway, et al., 2009; Wechsler et al., 2017). Current American Heart Association/American Stroke Association (AHA/ASA) guidelines for the early management of acute ischemic stroke recommend that "telemedicine/telestroke resources and systems should be supported by healthcare institutions, governments, payers, and vendors as one method to ensure adequate 24/7 coverage and care of acute stroke patients in a variety of settings" (Powers et al., 2019).

But despite the rapid growth of telestroke over the past two decades, and further expansion during the coronavirus disease (COVID-19) pandemic, significant disparities in access to telestroke persist, with lower rates of adoption in rural areas, and ostensibly in hospitals that would greatly benefit from telestroke services (Machado et al., 2021; Richard et al., 2020).

Beginning in 2020, the pandemic led to loosened state licensure requirements for who can provide telemedicine and where providers and recipients can be located (*e.g.*, in different states); however, not all states have made these provisions. Further, not all insurers or plans reimburse for the services, telemedicine parity laws are variable, and there are limitations on audio-only consultations. Moreover, qualifications of the healthcare provider are inconsistent. In some systems, neurosurgeons and non-stroke neurologists participate in telestroke calls, rendering inconsistency in education and experience. In the acute care setting, telestroke evaluations are especially helpful for quick and correct thrombolysis eligibility decision-making, and triaging patients for emergency mechanical thrombectomy. Provision of stroke-specific education and validation of the application of AHA/ASA Guidelines for the Early Management of Patients with Acute Ischemic Stroke may improve the proficiency of identifying and treating candidates for recanalization therapy (*i.e.*, intravenous thrombolytic, thrombectomy).

Based on our findings, disparities in access to telestroke may be due to lack of infrastructure like broadband internet, higher costs, inadequate funding, limited technology, and policy and regulation hurdles. Overall, more research is needed to understand and address these issues. While the findings below focus on the role of telestroke in the acute care setting, many observations and recommendations can be applied to all aspects of stroke care.

What is currently known about telestroke?

- Telestroke is the use of real time audiovisual telecommunications to provide stroke expertise and decision support for remote access patients and emergency providers in the acute stroke setting (Levine & Gorman, 1999).
- Telestroke/teleradiology evaluations of acute stroke patients can be effective for correct thrombolysis eligibility decision-making (IIa, B-R) (Powers et al., 2019).
- Telestroke services that utilize video-based consultation compared with telephone-only consultation are more accurate in determining eligibility for intravenous thrombolysis for

patients presenting with acute stroke signs and symptoms in the emergency department (Demaerschalk et al., 2012).

- When implemented within a telestroke network, teleradiology systems are effective in supporting rapid imaging interpretation in time for thrombolytic administration decision making. (I,A) (Powers et al., 2019).
- Telestroke networks may be reasonable for triaging patients with acute stroke who may be eligible for interfacility transfer in order to be considered for emergency mechanical thrombectomy (IIb, B-NR) (Powers et al., 2019).
- The use of telemedicine/telestroke resources and systems should be supported by healthcare institutions, governments, payers, and vendors as one method to ensure adequate 24/7 coverage and care of acute stroke patients in a variety of settings (I, C-EO) (Powers et al., 2019).

What are the gaps and opportunities?

- Smaller, rural, critical access hospitals are less likely to have adopted telestroke systems compared to larger, urban hospitals and short-term acute care facilities.
- Neurologist density has decreased in rural counties in the U.S., and existing neurologists in rural settings are aging out of their careers (Machado et al., 2021).
- Telestroke capacity in 2017 (Richard et al., 2020):
    - Hospital size: highest quartile (33.5%) vs. lowest quartile (14.8%)
    - Location: urban (30.2%) vs. rural (23.5%)
    - Type: short term acute care (31.7%) vs. critical access (17%)
- Telestroke units/county in 2018 (Area Health Resource Files, CDC data) (Machado et al., 2021):
    - Telestroke units are available in 51%, 37%, and 18% of large metropolitan, medium/small metropolitan, and rural counties, respectively.
    - Notably, 4 out of 5 rural counties do not have a telestroke unit.
- Barriers to adopting telestroke services in rural and critical access hospitals include, cost, capacity, local/state/federal policies and regulation, technological limitations, availability of rural broadband, and availability of telestroke providers.
- There is a lack of prospective, comparative research to confirm the effectiveness of telestroke and telestroke systems in the acute stroke treatment and interfacility triage of patients with large vessel occlusion.

