

Stroke

LANDSCAPE ANALYSIS

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Foreword

Over sixty hours of physician and patient shadowing. Thirty-five healthcare stakeholders interviewed. Three hospital centers visited. Four innovation conferences attended. And our journey has only just begun.

When we started the Health for America (HFA) at MedStar Health exploration phase in September 2016, we donned our pathfinder hats and jumped aboard the fellow“ship,” ready to explore the healthcare landscape of stroke. If we were in the early 19th century, our journey could have been likened to the voyage of the HMS Beagle; Charles Darwin had a personal journal, we have Excel observation trackers. The exploration phase urged us to observe our surroundings attentively and jot down anything and everything we found relevant to our cause. With open minds and empathetic hearts, we circumnavigated the world of stroke care.

However, preparing for and starting the journey as a team was not without its challenges. All four of us hailed from different professional backgrounds, continuing HFA's legacy of intentionally building interdisciplinary teams. We each had our own strengths and ways of thinking. Some of us are generally big-picture thinkers who prefer flexibility and uncertainty, while others are often more detail-oriented and thrive on structure and purpose. But it was precisely this amalgamation of personalities, leadership styles, and modes of problem-solving that made our team dynamic all the more versatile. Openly communicating with each other, we set out expectations for how to maximize productivity and maintain morale during this one-of-a-kind exploration.

Fortunately, we weren't alone in our roadmapping. If Darwin had captain Robert Fitzroy, we had HFA director Mandy Dorn. We received guidance constantly from our HFA alumni mentors who ensured that we hit the ground running, equipped to get around roadblocks along the way. All three of our MedStar Health physician mentors pointed us in the directions that allowed us to unearth more information about stroke care. The people we met along the way – emergency physicians, neurologists, social workers, occupational therapists, startup founders, and stroke survivors, just to name a few – added nuances to our understanding of stroke and health care in general. Like tourists seeking advice from locals, we listened to their stories and picked their brains for their expertise.

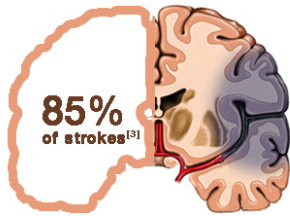
Two days before his voyage on the HMS Beagle concluded, Charles Darwin himself mused: *It is necessary to look forward to a harvest, however distant that may be, when some fruit will be reaped, some good effected.* Indeed, our journey is far from over; the landscape analysis, which outlines the stories and information about stroke care that we have sown thus far, has made us more prepared and informed for the upcoming ideation and implementation phases. It is a product of the fellows' literature reviews on relevant topics and anecdotes from site visits and physician/patient shadowing. As a result, our writing shifts to first-person occasionally within to represent our unique experiences at MedStar Washington Hospital Center, MedStar National Rehabilitation Hospital, and beyond. Ultimately, our goal is to design a novel user-centered solution for stroke care that will effect change in the healthcare system. While we have a long way to go, we will – as Darwin's words remind us – continue to look forward.



Background

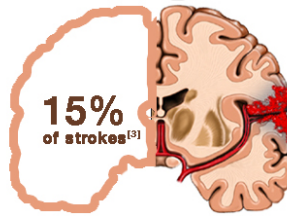
Stroke can be broadly defined as the lack of blood flow to a region of brain tissue and can occur in any vascular structure within the brain. Stroke symptoms can vary widely based on the individual and the region of the brain that has been deprived of blood flow.

Ischemic Stroke



A clot forms and blocks blood flow to part of the brain.

Hemorrhagic Stroke



A weakened blood vessel ruptures and causes bleeding in or around the brain.

Ischemic strokes take place when a blood vessel in the brain is blocked by a clot [1]. Transient Ischemic Attacks or TIAs, are “mini-strokes” whereby the symptoms from the clot appear temporarily. TIAs are warning signs that should be taken seriously. Often referred to as a “bleeding stroke,” hemorrhagic stroke occurs when a blood vessel ruptures within the brain. The rupture may be caused by an aneurysm (a ballooning and weakened arterial wall), traumatic brain injury, and arteriovenous malformations (an abnormal connection between arteries and veins) [2]. Although significantly less common, hemorrhagic strokes are often harder to treat, have a higher mortality rate, and can be more debilitating than ischemic stroke [3,4].

U.S. Numbers in Stroke

5th leading cause of death

140,000 deaths from stroke each year

1 in 20 deaths is due to stroke

Every 40 seconds someone has a stroke. [American Stroke Association]

“

**If you’ve seen one stroke patient,
you’ve seen one stroke patient.**

-HFA exploration lesson

”

Demographics

Every year, more than 800,000 people in the United States have a stroke. However, the burden of stroke prevalence falls along certain demographic lines.



About three-quarters of stroke occur in people > 65 years of age.

The risk of stroke doubles each decade after the age of 55 [5].



Women are more impacted by stroke than men, in part because women have longer life expectancy [6].

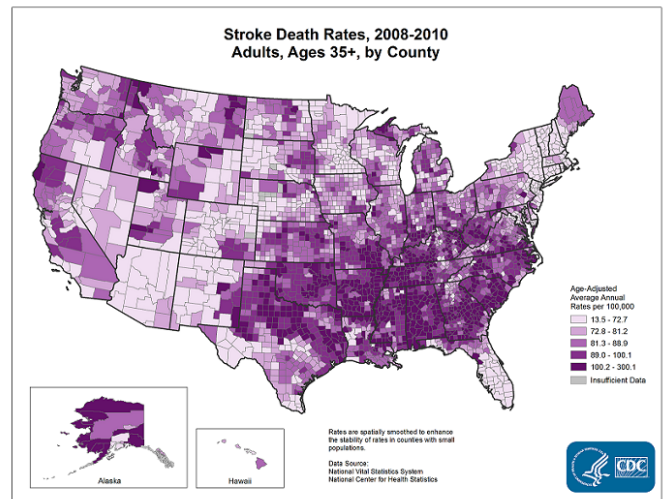


Stroke rates are higher for African-Americans than for any another racial group across all age groups, and mortality following stroke in African Americans is higher as well [6].



Margin populations susceptible to stroke include children, young adults, and pregnant women [6].

