Reducing the Burden of Stroke in Virginia

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Executive Summary

Stroke is persistently among the most common causes of death in the United States, but the cost of stroke mortality pales in comparison to its morbidity. Stroke survivors are frequently left disabled, which creates enormous personal, familial, and societal level costs. Survivors face high direct medical costs as well as the loss of autonomy and economic output. Family members and caregivers face costs in the form of lost economic opportunity for informal care provided and the emotional toll it takes. The incidence of stroke in Virginia is higher than the national average and faces over a billion dollars in annual costs to society.

To address this burden, I recommend the state of Virginia adopt a targeted hypertension reduction program, modeled off several successful programs piloted elsewhere. Of the alternatives discussed in this paper a hypertension reduction program scored the highest aggregate score based on its effectiveness at reducing the rate of disability from stroke in Virginia, cost-effectiveness, political and implementation feasibility, and equity.

A targeted hypertension reduction program is by far the most effective, cost-effective, and equitable alternative discussed, and ranked highly in political and implementation feasibility. Other alternatives focused on improving stroke treatment in the acute phase or at the systems of care level. These alternatives provide real benefits to stroke patients, but marginal gains in treatment effectiveness simply do not compare with preventing strokes outright.

Implementation of a targeted hypertension reduction program requires extensive collaboration between community members and leaders, healthcare systems, and healthcare providers themselves.

Based on this analysis, adoption of a targeted hypertension reduction program in Virginia has the potential to reduce overall disability from stroke in Virginia by 13.7% over a ten-year period.

Mandatory Disclaimer

The author conducted this study as part of the program of professional education at the Frank Batten School of Leadership and Public Policy, University of Virginia. This paper is submitted in partial fulfillment of the course requirements for the Master of Public Policy degree. The judgments and conclusions are solely those of the author, and are not necessarily endorsed by the Batten School, by the University of Virginia, or by any other agency.

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Finally, I need to thank my wife, Melissa Pitchford. Melissa, I tell anyone that will listen that I am the luckiest man in the world to get to grow old with the person I grew up with. You are the only reason I have made it this far, and likely the only reason I will make it any further. Thank you for being there for me.

To our son Jack Graves, though you cannot read this now I want you to know that whenever I hit a roadblock, it was thoughts of you that pushed me through to finish. I love you, and I delight in your very existence.

Client Overview

The Virginia Stroke Systems Task Force is an organization designed by statute to function as the clearinghouse for stroke care coordination across the continuum of care. The VSSTF is made up of representatives from hospitals, neurology departments, emergency medical services and research enterprises. The Virginia Stroke Systems Task Force (VSSTF) was established after a 2008 study by the Joint Commission on Healthcare (JCHC) recommended creating a permanent task force on improving stroke systems of care in the Commonwealth. The legislature passed SB 344 and HB 479 enshrining the VSSTF in law, requiring that the group implement regional stroke triage plans that accounted for specific geographic areas' available health resources, and develop criteria for triage and transport of stroke patients (Virginia Hospital and Healthcare Association), 2009).

Hospitals are required under VA code § 32.1-111.15:1 to share stroke patient data with the VSSTF for the purposes of establishing continuous quality improvement for the delivery of stroke care (Department Responsible for Stroke Care Quality Improvement; Sharing of Data and Information, 2020). The VSSTF is made up of stakeholders from throughout the state and represent physicians, researchers, nurses, emergency medical services and rehabilitation. The VSSTF meets quarterly and provides the opportunity for interdisciplinary collaboration but does not have enforcement power behind any recommendations given.

Problem Statement and Background

Too many Virginians suffer long term disability from stroke. Stroke is the leading cause of long-term disability in the United States, with direct and indirect costs estimated at $33.9 billion per year. Virginia is situated in the "Stroke Belt", a collection of Southern states with higher rates of stroke than the national average.

Stroke death rates in the United States have declined at least since the 1960's in large part due to improvements in modifiable risk factors and in stroke treatment over time. However, from 2013 onward this rate of decline slowed or reversed (Yang et al., 2017). The reason for this change in stroke incidence is unclear, but it accounts for an estimated 32,593 excess deaths nationally. Virginia experienced similar trends, with age-standardized death rates declining from 84.3 per 100,000 in 2000 to 47 per 100,000 in 2018. Virginia is part of the "stroke-belt", which consists of several states in the Southern Region of the United States where stroke is more prevalent than other regions. Stroke accounts for about one out of every twenty deaths in Virginia. Figures one and two below show the rates of death from stroke in Virginia for those aged 35-64, and those aged 65 and older.