How can we make improvements to dissolve these geographical disparities?

- Expand licensure to perform telestroke services across state lines.

- Allow universal parity between stroke care performed via telemedicine and in-person services.
- Maintain elimination of originating site restrictions for telestroke services. The 2018 FAST Act requires Centers for Medicare and Medicaid Services to reimburse for telestroke services regardless of where a patient receives treatment.
- In situations where video-based consultation is not available, allow reimbursement of emergency telephone consultation with stroke providers as a limited telephone-only encounter.
- Continue policies enacted within the COVID-19 Emergency Authorization Act that incentivize the adoption of telestroke services across all geographies.
- Stroke experts should work with legislature, policy makers, regulatory agencies, and commercial telecommunications providers to ensure access to high quality broadband for rural hospitals and settings.
- Empower state departments of health, governmental agencies, and regional health systems to partner in enabling the provision of telestroke services for critical access hospitals within stroke systems of care.
- Create more federal grant funding opportunities for the adoption of telestroke programs and networks for rural and critical access hospitals (*e.g.*, Health Resources and Services Administration, Agency for Healthcare Research and Quality, Centers for Disease Control and Prevention, National Institutes of Health).
- Develop loan repayment programs for telestroke providers who provide care for rural-based hospitals, with the long-term goal of growing and incentivizing the telestroke workforce.
- Work with the Accreditation Council for Graduate Medical Education (ACGME) and specialty boards to instill educational and training requirements in telemedicine competency (*i.e.*, telestroke skills for neurologists and stroke fellows in training).
- Promote skills training and certification for emergency providers, nurses, and support staff in telestroke competency.
- Expand telestroke research by integrating telestroke into acute stroke clinical trials and epidemiological studies and developing multicenter telestroke research networks.

Appendix C: Steering Committee and Task Force Members

Steering Committee

Co-Chairs

Mark J. Alberts, M.D.
Co-Physician-in-Chief
Ayer Neuroscience Institute
Chief of Neurology
Hartford Hospital
Professor
University of Connecticut Medical School

Richard Benson, M.D., Ph.D.
Director, Office of Global Health and Health Disparities
National Institute of Neurological Disorders and Stroke
National Institutes of Health

Members

Todd Crocco, M.D.
Professor and Director of Pre-Hospital Care and Telemedicine
Department of Emergency Medicine
University of Maryland School of Medicine

Glenn Graham, M.D.
Deputy National Director of Neurology
Founder and Executive Director, National TeleStroke Program
U.S. Department of Veterans Affairs
Professor of Neurology
University of California, San Francisco School of Medicine

Ameer E. Hassan, D.O.
Professor of Neurology
University of Texas Rio Grande Valley
Director, Endovascular Surgical Neuroradiology and Clinical Neuroscience Research
Valley Baptist Neuroscience Institute

Mary (Lee) E. Jensen, M.D.
Professor Emeritus
Department of Radiology and Medical Imaging
University of Virginia

Gaurav Jindal, M.D.
Associate Professor
Department of Diagnostic Radiology and Nuclear Medicine
University of Maryland School of Medicine

Becky A. Schierman, M.P.H.
Senior Director
Clinical Practice & Quality Improvement
American Academy of Neurology

Prehospital Stroke Care Task Force

Co-Chair

Todd Crocco, M.D.
Professor and Director of Pre-Hospital Care and Telemedicine
Department of Emergency Medicine
University of Maryland School of Medicine

Members

Ope Adeoye, M.D.
Professor of Emergency Medicine and Neurosurgery
Chair, Emergency Medicine Research Division
University of Cincinnati College of Medicine

Brendan Carr, M.D.
Professor and Vice Chair
Department of Emergency Medicine
Associate Dean
Sidney Kimmel Medical College at Thomas Jefferson University

Sherita Chapman Smith, M.D.
Assistant Professor
Department of Neurology
University of Virginia Health

Ed Jauch, M.D.
Professor
Department of Emergency Medicine
Director of Acute Stroke Trials
Medical University of South Carolina