The highest stroke-related mortality rates are concentrated in the southeastern United States [7]. The District of Columbia falls into this high-incidence region referred to as the “Stroke Belt,” which reports age-adjusted mortality rates above 1.3-1.5 times greater than the national average [8]. This disparity is largely attributed to lifestyle factors such as diet, hypertension, and smoking [9]. Moreover, educational attainment, socioeconomic status, and social support are correlated with stroke outcomes and prognosis [10].



Stroke Death Rates, 2008-2010, Adults Ages 35+, by County Schieb, Linda, CDC.

Health Outcomes

Stroke is like a drop that falls into a still pool of water – the ripples that radiate from its impact travel far. As a leading cause of functional impairment, stroke affects not only the lives of those who experience stroke, but also of their families and caregivers [11].

Stroke-caused brain injury and resulting damage to the rest of the body is unique for each patient based on location and size of infarct, a localized area of dead tissue due to lack of blood supply [12]. Stroke-induced disability is usually severe and only 10% of people recover completely [13]. Of stroke survivors, 75% are dependent on their caregivers for help with activities of daily living immediately following stroke. This dependence sometimes decreases with time as those affected by stroke regain function [14].

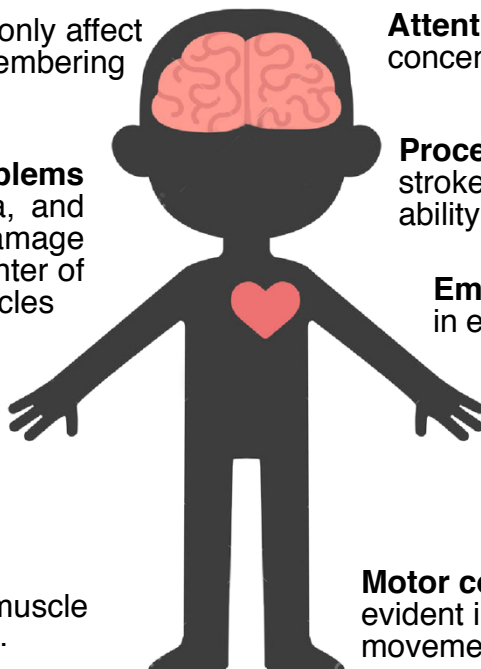
Disabilities can include any combination of the following [15]:

Memory impairments commonly affect short-term memory and remembering new information.

Speech and language problems such as aphasia, dysarthria, and dysphraxia arise if the damage occurred in the language center of the brain or for the muscles in the face or throat.

Weakness and paralysis of the muscles and particularly of the limbs often occur on one side of the body.

Spasticity causes residual muscle stiffness, tightness, and pain.



Attention deficits result in difficulty concentrating and multitasking.

Processing is difficult after a stroke and affects a person's ability to organize information.

Emotion changes can manifest in excess or absence of emotion.

Sensory changes are primarily visual problems or losses, but other senses, such as touch and pain, may change as well.

Motor control and balance are evident in difficulty executing movement and maintaining balance.

Costs

Nationally [16, 39]

\$71.55 billion in annual costs, which is expected to increase to **\$183.13 billion** by 2030.

\$33.65 billion in annual lost productivity, which is expected to increase to **\$59.54 billion** by 2030.

Individually [17,18]

Stroke care and rehabilitation in the first year:

\$18,963 (ischemic) or **\$32,325**

(hemorrhagic) for acute stroke care.

\$11,689 for outpatient rehabilitation annually.

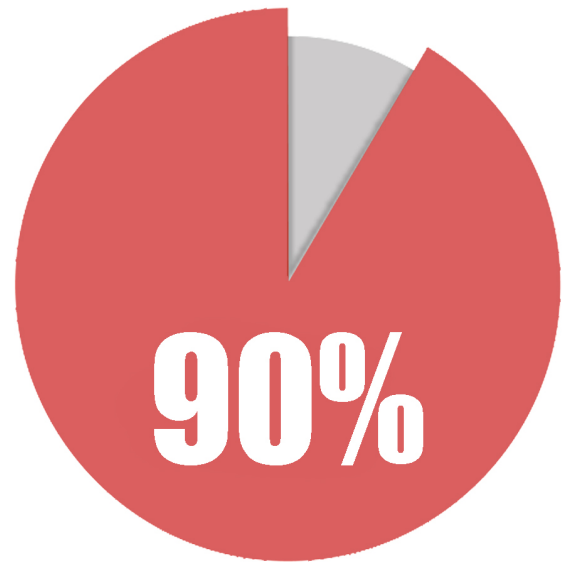
\$5,392 for medications annually.

Prevention

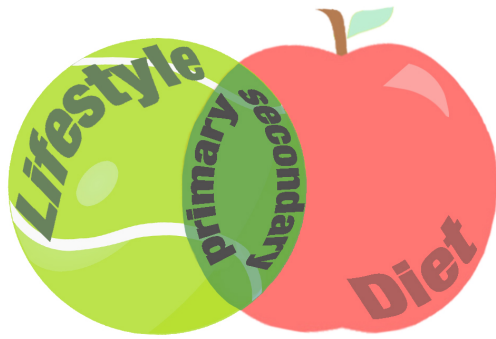
Because stroke is largely preventable, effective prevention remains the best approach for reducing the burden of stroke. Greater than 76% of all strokes are first events, making primary prevention especially important [20]. On average, 3%-4% of TIA or ischemic stroke survivors will experience a future ischemic attack.

Studies have attributed 90% of the risk of stroke to modifiable risk factors. Managing these risk factors places the power to prevent stroke into the patient's hands.

Modifiable risk factors for stroke include hypertension, diabetes, cholesterol levels, smoking and alcohol consumption, atrial fibrillation, sleep apnea, and sickle cell disease. Non-modifiable risk factors include age, genetic predispositions, prior stroke, and heart attack [21,22].



90% of stroke risk can be attributed to **potentially modifiable risk factors.**



Changing *dietary* and *lifestyle choices* can help manage risk factors and prevent both first-time (primary prevention) and repeated stroke (secondary prevention).

Major risk factors for stroke are depicted in the image below:



hypertension

Hypertension increases risk of stroke. Controlling blood pressure is the most effective strategy for reducing risk of ischemic and hemorrhagic stroke.



diabetes

Increases susceptibility to atherosclerosis and is associated with increased prevalence of hypertension and abnormal blood lipids. Proper diabetes management reduces risk for stroke [21].



cholesterol

High cholesterol is a risk factor for ischemic stroke, as damaged arteries and veins are more susceptible to clotting.