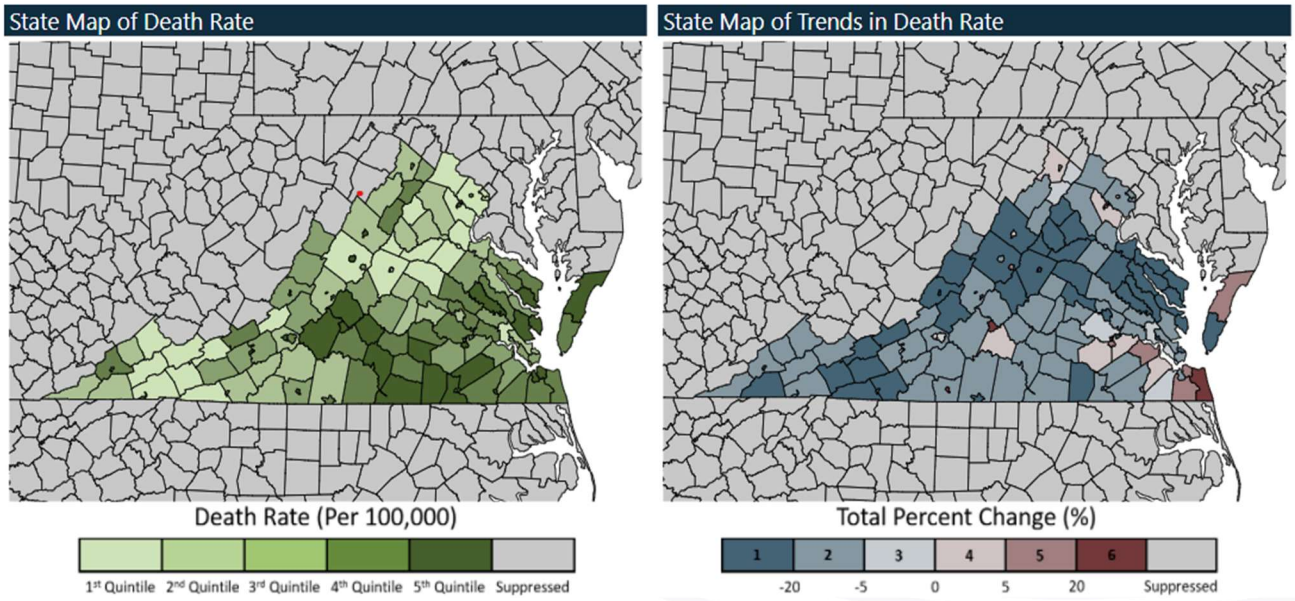

Figure 1. Stroke death rate in Virginia by County for individuals aged 65 and older. Data from 2019 National Center for Chronic Disease Prevention and Health Promotion , Division for Heart Disease and Stroke Prevention

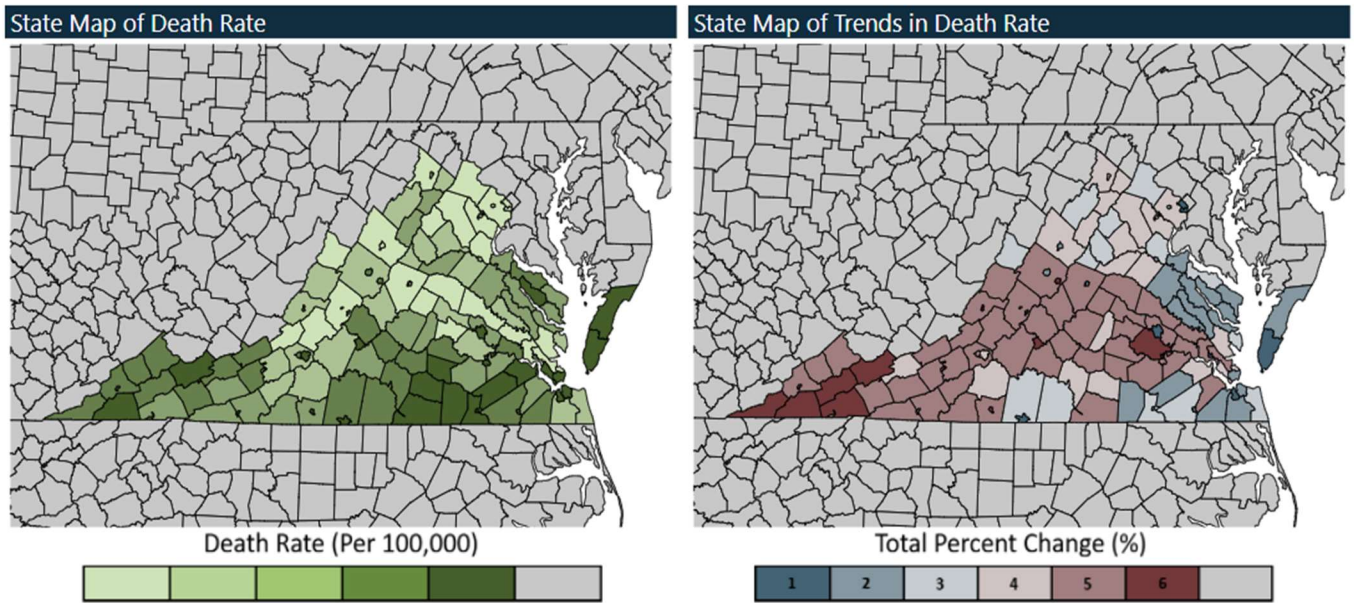

Figure 2. Stroke death rate in Virginia by County for individuals aged 35 - 64. Data from 2019 National Center for Chronic Disease Prevention and Health Promotion , Division for Heart Disease and Stroke Prevention

These data suggest that while mortality rates from stroke are on the decline for individuals aged 65 and older, there is a meaningful *increase* in death rates for those aged 35 to 64. This trend is most visible in southwest and central regions, extending through the interstate 64 corridor to the tidewater region. These trends are consistent with findings that while mortality from stroke declined from the early 2000's, these gains have either stagnated or reversed, especially for younger populations. Figure 3 illustrates data from CDC's Behavioral Risk Factor Surveillance System that indicate this shift is driven by increases in stroke incidence in the 55-64 population range.