Holly Ledyard, M.D.
Associate Professor
Department of Neurology
University of Utah School of Medicine

Sheryl Martin-Schild, M.D., Ph.D.
Stroke Medical Director
Louisiana Emergency Response Network
President and CEO of Dr. Brain, Inc.
Medical Director of Neurology and Stroke
New Orleans East Hospital and Touro Infirmary

Ashish Panchal, M.D., Ph.D.
Associate Professor of Emergency Medicine
Department of Emergency Medicine
The Ohio State University Wexner Medical Center

Chris Richards, M.D.
Assistant Professor of Clinical Emergency Medicine
University of Cincinnati College of Medicine

Rafael Rodriquez -Mercado, M.D.
Associate Professor
Director of Endovascular Neurosurgery
University of Puerto Rico School of Medicine

Andy Southerland, M.D.
Distinguished Teaching Associate Professor of Neurology and Public Health Sciences
Executive Vice Chair and Residency Program Director
Department of Neurology
University of Virginia

Todd Wagner, Ph.D.
Director
Health Economics Resource Center
U.S. Department of Veterans Affairs

Charles Wira, M.D.
Associate Professor
Department of Emergency Medicine
Yale School of Medicine
Yale-New Haven Stroke Program

Stacey Quintero-Wolfe, M.D.
Associate Professor
Residency Program Director
Director of Neurointerventional Surgery
Wake Forest School of Medicine

Hyperacute and Acute Stroke Care Task Force

Co-Chairs

Ameer E. Hassan, D.O.
Professor of Neurology
University of Texas Rio Grande Valley
Director, Endovascular Surgical Neuroradiology and Clinical Neuroscience Research
Valley Baptist Neuroscience Institute

Mary (Lee) E. Jensen, M.D.
Professor Emeritus
Department of Radiology and Medical Imaging
University of Virginia

Members

Ope Adeoye, M.D.
Professor of Emergency Medicine and Neurosurgery
Chair, Emergency Medicine Research Division
University of Cincinnati College of Medicine

Brendan Carr, M.D.
Professor and Vice Chair
Department of Emergency Medicine
Associate Dean
Sidney Kimmel Medical College at Thomas Jefferson University

Kevin Cockroft, M.D.
Director of Cerebrovascular and Endovascular Neurosurgery
Department of Neurosurgery
Penn State Hershey Medical Center
Pennsylvania State University College of Medicine

Mahesh Jayaraman, M.D.
Director, Interventional Neuroradiology
Brown University
Director of Comprehensive Stroke Center
Neurointerventional Services
Rhode Island Hopital

Tracy Madsen, M.D., Ph.D.
Associate Professor
Department of Emergency Medicine
Brown University

Sheryl Martin-Schild, M.D., Ph.D.
Stroke Medical Director
Louisiana Emergency Response Network
President and CEO of Dr. Brain, Inc
Medical Director of Neurology and Stroke
New Orleans East Hospital and Touro Infirmary

Eliza Miller, M.D.
Assistant Professor of Neurology
Department of Neurology
Columbia University

Rafael Rodriguez-Mercado, M.D.
Associate Professor
Director of Endovascular Neurosurgery
University of Puerto Rico School of Medicine

Anjail Sharrief, M.D., M.P.H.
Associate Professor of Neurology
Director of Stroke Prevention, Institute of Stroke and Cerebrovascular Disease
University of Texas Health McGovern Medical School

Andrew Southerland, M.D.
Distinguished Teaching Associate Professor of Neurology and Public Health Sciences
Executive Vice Chair and Residency Program Director
Department of Neurology
University of Virginia

Prasanna Tadi, M.D.
Assistant Professor
Department of Neurology
Creighton University School of Medicine

Venu Vadlamudi, M.D.
Associate Professor of Radiology
University of Tennessee Health Science Center
Medical Director, Stroke and Cerebrovascular Disease Program
Inova Alexandria Hospital (2020-2021)

Charles Wira, M.D.
Associate Professor
Department of Emergency Medicine
Yale School of Medicine
Yale-New Haven Stroke Program

Inpatient Stroke Care Task Force

Co-Chairs

Karen Furie, M.D., M.P.H.
Professor and Chair
Department of Neurology
Warren Alpert Medical School at Brown University