AFib

Atrial fibrillation is associated with a 4- to 5-fold increase in ischemic stroke, resulting from embolism of stasis-induced thrombi which can be managed with anticoagulation medications [23].



sickle cell disease

SCD puts children at risk for experiencing stroke. Transfusion therapy has led to significant progress in prevention of stroke in children with SCD [21].



sleep apnea

Sleep apnea contributes to the risk of stroke. Increasing severity of sleep apnea is associated increasing risk [21].



alcohol

Light to moderate alcohol consumption is associated with reduced risk of total and ischemic stroke, whereas heavier alcohol consumption increases stroke risk [21].



smoking

Smoking cessation and community-wide smoking bans reduce stroke risk [21], because smoking increases clot formation and arterial plaque build-up.

Nutrition and physical activity are essential to both primary and secondary prevention. Diet can help manage blood pressure levels and cholesterol-induced damage to the vascular system. Physical activity helps manage diabetes and hypertension. Lifestyle choices such as moderate alcohol consumption and cigarette smoking cessation further reduce risk. Medications to control blood pressure and lipids, anticoagulants for at-risk individuals with atrial fibrillation, and diabetes management medications complement the lifestyle interventions needed to mitigate stroke risk factors [20].

Recognition And Treatment

F

FACE: Ask the person to smile. Does one side of the face droop?



A

ARMS: Ask the person to raise both arms. Does one arm drift downward?



S

SPEECH: Ask the person to repeat a simple phrase. Is their speech slurred or strange?



T

TIME: If you observe any of these signs, call 9-1-1 immediately.



Time is Brain

Calling 911 as soon as stroke symptoms appear can greatly reduce the amount of time that elapses before someone receives the care that might make the difference between walking out of the hospital a few days later, or leaving in a wheelchair weeks to months later.

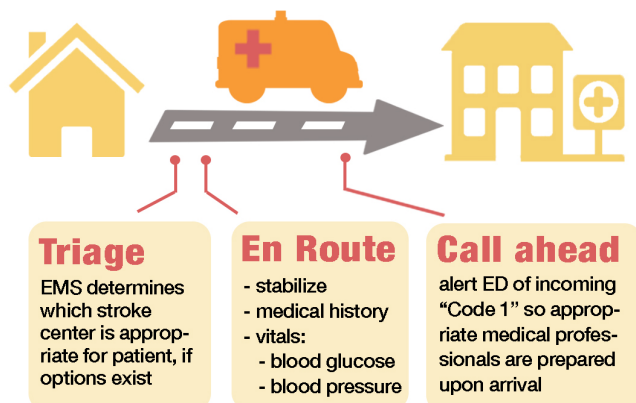
The acronym F.A.S.T. is an easy and popular way of remembering the signs of stroke.

The extent of brain tissue damage from stroke correlates with the length of time that neurons are deprived of oxygenated blood [24]. For this reason, acute stroke care focuses on minimizing the door-to-needle time, which is the time from which the patient enters the hospital to the delivery of clot-busting/clot-retrieving treatments that restore proper blood flow to obstructed vessels in the brain.

The length of this crucial time window depends on three factors: how quickly stroke symptoms are recognized, how rapidly a 911 call is made, and how efficiently the emergency medical services (EMS) and acute stroke treatment teams deliver care to the patient.

Zooming in, door-to-door time is very critical and requires a systematic strategy for routing EMS services to the appropriate hospital for the patient. This time frame is depicted in the image to the right:

Door-to-Door Time



Door-to-Needle Time



Upon arrival to the emergency department, the patient is quickly evaluated and sent for imaging with the intent of ruling out a hemorrhage, which would preclude the administration of tissue plasminogen activator (tPA). This is usually done through Computed Tomography (CT) [25]. However, in some comprehensive stroke centers like MedStar Washington Hospital Center (MWHC), where active investigational protocols are being applied, initial imaging is performed using Magnetic Resonance Imaging (MRI) rather than CT. Beyond ruling out a hemorrhage, MRI helps determine the location of the blood clot(s) [26]. Based on the imaging results, time elapsed since initial onset of symptoms, and the National Institutes of Health (NIH) stroke scale evaluation by the acute stroke team, the most appropriate course of care is then determined.

Of existing thrombolytic medications, the clot-busting drug tPA is the only FDA approved treatment for patients who have been diagnosed with ischemic stroke. As per FDA guidelines, IV tPA is administered if less than 4.5 hours have elapsed since the onset of symptoms [27]. tPA breaks down the vessel-occluding clot responsible for the stroke. If the victim of a presumed ischemic stroke is not eligible for tPA, or the clot is too large to be broken down by tPA alone, the patient still may be eligible for surgical procedures such as an embolectomy or a thrombectomy [28].

The standard protocol of care for hemorrhagic stroke is vastly different. tPA cannot be utilized, as it would have adverse effects on the hemorrhage and exacerbate bleeding. Once a hemorrhage is detected via CT or MRI, beta blockers may be administered to decrease heart rate and contractility. If intracranial pressure cannot be regulated through non-invasive measures, a ventriculostomy may be performed in order to decrease ICP (increased cranial pressure) by releasing blood and/or cerebrospinal fluid from the patient's intracranial space [31].

Stroke Mimics

Although administration of tPA can be done as long as the patient does not have a perceived risk of hemorrhage, tPA is a costly drug and once administered, requires the patient to be monitored at the hospital for 24 hours due to the risk of complications.[30] For this reason, the ability to rule out “stroke mimics” prior to the administration of tPA is an attractive benefit of using MRI rather than CT.

Rehabilitation

Rehabilitative therapy works to help stroke survivors regain functions that are impaired by stroke [32]. Therapists fall within three subspecialties – physical therapy, occupational therapy, and speech language therapy.

Physical Therapists (PTs) utilize different exercises to treat motor and sensory impairments resulting from stroke. Using their training in musculoskeletal physiology and locomotion, they assess each patient and strategize how to regain use of muscles or teach compensatory skills for impairments [33]. PT emphasizes isolated movements and mass repetition, and also utilizes techniques such as constraint-induced movement therapy and mobility training using walking aids [34].