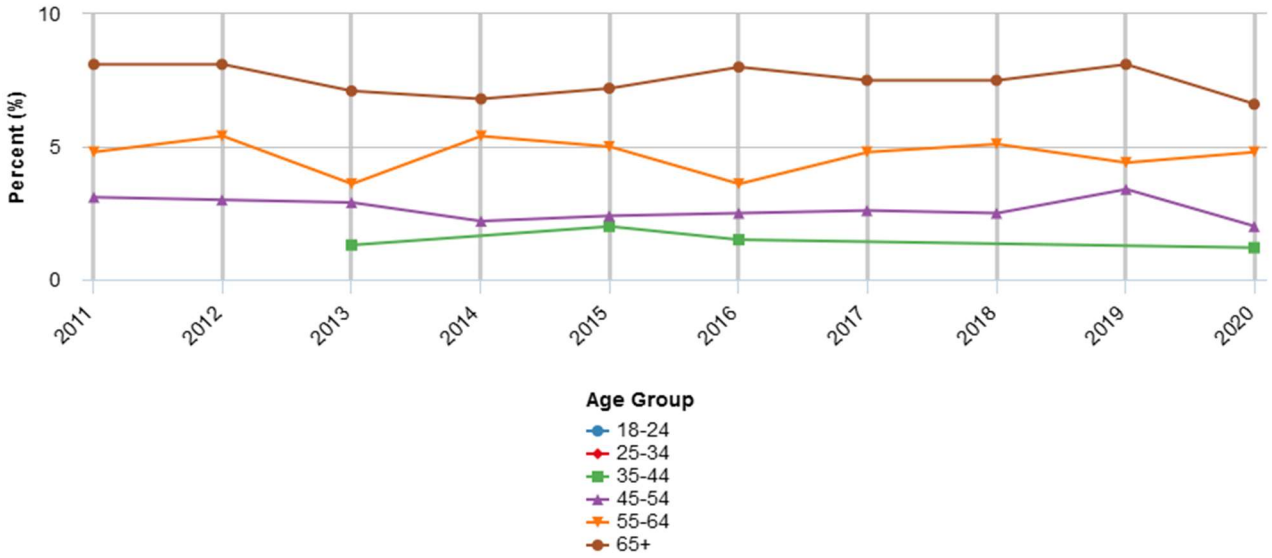

Figure 3. Stroke prevalence in Virginia by age group from 2011 to 2020. Data from CDC Behavioral Risk Factor Surveillance System, Question "Have you ever been told that you had a stroke?"

Costs to Society

The burden of stroke on society manifests in direct costs in the form of medical care and treatment, economic opportunity costs in the form of lost wages, and indirect costs from the burden of informal caregiving done by families and support networks of stroke survivors.

Direct Costs

To estimate the direct costs of stroke I first take the annual rate of stroke incidence and average costs associated with ambulance transfer, emergency department fees, inpatient hospital stays, office-based visits, and prescription medicines. As is the case with all United States healthcare costs, there is substantial variance in the actual cost per patient. A systematic review by Rochmah et al found that the economic burden of stroke ranged from $1809.51 to $325,108.84 per patient (Rochmah et al., 2021). Total economic costs are correlated with the level of disability from the stroke, with patients experiencing full hemiparesis (one sided paralysis) requiring longer, more intensive rehabilitation that is necessarily more expensive. Zorowitz found that these patients often have rehabilitation costs close to 150% of non-paralyzed stroke patients (Zorowitz et al., 2009).

As of 2015, about 26,000 Virginians suffered a stroke that had a previous stroke while 17,000 had a first-time stroke. The Center for Financing at the Agency for Healthcare Research and Quality provides 2018 estimates for the mean expenditure per person for conditions and event type. Patients with cerebrovascular disease pay an average of $1,938 for emergency department care, $11,462 for home health visits, $25,722 for inpatient stays, $1,063 for office-based events and $578 for prescription medications, this includes either inpatient or outpatient rehabilitation costs (*Mean Expenditure per Person with Care by Condition and Event Type, United States, 2018 Medical Expenditure Panel Survey*, 2018). Given that stroke prevalence remained stable in Virginia from 2015 through 2018, I projected an estimated incidence of stroke using population data from the Weldon Cooper Center. I then adjusted mean expenditures using the CPI for medical care from 2018 – 2020 to estimate total direct medical costs. (See Appendix for calculations.)