Lawrence R. Wechsler, M.D.
Professor and Chair
Department of Neurology
Perelman School of Medicine at the University of Pennsylvania

Members

Aaron Anderson, M.D.
Assistant Professor
Vice-Chair Diversity, Equity, and Inclusion
Department of Neurology
Emory University School of Medicine

Karen Albright, D.O., Ph.D., M.P.H.
Associate Professor
Departments of Neurology and Pharmacology
State University of New York Upstate Medical University

Justin Caplan, M.D.
Assistant Professor of Neurological Surgery
Department of Neurological Surgery
Johns Hopkins University School of Medicine

Sherita Chapman Smith, M.D.
Assistant Professor
Department of Neurology
University of Virginia Health

Prasanna Tadi, M.D.
Assistant Professor
Department of Neurology
Creighton University School of Medicine

Michael Mullen, M.D.
Associate Professor
Lewis Katz School of Medicine at Temple University
Director, Stroke Program
Temple University Hospital

Sandra Narayanan, M.D.
Vascular and Interventional Neurologist
Pacific Neuroscience Institute
Director, Neurointerventional Program
Providence Saint Joseph Medical Center
Associate Professor
Departments of Neurology and Neurological Surgery
University of Pittsburgh Medical Center
(2019-2022)

Soojin Park, M.D.
Associate Professor
Department of Neurology
Columbia University Vagelos College of Physicians and Surgeons

Babu Welch, M.D.
Professor of Neurosurgery and Radiology
Director of the University of Texas Southwestern Microvascular Laboratory
University of Texas Southwestern Medical Center

Shadi Yaghi, M.D.
Associate Professor
Department of Neurology
Warren Alpert Medical School at Brown University
Co-Director, Comprehensive Stroke Center
Rhode Island Hospital

Appendix D: Acronyms and Abbreviations

AAN	American Academy of Neurology
ACGME	Accreditation Council for Graduate Medical Education
AHA	American Heart Association
AHORA	Andar, Hablar, Ojos, Rostro, and Ambos Brazos o Piernas
ALS	advanced life support
ASA	American Stroke Association
BE-FAST	Balance, Eyes, Face, Arm, Speech, and Time
CDC	Centers for Disease Control and Prevention
CI	confidence interval
CME	continuing medical education
CMS	Centers for Medicare & Medicaid Services
COVID-19	coronavirus disease 2019
CSC	Comprehensive Stroke Center
CT	computed tomography
CTA	CT angiography
DEI	Diversity, Equity, and Inclusion
DVT	deep venous thrombosis
ED	emergency department
EM	emergency medicine
EMS	emergency medical services
EMT	emergency medical technician
ESO	Electronic Health Records for Emergency Services
ET3 model	Emergency Triage, Treat, and Transport Model
EVT	endovascular thrombectomy
FAST Act	Fixing America's Surface Transportation Act

FAST	Face, Arm, Speech, Time
FL	Florida
GWTG program	Get with the Guidelines program
HIT	health information technology
ICD	International Classification of Diseases (ICD)
ICM	implantable cardiac monitor
IV tPA	intravenous tissue-type plasminogen activator
JAMA	Journal of the American Medical Association
LRP	loan repayment program
LVO	large vessel occlusion
MEDPAR	Medicare Provider Analysis and Review database
MIST	Mobile Interventional Stroke Team
MRI	magnetic resonance imaging
NEMSIS	National EMS Information System
NIH	National Institutes of Health
NINDS	National Institute of Neurological Disorders and Stroke
NQF	National Quality Forum
nSES	neighborhood socioeconomic status
OR	odds ratio
PCP	primary care physician
PR	Puerto Rico
PSC	primary stroke center
RÁPIDO	Rostro caído, Alteración del equilibrio, Pérdida de fuerza, Impedimento visual, Dificultad para hablar, Obtenga ayuda rápido
REGARDS study	REasons for Geographic And Racial Differences in Stroke Study
SES	socioeconomic status
STEMI	ST-elevation myocardial infarction

TIA	transient ischemic attack
tPA	tissue plasminogen Activator
TSC	thrombectomy capable stroke center
US	United States
VA	U.S. Department of Veterans Affairs

Appendix E: Acknowledgements

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