Occupational Therapists (OT) focus on helping stroke survivors relearn self-directed daily activities such as grooming, cooking, and using the bathroom, and even extend to more complex tasks such as returning to work or resuming hobbies. OT teaches patients how to break complex activities into manageable parts and how to develop compensatory approaches to activities of daily living. A large part of OT also involves customizing treatment goals based on the needs and home environments of the patients [35].

Speech Language Pathologists (SLPs) work with stroke survivors with aphasia, apraxia, dysphasia, dysarthria, and social and cognitive communication disorders. SLPs help patients improve speech motor coordination and develop supplemental means of communication [36]. SLPs also equip patients with problem-solving and social skills. Sessions typically involve reading out loud, practicing articulation, writing, role-playing, and deductive reasoning exercises.

Physical Medicine and Rehabilitation (PM&R) Specialists, also referred to as physiatrists, are the physicians who lead the rehab team's efforts to restore movement and function in patients. They pick up where acute care leaves off by prescribing medications, conducting physical evaluations, designing a recovery plan, and recommending assistive/adaptive technology [37]. It is also the physiatrist's role to manage co-morbidities and apply secondary prevention measures [38].

Rehabilitative treatments and therapy occur both during inpatient and post-discharge throughout outpatient care. The inpatient and outpatient rehabilitation teams, both of which consists of PM&R/PT/OT/SLP, serve different goals. In inpatient rehabilitation, the primary medical focus is to stabilize and control life-threatening conditions. This includes pain management, ambulation, and mobility training. The outpatient outlook is more long-term and usually takes on the format of a partial day program. One example is the Neuro Day program at MedStar National Rehabilitation Hospital (MNRH). To the extent that the outpatient team is able to rehabilitate patients, compensatory strategies are simultaneously introduced during sessions to address the “plateau effect” seen in the latter stages of the patient’s recovery.

Stakeholders

Stroke care is a temporal continuum that involves stakeholders from a diversity of fields. As HFA moves into creating disruptive innovation in stroke care, the influence and investments of all these stakeholders must be considered [40].



Pharmaceutical companies control the development and pricing of tPA among other life-saving medications for primary and secondary prevention. Stroke survivors and at-risk individuals require blood-thinners, anti-platelet medications, and prophylactic medications.



Medical device industry works in research and development of technology in acute diagnosis, as well as in creating assistive/adaptive devices in rehabilitation.



Primary care physicians are the first line of defense in upstream primary and secondary prevention, such as detecting and managing hypertension, encouraging medication compliance, and making lifestyle changes.



Acute Stroke Teams include neurologists, PM&R specialists, and emergency physicians. They are the multidisciplinary, coordinated hospital team in charge of diagnosing and treating patients suspected of a stroke.



PT/OT/SLP/Neuropsychologists directly work with stroke survivors during rehabilitation.



Hospitals and health systems employ providers and are the physical space in which patients are treated. Different hospital designations – Acute Stroke-Ready Hospital (ASRH), Primary Stroke Center (PSC), or Comprehensive Stroke Center (CSC) – play a critical role in delivering appropriate care to stroke patients.



Emergency Medical Services teams consist of the first responders who identify and stabilize stroke symptoms in the field and decide which hospital is appropriate to route the patient based on proximity and needs.



Private and Public Insurers have the power to shape the ways in which stroke care is managed, paid for, and delivered. For instance, insurance dictates the number of outpatient rehabilitation sessions for which a patient qualifies based on assessment.



Caregivers and social workers provide the social support necessary for stroke patients to emotionally and physically adapt to new disabilities.



Communities create channels of influence that impact stroke outcomes through additional social, financial, and medical support, as well as play an inherent role in education and prevention.

Controversies

► **Is the science clear on the efficacy of endovascular therapy?**

There used to be controversy around endovascular therapy, which is the use of mechanical means for thrombectomy (such as balloon angioplasty), in acute ischemic stroke patients. However, the science is now clear on the evidence for endovascular therapy. In the treatment of anterior large vessel occlusion strokes that are less than 6 hours from symptom onset, endovascular therapy is currently considered the standard of care, based on findings from multiple randomized clinical trials (MR CLEAN, ESCAPE, EXTEND-IA, SWIFT PRIME, REVASCAT). In 2015, the AHA/ASA updated their guidelines for acute ischemic stroke, concluding that endovascular treatment is clinically beneficial in selected patients. To facilitate delivery of quality care, the report highlights the importance of having organized systems in hospitals. It is also worth noting that many in the stroke community recognize the need to define the role of EMS in the triage of patients who need endovascular therapy [41].

► **What imaging modality should be used for patients suspected of stroke?**

The stroke community has been divided with regards to imaging modalities for stroke diagnosis. One camp advocates for the usage of CT while another prefers MRI. The former group holds a “minimalist” take on the issue, asserting that CT imaging suffices, does not delay treatment, and can be applied easily at a community level. The latter “extremist” group argues that CT is an imprecise tool and can be supplanted by MRI, which can identify blood clots and spot hemorrhages that otherwise might not be as easily seen in CT scans. The preferred imaging tool may ultimately depend on hospital resources and workflows. Some hospitals where MRI is readily available, in terms of sufficient equipment quantities and personnel, integrate MRI into their stroke protocols. For instance, MedStar Washington Hospital Center added an MRI room directly adjacent to their emergency department, which allows the stroke team to quickly evaluate and scan the patient after ED team hand-off. However, community hospitals with limited access to MRI can optimize care using CT and still yield positive stroke outcomes [42].

► **How intensive and timely should therapy be after stroke?**

There is debate around initiation time and intensity of rehabilitation for stroke patients. Many believe that early intervention benefits patients. A systematic review of 38 randomized clinical trials has found that rehabilitation therapy given at an early time correlates with improved functional outcomes at discharge and follow-up. However, there is a lack of consensus on how to define “early after stroke” and how it can be meaningfully quantified. Some studies also show that early rehabilitation therapy is associated with higher drop-out rates and weaker long-term gains. On the intensity of therapy, two meta-analyses found that greater intensity yields weak positive results. One study concluded that “improvement in performance appears related to early initiation [of rehab therapy] but not to the duration of intervention” [43].