For consistency's sake to calculate ambulance transfer fees I used the 2018 Medicare Ambulance Fee Schedule. Stroke qualifies under Healthcare Common Procedure Coding System (HCPCS) code A0427, Advanced Life Support, Emergency, Level 1 (*Medicare's Ground Ambulance Data Collection System: Sampling and Instrument Considerations and Recommendations*, 2019). The average reimbursement for this level of care is $516 (*Ambulance Fee Schedule Public Use Files*, 2020). Around 60% of patients with acute stroke present to the hospital via ambulance (Xirasgar et al., 2019).

Total estimated direct costs amount to $98,199,652 in 2018, rising to $102,263,521 in 2019 and then to $107,302,988 in 2020.

Opportunity Costs

To calculate the opportunity costs of stroke I estimate the effect of lost wages for the individual that suffered the stroke as well as the effect on a stroke patient's family experienced because of the informal care they must provide if there is permanent disability.

Girotra et al found that the annual wage for individuals that have suffered a stroke is $19,663 compared to $37,268 for those that have not suffered a stroke. Stroke patients also miss more than twice as many workdays and have an overall employment rate 60% less than their non-stroke counterparts. They go on to estimate the average productivity cost per person which comes to an average of about $27,400 per survivor (Giotra et al., 2020). Using the previous population incidence estimate of 44046 for 2020, this amounts to indirect costs of approximately $1,206,867,823. This is likely an overestimate, but nevertheless highlights the substantial economic costs of stroke.

Opportunity costs from stroke mortality are substantial, owing in part to how younger populations are more likely suffer a hemorrhagic stroke rather than an ischemic stroke. Hemorrhagic strokes are more likely to lead to permanent disability or death. Lee et al estimate that patients under the age of 65 lose approximately 14.1 quality adjusted life years (Lee et al., 2010). The American Heart Association estimates that opportunity costs from stroke mortality account for $19.1 billion (Khan et al., 2021; Virani et al., 2020).

Indirect Costs

The burden on family members that provide informal care to patients disabled by stroke is difficult to quantify, but Joo et al developed estimates from the Health and Retirement Study in 2006 – 2008. They found that the weekly incremental informal caregiving hours attributable to stroke was about 8.5 hours per patient, which equals around $4,356 in economic value per stroke survivor and added up to an estimated $14.2 billion dollars (Joo et al., 2014). Using these figures I estimate the costs of informal caregiving as $191,865,556.

Total Opportunity and Indirect Costs = $1,206,867,823 + $191,865,556 = $ 1,398,733,380.10

Externalities

Ambulances are not designed for fuel or ecological efficiency and create approximately 31.3 kilograms of carbon dioxide per call for service (Sheldon, 2019). The social cost of carbon dioxide is estimated at around $41 per ton of carbon dioxide as endorsed by the National Academy of Sciences (Law), 2017). Using the same estimate of total number of stroke patients transported by ambulance above (26,428) stroke care leads to an additional 827,189 kilograms of carbon dioxide release into the atmosphere. Converting this figure to tons (413.6) and then multiplying by the social cost of carbon totals $16,957.

Pollution Externalities = $16,597

Total Estimated Cost to Society = $16,597 + $1,206,867,823 + $191,865,556 = $1,398,750,337

The Role of Government

National, state, and local governments each play a role in reducing disability from stroke. Medicare, a federally funded and administrated program, provides the majority of reimbursement for acute stroke care. States administer and regulate the actual practice of healthcare within their borders as well as Medicaid, which provides most of the reimbursement for long term care for stroke. Local governments manage emergency response to acute stroke and facilitate community programs through partnerships with state and federal agencies and local hospitals. Below I discuss the three levels of government, focusing on interventions at the state level and describing but freezing the policy environment for local and the federal government.

Federal Government

The federal government's role in reducing disability from stroke centers on programs like Medicare and the funding of research and development projects through the Department of Health and Human Services. Medicare covers approximately 72% of all patients with stroke and approximately 75% of the total stroke cost in the United States (Trogdon et al., 2007). This is because the risk of stroke rises with age at the same time the likelihood of disability free recovery declines. When adjusted for inflation, the rate at which Medicare reimburses for stroke declined by 11% from 2000 to 2019 (Pines et al., 2021).

This is further complicated by younger individuals that qualify for Social Security Disability Insurance (SSDI) left disabled by a stroke that are then unable to return to work. This group qualifies for Medicare coverage after 24 months of documented disability and only qualify for Medicaid if they meet state income requirements. Hannah Caballero, a social worker that specializes in Neurology at the University of Virginia stated that "You better hope you have a spouse who can cover you under their insurance, or they go to the marketplace. The people that fall through the cracks end up using the emergency department more and lack primary care, costing the system additional resources."[1]

The federal government exerts additional influence on stroke care through the regulatory environment. Telestroke services are now commonplace in emergency departments that do not have access to in-house neurological services. Unfortunately, regulation has limited the expansion of telemedicine services with Medicare only reimbursing for consults from certain "originating sites". In the wake of the COVID19 pandemic the federal government relaxed restrictions on telemedicine allowing for experimentation in telemedicine care delivery (*COVID-19 Emergency Declaration Blanket Waivers for Health Care Providers*, 2021). While this relaxed regulatory environment provided opportunity for the expansion of telestroke services, the rate of telestroke consults declined during the COVID19 pandemic (S. O. Shah et al., 2021).