Emerging Themes

Gaps In Stroke Literacy

► Recognizing symptoms

A highly aware and educated public is one that is more likely to be healthy. The same can be applied to populations at-risk for stroke. People with limited understanding of health and well-being are less equipped to use preventive services, more prone to chronic medical conditions, and have a higher rate of hospitalization [44]. For stroke patients, health literacy is crucial in ensuring quality care and better health outcomes.

Acting “F.A.S.T.” (see recognition and treatment section) is vital because stroke outcomes are hugely dependent on response time. Unfortunately, public knowledge of early warning signs of stroke has not significantly improved [45]. For low-income and minority populations, the knowledge gaps are wider. In one 2009 study, only 2.8% of the Hispanic participants was able to identify all major stroke symptoms and less than half of African-American respondents knew to call 911 right away when stroke symptoms are recognized [46].

During patient interviews, we encountered multiple stroke survivors who called friends and relatives first before dialing 911. At the early onset of their stroke symptoms, they did not seem to feel a sense of urgency. The 911 call would only be made after their friends/relatives realized that something was wrong (e.g. impaired speech). This goes to show recognizing symptoms should be immediately followed by a call to emergency response. Public health campaigns should thus reframe their PSAs to emphasize the “T” in F.A.S.T. and effectively communicate the rationale for why delaying the emergency call can have drastic negative effects on stroke outcomes.

► Awareness of risk factors

Despite the preventable nature of stroke, awareness of stroke risk factors has been reported to be low in the general population. One study showed that less than half of participants were able to identify established risk factors such as high cholesterol and smoking [47]. While knowledge of risk factors improved in the general population between 1995 and 2000, there was no significant improvement in knowledge between 2000 and 2005.

In many of our physician encounters, we have found that hypertension was part of a patient’s medical history. We were told by the physicians we shadowed that it is not uncommon for stroke survivors to be unaware of their hypertension prior to the stroke. Stakeholders that we interviewed have also repeatedly emphasized the need to spread awareness around hypertension detection and management especially in underserved minority populations, with one physician dubbing hypertension as the “silent killer.”

► Misconceptions

People who have a strong awareness of stroke symptoms and risk factors are not necessarily free of misconceptions. In fact, 1 in 6 people seems to believe that stroke is not preventable and 1 in 3 thinks stroke survivors fully recover in several months [48]. After talking to patients, it became apparent that we also fell victim to stroke misconceptions. Several of these misconceptions are as follows:

Misconceptions	Clarifications
Doctors always know the cause of stroke in an individual patient.	Up to 30% of stroke cases don't necessarily have known causes [49]. This was the case in two of our encounters with patients, both of whom were physically active and posed no risk factors prior to their stroke.
Strokes only affect older people.	Although strokes are more common among the elderly, strokes can happen at any age. Approximately 25% of strokes occur in people under the age of 65. In 2005, stroke incidence increased among those 20-54 years of age [50]. Newborns and pregnant women can also be at risk for stroke.
Taking an aspirin can treat a stroke.	This is only helpful if the stroke is ischemic (i.e. involves the blockage of a blood vessel). However, if the stroke is hemorrhagic, taking an aspirin may worsen the situation. Until the appropriate neuroimaging scans are available, it should not be assumed that the stroke is treatable by a blood thinner like aspirin.
All strokes are the same.	Because strokes can affect different parts of the brain and multiple comorbidities may be present, the outcomes vary greatly between stroke survivors. It became apparent during our shadowing that "seeing one stroke survivor meant seeing one stroke survivor."
There is not much to life after a stroke.	While it may seem that stroke survivors lose total independence and functionality, quality rehabilitation therapy can put them back on track and prepare them for activities of daily living. Two of the stroke survivors who we met were able to travel and go on cruises despite their disabilities. One stroke survivor was able to return to work several months after the stroke and another was able to jog and weight-lift regularly.

► Current solutions

- English and Spanish PSAs on the signs of stroke and the importance of calling 911 by the National Institutes of Health
- Awareness initiatives such as *Come Back Strong*, *Faces of Stroke*, and *Fibs Or Facts?* by the National Stroke Association
- *Together to End Stroke* campaign by the American Stroke Association that aims to increase Americans' knowledge of stroke risk factors, FAST, and post-stroke resources

Managing Risk

Stroke is a leading cause of long-term disability. Given that 90% of stroke risk can be attributed to modifiable risk factors; management of hypertension, diabetes, and cholesterol levels can be a powerful tool in preventing both first-time and repeated stroke [51].

► Preventative screening

Oftentimes, people do not realize they are living with risk factors that can heighten their chances of stroke. High blood pressure (BP) is the best example of this. Hypertension typically does not present itself with clear and noticeable physical symptoms and may go untreated for extended periods of time.



Less known risk factors such as sleep apnea and plaque buildup in the carotid artery likewise go unnoticed. Preventative screening for these factors can significantly reduce risk. One study found that a prophylactic ultrasound screening of the carotid artery reduces the risk for stroke by 8% and should be considered by people who have a family history of heart disease and high cholesterol [52,53].

► Non-compliance

Preventative screening requires a patient to regularly visit their primary care provider (PCP) for checkups. As we saw from the time we spent shadowing a medical team in MedStar's inpatient rehabilitation unit, many of the patients recovering from stroke had not seen a primary care doctor in many years prior to their having a stroke. For some patients, even after they leave the inpatient rehabilitation facility, they might not seek any follow-up with a PCP, which can pose challenges with regard to management of comorbidities. One finding that surprised the HFA fellows is that only 5% of stroke survivors had a follow-up appointment within the first week of discharge [19]. Another layer to consider is lack of adherence to the prescribed medication regimen. Someone with hypertension or diabetes might fail to manage these conditions, despite knowledge of the diagnosis. Medication compliance is a complicated issue that is affected by factors like insurance coverage, caregiver access, and socioeconomic status.

► Changing lifestyle and behavior

Many of the risk factors for stroke can be controlled by diet and exercise. Hypertension, a leading risk factor for stroke, can be kept in check using a low-sodium diet and stress management regimens (e.g. yoga and meditation). Diabetes can be managed with low-carbohydrate diet and exercise. Similar healthy lifestyle practices can keep cholesterol levels and other modifiable risk factors at bay. However, changing old habits is never easy. While the solution for primary and secondary prevention of stroke seems clear, in reality, it is often difficult for patients to put them into practice due to motivational challenges and general barriers to healthcare access.