Federal funding for stroke research is done through the Department of Health and Human Services' National Institute of Neurological Disorders and Stroke (NINDS). The 2021-2026 NINDS Strategic Plan identifies several priority areas for stroke research, but mostly focus on clinical interventions, advanced biomarker tracking and promoting a diverse neurological

[1] Personal Communication, 12-5-2021

sciences workforce (*National Institute of Neurological Disorders and Stroke (NINDS) Strategic Plan 2021- 2026 Investing in the Future of Neuroscience*, 2021).

Local Government

Local governments operate and administer emergency and social services that touch each element of the stroke continuum of care.

Community centers designed for aging populations are frequent venues for community education and primary prevention efforts. Since the primary audience for stroke community education efforts are older, less likely to be employed, and more likely to face mobility issues, these community centers provide a high yield for outreach. These centers also provide the opportunity to partner with local health systems to provide primary medical prevention services like blood pressure management (Siegler et al., 2015). The employees at these centers are highly connected within their communities can serve as champions or liaisons for local implementation of broader efforts.

Public schools serve as another high yield venue for community education and outreach efforts. While students are not at high risk of stroke themselves, disseminating information on the signs and symptoms of stroke would increase the likelihood of the student quickly identifying that their family member was suffering from one (Son et al., 2017). Printed materials given to students could then be given to their family members accomplishing the same goal.

Local governments are also the primary administrators of emergency medical services. Emergency medical services in the United States are known internationally as disparate and heterogenous in both staffing model and quality of services provided (M. N. Shah, 2006). As many as a third of Americans are served by EMS services that utilize a volunteer staffing model rather than a paid or professional model. These areas are also more likely to be rural and have higher rates of poverty. Paid departments vary from dedicated EMS services, hospital-based services, fire department 'combined systems' or third service contract providers. Regardless of the end service provider, local governments must enter into formal agreements with the emergency services agency.

State Government

State governments play a key regulatory role in reducing disability from stroke. States maintain regulatory oversight of clinician scope of practice and licensing, including for emergency services personnel. For emergency services personnel states are the primary authority for clinical and operational protocols regarding stroke identification and triage. States also administer Medicaid and other programs like "stroke systems of care" that are designed to improve coordination across the continuum of care. Many states sponsor clinics in areas of low healthcare resources and/or high rates of poverty.

Stroke Care in Virginia

At the state level, stroke care in Virginia is governed under both legislative and executive branch policy. While each level of government plays an integral part in stroke care, here I focus on the state level while freezing other levels of government. The Virginia Stroke Systems Task Force (VSSTF) was established after a 2008 study by the Joint Commission on Healthcare (JCHC) recommended creating a permanent task force on improving stroke systems of care in the Commonwealth. The legislature passed SB 344 and HB 479 enshrining the VSSTF in law, requiring that the group implement regional stroke triage plans that accounted for specific geographic areas' available health resources, and develop criteria for triage and transport of stroke patients (Virginia Hospital and Healthcare Association), 2009). Hospitals are required under VA code § 32.1-111.15:1 are required to share stroke patient data with the VSSTF for the purposes of establishing continuous quality improvement for the delivery of stroke care (Department Responsible for Stroke Care Quality Improvement; Sharing of Data and Information, 2020). The VSSTF is made up of stakeholders from throughout the state and represent physicians, researchers, nurses, emergency medical services and rehabilitation. The VSSTF meets quarterly and provides the opportunity for interdisciplinary collaboration but does not have enforcement power behind any recommendations given.

Prehospital care in Virginia is governed by regional "councils" regulated under Virginia Administrative code 12VAC5-31-2330. While individual EMS agencies operate with substantial autonomy with specific treatment protocols varying across departments, EMS councils provide a clearinghouse for training, quality improvement and state accountability. EMS councils publish regional treatment protocols that to encourage departmental interoperability, but individual EMS agencies are under no obligation to follow them.

What is a Stroke?

Fundamentally, a stroke is the interruption of blood flow to the brain causing progressive tissue injury. There are two primary types of strokes, hemorrhagic and ischemic. Hemorrhagic strokes are caused by ruptured blood vessels in the brain and account for 10% of all strokes but are typically more severe than ischemic strokes which are caused by clots that block blood circulation in the brain. Compared with ischemic strokes, hemorrhagic strokes are about 1.5 times more likely to cause death or permanent disability (Andersen et al., 2009).