Building Empathy

HFA fellows participated in a variety of simulation activities to better understand some of these challenges and build empathy. We attempted to maintain a low-carbohydrate, low-lipid, and low-sodium diet (on a budget) to control for comorbidities such as diabetes, hyperlipidemia, and hypertension. We constantly checked our blood pressure and blood glucose levels, while making sure we took all of our fake daily medications (upwards of 12!). Moreover, we incorporated exercise in our daily routines. Needless to say, even for healthy and able-bodied individuals like ourselves, compliance proved to be difficult.

► Current solutions

- Scheduling services (e.g., ZocDoc) that simplify the process of finding a primary care provider and scheduling checkups
- Mobile apps that keep track of daily medications and send reminders when it is time to take medication
- Lifestyle management programs that provide dietary and exercise guidelines
- Wearable tech devices that continuously monitor and digitize blood pressure data and blood glucose levels

Barriers To Access

The affordability and availability of quality stroke care is not the same for every patient. Disparities in stroke treatment and subsequent health outcomes are caused by barriers to access.

► Disparity of care due to socioeconomic status and race

The ascription of health inequality to race and socioeconomic status is well-documented across all diseases, not just stroke. Most significantly affected by the burden of stroke in the U.S. is the African-American population. Stroke risk factors such as hypertension, diabetes, and obesity are seen in higher rates among African-Americans than their Caucasian counterparts [54]. Food deserts, failing public schools, and limited access to parks plague predominantly black neighborhoods more often than predominantly white neighborhoods. These barriers to access are what many consider to be a direct result of institutionalized racism [55,56].

Studies show that people from low-income and racial minority communities exhibit greater reluctance to call emergency services due to financial concerns, lack of knowledge about need for urgent treatment, mistrust of the medical system, and differences in attitudes. Low-income and racial minority patients are also less likely to receive tPA for ischemic stroke and more likely to experience longer waiting times in the emergency department compared to white counterparts [28].

► Medical resource paucity in rural areas

Long distances to the nearest stroke center and a dearth of stroke specialists who can perform treatments such as endovascular therapy make quality stroke care geographically inaccessible for rural populations. In increasing order of capabilities, hospitals are designated by the American Stroke Association (ASA) as Acute Stroke-Ready Hospitals (ASRH), Primary Stroke Centers (PSC), and Comprehensive Stroke Centers (CSC). Using U.S. Census data, it was found that only 81% of the U.S. population had access to intravenous-capable hospitals within a 60-minute transportation window, and only 56% had access to endovascular-capable hospitals [57].

► Current solutions

- Medstar's Connected Health projects, which include stroke telemedicine spearheaded by our physician mentor Dr. Amie Hsia and aim to provide emergency telestroke consultation for under-resourced hospitals.
- Culturally-responsive events that spread awareness about stroke such as the the ASA's annual "Igniting the Power" weekend in Atlanta, featuring prominent African-American community leaders [58].

Difficulties In Detection And Diagnosis

Door-to-needle time depends on the ability of the patient (or witnesses) to recall the time of onset of stroke symptoms. In many cases, if the time of symptomatic onset cannot be determined, timely treatment becomes more difficult, potentially disqualifying the patient for tPA or endovascular therapy. The swift detection and diagnosis of stroke play a vital role in improving the patient's prognosis and outcome.

► Detection

A necessary question physicians ask of stroke patients is, “When do you last recall being ‘normal’?” during assessment. Establishing last known normal can be difficult for those experiencing stroke, especially if they went to sleep symptom-free. Strokes that occur during sleep are called “wake-up strokes,” since the symptoms are only noted upon waking up [59]. Wake-up strokes represent approximately 20% of ischemic stroke victims. Even if the patient is awake during the onset of stroke symptoms, confusion and general lack of awareness often make recalling the time of symptomatic onset difficult for patients. Pilot studies that analyze the capability of MRI to determine the onset time of stroke are currently ongoing, but timely detection of stroke remains a major issue [60].

► Diagnosis

Strokes are diagnosed based on neuroimaging scans, patient medical history, and NIH Stroke Scale evaluation [61]. Oftentimes, CT imaging is only used to rule out a hemorrhage, so that tPA may be administered. In some circumstances, this results in the administration of tPA to individuals who may be suffering a stroke mimic. A patient experiencing a stroke mimic may portray similar signs and symptoms of a stroke, but for a different cause.

Both Code 1 stroke simulations we observed at MWHC turned out to be stroke mimics.

► Current solutions

- Relying on the accounts of those who witnessed the stroke symptoms
- MedStar Health’s protocol to utilize MRI instead of CT data to determine the nature of the stroke

Members of the acute stroke care medical teams that we observed at MWHC told us that at times they have unlocked patients’ phones or looked at receipts to determine their last known normal.

Systematic Hospital Inefficiencies In Acute Care Coordination

The workflow of the hospital’s ED and EMS have a profound impact on stroke patient outcomes. Two key workflow periods are the transition from home to hospital through EMS, and the time between when a stroke patient arrives at the ED and when intervention is made (often infusion of tPA). Minimizing the duration of these periods and maximizing the accuracy of relevant patient data are crucial in optimizing patient health outcomes.

► Evidence-based decision making

Stroke protocol varies from hospital to hospital. Inclusion/exclusion criteria for tPA can even vary among hospitals in the same system. In addition, many hospital systems still refer to stroke protocol and NIH Stroke Scale in hardcopy as opposed to digital format. Due to the challenges with regard to protocol universality, physicians new to an ED may experience confusion during the admission of a stroke patient, resulting in a potential decrease in efficiency.

► Workflow

The speedy delivery of a patient by EMS is important in ensuring treatment is delivered quickly. However, miscommunication between EMS and the ED can result in inept care. Communication between EMS and ED entails EMS calling the ED, informing them of an incoming stroke patient, and notifying them of any relevant patient information. Examples of potentially useful information EMS can communicate to the ED are whether or not the patient has a pacemaker, history of stroke or diabetes, or blood glucose levels.

Communication between ED nurses, lab technicians, and radiologists is crucial to ensure the proper equipment and personnel are immediately available to stroke patients.