The causes of stroke are multifactorial and are made up of modifiable and non-modifiable risk factors that are shared between both hemorrhagic and ischemic subtypes. Modifiable risk factors include hypertension and diabetes that lead to long term damage to the blood vessels that perfuse the brain. Genetics are a non-modifiable risk factor and play an important if currently ill-defined role in stroke risk. Comparatively few strokes are attributable to monogenic conditions, with the vast majority stemming from multifactorial environmental and genetic influences (Traylor et al., 2012).

An important risk factor for ischemic stroke are cardiac arrhythmias such as atrial fibrillation. Atrial fibrillation is characterized by an irregularly irregular heartbeat caused by the

top two chambers of the heart beating chaotically (fibrillating), leading to the development of blood clots that transit directly from the heart into the brain. This "embolic" subtype presents both the most catastrophic of and most amenable to treatment ischemic stroke (Joundi et al., 2016).

Existing Evidence, State of Practice

The primary goal of stroke management is revascularization and limitation of secondary brain injury. It is estimated that for every minute delay to cerebral revascularization the patient loses 1.9 million neurons (Saver, 2006). This is accomplished through one of two treatments, intravenous tissue plasminogen activator (t-PA) and endovascular or 'clot retrieval' therapy. Functionally speaking, for every fifteen minute decrease in time to endovascular therapy a patient's odds of discharge home increase by 2.13% and their odds of in-hospital mortality or hospice discharge decreases by 1.48% (Jahan et al., 2019). Other studies have found similar results, with one finding that for every five minute delay in reperfusion one out of 100 patients has a worse disability outcome (Sheth et al., 2015).

Importance of Access to Reperfusion Therapy

The vast majority of patients that are eligible for reperfusion therapy do not receive it due to delay in presentation to hospitals (Herpich & Rincon, 2020). One estimate found a possible two to five fold increase in reperfusion eligible patients that do not receive therapy because of prehospital and interhospital systems of care (Rai et al., 2016). Major factors affecting treatment delays include emergency medical pathways, stroke symptomatology, patient and bystander behavior, patient health characteristics and stroke treatment awareness (Pulvers & Watson, 2017). Hospital specific factors likely play a role as well, with reperfusion therapy rates ranging from 5.7% to 21.7% depending on individual facility factors (Jahan et al., 2019).

Public Awareness and Education

Efforts to prevent stroke show promise but may be limited by time and effort available. There is mixed evidence on the effectiveness of community education programs. Community education efforts on stroke signs, symptoms and risk factors tend to improve stroke in an area, but effects are limited to the duration of any public awareness campaign (M et al., 2014). Other studies found no meaningful benefit in stroke related outcomes (R et al., 2011). A systematic review assessing the effectiveness of interventions for increasing stroke awareness in ethnic minorities found inconclusive results (Gardois et al., 2014). This data is commensurate with data from public outreach efforts by the American Heart Association related to ischemic heart disease that showed improvement in outcomes that were limited by healthcare systems' ability to provide emergent intervention (Rai et al., 2016).

Outcome Measure

With these details in mind, my primary outcome measure will be the estimated number of people left with significant disability following a stroke. The standard measure for post-stroke disability is the modified Rankin scale (mRS), where a patient is given a value ranging from 0 (no symptoms) to 6 (deceased) (Broderick et al., 2017). An mRS of 3 or greater represents moderate to severe disability. A discharge mRS assessment is standard practice for stroke patients and a frequent endpoint in stroke quality measures and research.

The Evidence on Policy Alternatives

Several models exist to reduce the burden of disability from stroke. In this section I discuss the role of stroke education, primary and secondary prevention strategies, coordinated stroke systems of care, and emergent treatment options.

Patient, Provider and Community Education

The effectiveness of patient and community education rests on two causal assumptions, that identifying unmet needs will lead to their amelioration and that provision of information will lead to behavior change and self-management. Mellon et al performed the most comprehensive review of public education campaigns on reducing delays to treatment for stroke patients (Mellon et al., 2015). The authors evaluated fifteen published studies, one randomized control trial, two time series analyses, three controlled before and after studies, five uncontrolled before and after studies, two retrospective observational studies, and two prospective observational studies. Given the heterogenous nature of the relevant publications, a systematic review was methodologically impossible. While most individual studies reported some form of positive effect, the reporting of specific intervention strategies were sufficiently vague that distinguishing causal elements remained impossible. Additionally, the authors found that while multimedia campaigns have demonstrated efficacy in increasing stroke knowledge and awareness, and the intention to treat stroke as an emergency. However, bridging the gap between intention and action remains unsolved. The review found that the intervention that evidenced the largest behavioral change was developed from focus groups with stroke survivors in order to identify themes and issues that contribute to delay (Morgenstern et al., 2002).

Morgenstern et al used a two phase, multilevel community intervention. The first phase involved data collection to establish baseline need in the target communities. The community process relied on information from focus groups with stroke patients and caregivers to identify issues contributing to delay times for hospital presentation. The data collected from this phase implied that simply providing knowledge of stroke symptoms and asking patients to call 911 were unlikely to be effective (Morgenstern et al., 2002). Instead, targeting outcome expectations, stroke recognition skills and self-efficacy, and perceived community norms and removing community-specific barriers were critical. These results emphasize the need to not just proffer information and instructions, but to empower self-efficacy and hope of a positive outcome.