While the fellows were shadowing in the ED, a stroke patient was delivered to the ED without being called in prior to arrival. In addition, EMS miscommunicated the patient's lab results, taken during transport to the hospital.

► Current solutions

- NIH stroke scale apps exist at a low price (or free), which can be downloaded to a wide variety of smart devices such as Android or iOS based platforms [62].
- Digitalized decision trees, which guide standard care protocol of stroke patients at MWHC.
- Labeling systems that ensure Code 1 lab tests are prioritized.

Challenges In Transitioning To The “New Normal” After Stroke

When navigating the transition from hospital to home, stroke patients face substantial health-related, social, and emotional challenges. With shortening hospital stays and fragmented care coordination, poor transitioning for patients can result in adverse outcomes, slower recovery, poorer quality of care, and readmission.

► The translation of therapy to life

Patients we met noted that things change when they are discharged and wheeled out of the hospital's sliding doors to enter the real world as a stroke survivor. Therapists and social workers help stroke survivors translate the skills learned in therapy to ADL within their home and natural environments. However, as realistic as many of the activities and exercises are, therapy is still limited to the hospital environment, where patients are constantly surrounded and monitored by health professionals. The adjustments and skills learned in therapy become substantially harder when patients are thrown into environments with unpredictable stimuli, completely novel surroundings, and little to no assistance. Moreover, outpatient PT/OT/SLP treatments terminate after a set number of sessions due to coverage and resource constraints. The cutoff that results is rather abrupt, as there is often no one to whom the continued therapy can be transitioned.

Stroke Survivor Experience

"I had practiced going up the stairs so many times at the rehab hospital. I had it down. But the day I was discharged and finally got to go home, I just stood staring at the bottom step of the staircase in my foyer. I couldn't do it. I couldn't make the connection and get up my stairs"

► Accessibility

Difficulties due to disability pose a significant vulnerability and inconvenience for stroke survivors. The inability to ambulate for necessary functions, general mobility issues, and fatigue drastically affect quality of life. While much of therapy focuses on regaining motor control, survivors must also learn how to compensate for their impairments and work to minimize any disabling outcomes in their lives.

Moreover, aphasia, cognitive communication disorders, and impairments in memory, learning, and awareness create challenges in stroke survivors' interactions with those around them. Functioning in a fast-paced world involves receiving and executing communication effectively, which is especially critical for stroke patients who already have layers of physical disabilities. Between managing medications and scheduling appointments, stroke survivors often find it challenging to multi-task due to the cognitive deficits that result from stroke.

Transportation is cited as one of the major accessibility concerns in receiving care, especially for stroke survivors with disabilities [63], who may have outpatient rehab, physician visits, and pharmacy pickups. Since driving is not possible for some stroke patients or must be delayed for others, transportation largely relies on caregivers or public transportation. However, the vehicles for transportation are often inaccessible for patients using wheelchairs, walkers, or other assistive technologies.

Many accessibility issues are a result of the built environment that provide the settings for typical human activities. The gaps in built environment are present in everyday physical surroundings – lack of wheelchair accessible building design, furniture design, or over-intensive sensory stimuli in commercial spaces. Street quality and availability of sidewalks for walking and biking have a significant effect on social and physical activity for recovering stroke survivors [64,65].

► **Current solutions**

- MedStar telerehabilitation (or e-rehabilitation) projects [66].
- Assistive and adaptive technologies such as power-assist wheelchairs, wheelchair carriers, and sit-to-stand equipment.
- Robotic technologies, such as end-effector and exoskeletons systems for limb recovery [67].
- MedStar’s collaboration with Uber that allows patients to receive appointment reminders and estimated trip cost [68].

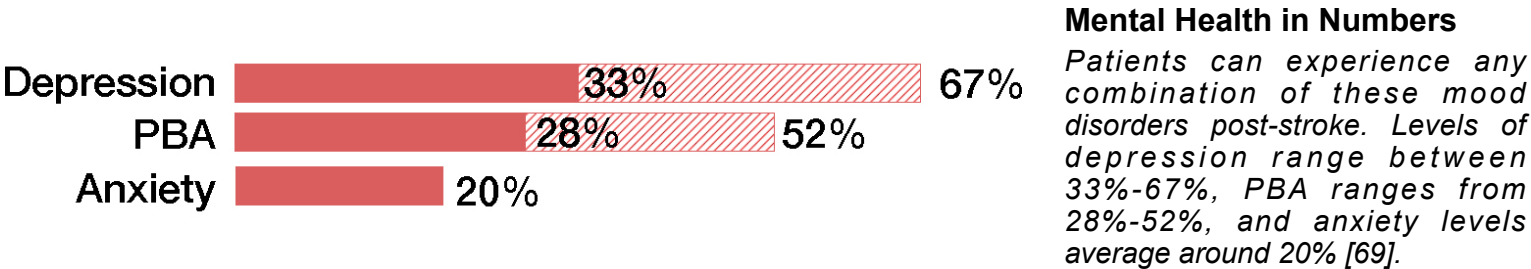
Impact Of Stroke On Psychological Health And Well-being

It’s easy for us to recognize and acknowledge someone’s physical injuries, but it is equally important not to overlook psychological wounds. Stroke affects not only someone’s physical health, but also their mental well-being. Physical and psychological well-being are inextricably linked, especially when it comes to brain injury. Psychological and emotional challenges stand as obstacles on the path to recovery and addressing this dimension of stroke care is crucial for achieving optimal recovery.

► **Mental health issues**

After stroke, a number of psychological shifts take place for patients. First, there may be a general lack of awareness (and sometimes outright denial) whereby patients are unable to immediately recognize the extent of damage incurred from their stroke during the early periods of their recovery. Through stakeholder interviews, we learned that impaired self-awareness is a major stumbling block on the path to recovery.

Over time, as awareness returns and the reality of the situation sets in, emotional well-being is subsequently impacted. Stroke survivors often experience mood disorders such as depression and anxiety. Pseudo-bulbar affect (PBA) is also not uncommon, which leads to changes in personality and emotional lability - a mismatch between feelings and expression [69]. These mood disorders significantly alter the lives of survivors and their families, much like the physical disabilities that result from a stroke.