Interestingly, the professional component of Mogenstern et al's intervention likely had the largest impact. From phase I to phase II of their study, treatment with tPA of eligible patients rose from 14% to 52%.

The results of the study demonstrate the failure of the public education side of the intervention since delay time reductions in the intervention community did not exceed those in the comparison community. However, this result must be interpreted with caution because the community and professional education components were inextricably linked. Community members were encouraged to request that EMS providers radio ahead to the receiving stroke center and request treatment with tPA upon arrival at the hospital. Isolating the effect of any one part of this effort is extremely difficult, but the authors posit that there were diffusion effects in

the professional community that drove process improvements and buy-in. Disentangling the relative effects between community and professional education is therefore impossible under this study design, but the takeaway lesson that education and outreach efforts should include both patients and professionals stands.

Like stroke, myocardial infarction is a time sensitive medical emergency that requires rapid identification and treatment to maximize the likelihood of a positive outcome. Efforts to reduce the burden of acute ischemic heart disease have long included public education campaigns. A large randomized control trial aiming to reduce prehospital delay in acute coronary syndrome (n=5,322) found that a one-to-one educational and counseling intervention with patients that had documented heart disease did not change prehospital delay times, but the experimental group was more likely to call emergency services and self-administer aspirin (Moser et al., 2006). Figure 4 below describes the characteristics associated with delays in seeking treatment by patients with stroke as described and adapted from Moser et al.

Factor	Effect on Delay in Acute Ischemic Stroke
Sociodemographic characteristics	
Older age	No difference
Female sex	No difference
Lower educational level	No difference
Black or Latino race	Increase
Low socioeconomic status	Increase or no difference
Clinical characteristics	
Prior myocardial infarction	No difference
Diabetes	No difference
Hypertension	No difference
Heart failure	No difference
History of atrial fibrillation	No difference
Smoking	No difference
Hyperlipidemia	No difference
Prior stroke or transient ischemic attack	Decrease
Social	
Living alone or being alone at symptom onset	Increase
Consultation with physician	Increase
Consultation with a family member versus a nonrelative	Increase
Consultation with a nonrelative	Increase
Cognitive and emotional	
Knowledge of symptoms or risk factors	No difference
Appraisal of symptoms as not being serious or urgent	Increase
Self-treatment	Increase

Table 1: Moser et al's findings on factors that contribute to delays in seeking care for acute ischemic stroke.

Primary Prevention

Primary prevention programs focus on provider and patient education on modifiable and non-modifiable risk factors. For instance, cigarette smoking, diet and exercise are considered modifiable risk factors while genetic predisposition is a non-modifiable risk factor.

Narrowly targeted programs were judged as successful more often than broad-based programs. Examples of successful programs include the Choose to Move program which targeted American women aged twenty five or older on prevention with individual follow-up (Iverson, 2012). The program was executed by a consortium of organizations led by the American Heart Association. Conversely, the Talk With Your Pharmacist program had individual pharmacists identify patients at high-risk of stroke and then provided them prevention measures tailored to their risks before following up with the patients and their primary care physicians (Eppert, 2011). Marvanova and Henkel found that after the implementation of a pharmacist led community education program, participants were able to recall and name significantly more primary and secondary risk factors than preintervention (Maranova & Henkel, 2019). These studies show that it is feasible to implement patient education programs with appropriate stakeholder buy-in, and that there are at least short-term informational benefits conveyed to participants. Unfortunately, there is little evidence that the effect of these programs persists in the long term or translate into meaningful clinical benefit.

Seventy-five percent of stroke patients have hypertension. Diener and Hankey found in 2020 that for every 10mmHg increase in systolic blood pressure reduces the relative risk of stroke by 41% (95% CI: 33% to 48%) compared to normotensive patients and an absolute risk reduction of 0.09% (Diener & Hankey, 2020). In a meta-analysis of 147 randomized trials, Law, Morris, and Wald found that for every 10-mmHg reduction in systolic blood pressure, the risk of stroke declined by 36%. Community interventions that have shown 10mmHg reductions in systolic blood pressure include the barbershop model, and the pharmacist led model (Arnett et al., 2019; Diener & Hankey, 2020; Howard et al., 2016; Victor et al., 2018).

Determining the value of primary prevention programs for stroke and cardiovascular disease presents methodological challenges. Assessing the value of prevention in healthy patients is generally more difficult than evaluating therapy for established disease. Most prominent risk factors for stroke, like hypertension and hyperlipidemia, do not present immediate consequences for the individual, but increase relative risk in the long term. Nevertheless approximately 75% of persons who have a stroke also have hypertension, making hypertension the most potent modifiable risk factor for stroke (George et al., 2017). This creates a time horizon problem where the benefits of primary prevention may take decades to manifest themselves in younger patients (Arnett et al., 2019). Nevertheless, cost-effectiveness analyses of hypertension and statin medications, particularly low-cost formulations, provide substantial population benefit. Richman et al found that lifetime costs associated with intensive management of hypertension provided a benefit of 10.5 quality adjusted life (QALY) years at a cost of approximately $23,777 per QALY gained assuming a standard willingness to pay threshold of $50,000 (Richman et al., 2016).