► **Sustaining motivation during recovery**

Recovering from stroke can be a continuous process that takes weeks, months, and years. Physical, occupational, and speech-language therapies can help survivors reach higher levels of independence and improve the quality of life. Often, it is difficult for patients to sustain motivation during the recovery process since rehab can feel like a heavy burden when added to simply coping day-to-day with post-stroke pain and disability. Depression and anxiety can deter progress in rehab, which further underscores the importance of monitoring and addressing mental health in stroke survivors [70].

► Support networks

Stroke recovery is not an isolated process; it takes place within the context of family, caregivers, and community. As stroke survivors become either temporarily or permanently dependent on their support networks, the care extended by these networks affects the extent of recovery and quality of life for those who have experienced stroke. As we saw from our patient encounters, members of the community step in when families cannot cope alone, and family members and caregivers facilitate the recovery process and transition to a “new normal.”

Support networks are also essential to secondary prevention. Caregivers and family members often are the ones who keep track of medications and follow-up appointments, and encourage lifestyle changes, such as a balanced diet and physical exercise. Motivation and compliance depend heavily on support networks.

► Current solutions

- Neuropsychology counseling to manage mood disorders such as depression, anxiety, and PBA through therapy and medication.
- CaringBridge which provides emotional support through personal journaling.
- Meal Train which allows friends and relatives to order meals for their sick loved ones.
- Local support groups like MedStar’s The Comeback Club that help with the recovery process through peer-led sessions.

Challenges In Implementing Stroke Innovation

Health care abounds with new technology and novel solutions. Stroke care is ripe for innovation, from the acute treatment phase all the way to the rehabilitation phase of the patient care experience. However, new healthcare solutions oftentimes bring challenges, especially during implementation.

► Telestroke and telerehabilitation implementation

One of the challenges in implementing telemedicine solutions is getting buy-in from all stakeholders in the hospital. For instance, during one of our interviews, we were told that just because the technology is present, it doesn’t necessarily mean that the hospitals would have the resources to integrate it into their system. Nor does it mean that physicians would be willing to change their current practices. Software compatibility and reliable internet connectivity are challenges for many hospitals. Additionally, training is usually needed to navigate the software and additional workarounds end up taking place when users adjust the microphones and cameras of the telemedicine equipment to ensure quality audio and video.

Another huge issue is the return on investment. A telestroke cart costs roughly \$12,000 and televisits are oftentimes not reimbursed by insurance companies. Physicians who are salaried may not have the incentive to incorporate telemedicine into their practice, given the aforementioned challenges. Telerehabilitation is another specialty that provides outpatient rehabilitation for stroke survivors. However, limitations also exist around access to the right computer and internet connectivity. Ensuring proper set-up before each session in the patient’s home is another challenge for telerehabilitation. For hospitals that don’t see the payoff and the logistical value, implementing telestroke initiatives might not be sustainable.

► Variation in symptomatology and disability

To the extent that stroke outcomes vary greatly, stroke care innovations must address many patient profiles and needs. This can prove to be challenging as there is no one-size-fits-all solution in stroke care. A patient can be paraplegic and suffer from severe aphasia while another may have slight paresis on the left side of their body and experience short-term memory problems. Symptoms can also look different from patient to patient, which may complicate clinical diagnosis and present technical difficulties to innovators looking into diagnostic tools.

► Innovation for older, poorer populations

Many innovations in the digital healthcare space rely on tablets, smart phones, and computers. Apps are usually downloaded, installed, and updated in order for the software to serve the user. However, the majority of stroke patients are over the age of 65 and many do not have the financial means to sustain extensive data usage on their devices. The elderly population may not be receptive to using digital solutions that require them to navigate the internet and learn new technology. In fact, only 4% of those over 50 years old use smartphones on a daily basis as of 2010 [29]. While there are plenty of opportunities to streamline and improve stroke care with the latest technology, motivating and engaging stroke survivors, given their demographics, may be easier said than done.

► Current solutions

- Companies like Specialists On Call that offer telemedicine services specifically for stroke
- PumpOne which provides physical/occupational therapy services through a mobile platform
- Symptify which features an algorithm that can diagnose many conditions given the user's symptoms
- Care Angel which leverages telephone calls to provide virtual caregiving assistant technology to senior citizens

Market Research

The exploration phase of the HFA fellowship will be followed by ideation. In order for our ideas to be viable business solutions, we must be cognizant of the stroke market from an entrepreneurial standpoint. Stroke is a multi-billion dollar industry that can be categorized into the following markets.

- Primary and secondary prevention market (e.g. anti-hypertensive drugs) - \$66.2 billion in 2015 [71].
- Diagnostics market - \$800 million in 2015 [72].
- Acute ischemic stroke drug market - \$460 million in 2009; expected to reach \$610 million in 2019 [73].
- Assistive devices market - \$12.3 billion in 2012; expected to reach \$19.6 in 2019 [74].
- Physical rehabilitation market - \$30 billion in 2015 [75].

There are several key factors that will contribute to the rising values of these markets. One is the aging population in the United States. Other factors include unchanging lifestyle practices that are associated with obesity, hypertension, and high cholesterol [76]. Moreover, excessive consumption of tobacco and alcohol along with increased stress levels from work and current socioeconomic conditions are likely to drive demand for stroke care according to U.S. market forecasts.

Conclusion

The broad continuum of stroke care continues to be shaped and molded by new technologies and services. Undoubtedly, we are witnessing progress and evolution. Lean design principles are streamlining the process of delivering lifesaving treatment to those experiencing stroke, and novel rehabilitation applications continue to burgeon forth. Yet despite these advances, challenges persist: barriers to successful prevention, lack of recognizing and addressing symptoms in a timely manner, access to care, and transition to a “new normal” post-stroke, among many others.

The greatest gaps in stroke care seem to be primarily in the arena of prevention, especially secondary prevention and the transition from inpatient care back to the new normal of daily living at home. As Health for America fellows, our ultimate goal is to help close these gaps during the upcoming ideation and implementation phases using human-centered design principles, lean startup methodology, and innovative thinking. With this goal in mind, we want to end with the following quote from Dr. Mark Smith, Chief Innovation Officer of MedStar Health: *Question the perception of what’s possible – who says four young people can’t create the next big thing in stroke care?*

Embracing Dr. Smith’s words and the great expectations of what’s ahead, the 2016-2017 Health for America fellows hereby humbly invite you to stay tuned.

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