Patient education programs targeting populations that would benefit from an antithrombotic or anticoagulant agent have been successful (Man-Son-Hing et al., 1999). These programs are targeted toward patients with risk factors that are *likely to cause concern among the patients themselves* such as an irregular heartbeat or previous history of stroke.

Secondary Prevention

The National Health Service (NHS) in the United Kingdom offers a "six-month review" secondary prevention program. The program schedules an appointment at the time of discharge from hospital following a stroke diagnosis. The idea being that after six months the patient will have adapted to their new level of functioning and can coordinate further interventions with their care team to reduce the impact of existing disability and prevent further functional decline. A cluster-randomized control trial performed by Forster et al found no statistically significant benefit in either clinical or cost-effectiveness outcomes compared to the previous standard of care using the General Health Questionnaires-12 mean test scores (Forster et al., 2015). (95% confidence interval, -1.8 to 0.7, P=0.394) Costs of stroke care, total health and social care costs, and quality-adjusted life year gains at six and twelve months were similar between groups.

Implementation of Primary and Secondary Prevention Campaigns

Implementation of patient and community education programs pose substantial barriers. The only comprehensive audit of the NHS Six Month Review found that the review was only performed in about a third of clinical commissioning groups (Walker et al., 2014). Given that the NHS is more centralized than the United States healthcare system, results are likely to be even more variable. Abrahmson and Wilson utilized a multiple case study design across three sites in England to argue that the six month review program failed to provide significant benefit because even if patients and providers were able to identify unmet needs, access to the resources needed to address those needs remained elusive (Abrahmson & Wilson, 2019).

"It's a long time to wait before they came round, I wanted to get moving because the physio was so good in hospital … but then when you come home there's nothing … I wanted to just get going and build on what I was doing in the hospital." (Site 3, female, 79 yrs., interview)

"We had originally been promised [community therapy] twice a week and it was only once a week and then we had to complain and eventually they said, 'Oh right, okay, we'll do twice a week'." (Site 2, male, 63 yrs., interview)

Much of the evidence on education and prevention programs come in the form of individual program assessments and reports. Systematic reviews of such programs are helpful, but are still limited by heterogeneity in program design, study population and geographic/cultural circumstances. Nevertheless, of the data available public and provider education programs seem to improve stroke disability outcomes if they are targeted, backed by substantial professional buy-in, and can offer resources to patients rather than simply identifying the need for them.

Primary and Secondary Prevention Campaign Implementation in Virginia

Implementing an effective primary or secondary prevention campaign in Virginia will require cooperation between several stakeholders, but the state has regulatory authority to do so. Virginia's Chronic Disease Prevention and Health Promotion Collaborative acts as a coordinating authority for public health prevention efforts. The department publishes a "Shared Agenda" designed to set the agenda for strategies, key indicators, baselines, and targets for prevention efforts (*Shared Agenda for the Chronic Disease Preventive Collaborative Network*, 2016). This report is compiled for each Executive administration, meaning that the window of opportunity to incorporate stroke prevention efforts is limited. Coordinating efforts with the Chronic Disease Collaborative Effort provides the most straightforward route for Virginia to promote a campaign on stroke prevention.

Stroke Systems of Care

Stroke systems of care aim to reduce barriers to effective and efficient care through stakeholder cooperation and engagement. The stroke system of care paradigm attempts to integrate eight different domains of stroke care, underpinned by continuous quality improvement (Adeoye et al., 2019). Figure 4 shows the American Heart Association's eight domains of a stroke system of care.

Figure 4, Elements of a Stroke System of Care

The literature on stroke systems of care is promising. Ganesh et al performed a retrospective analysis of integrated systems of stroke care in Canada, finding a reduction in crude 30-day mortality from 15.8% in fiscal year 2003/2004 to 12.7% in FY 2013/2014 for provinces with integrated systems of stroke care compared to a steady rate of 14.5% for those that did not with an adjusted incidence rate ratio (aIRR) of 0.86 (CI:0.79-0.92) (Ganesh et al., 2016). While mortality and disability are separate outcomes, a reduction in mortality is a promising indicator for reduced morbidity.

Stroke systems of care are not created equally, however. While most states have codified stroke systems of care through regulation or legislation, performance is inequitable (Hammond-Heaton & Lucian, 2016). This implies that ineffective implementation of stroke systems of care are an independent factor for poor outcomes. Song et al found that Medicare patients at hospitals in the United States that implement the AHA's Get with the Guidelines (GWTG) approach to stroke systems of care was associated with improved functional outcomes at discharge and reduced post discharge mortality compared to Medicare beneficiaries from hospitals that took part in a secular stroke system of care. The authors used a matched cohort and a difference in differences design to calculate hazard ratios, finding Medicare patients were discharged with 1% less functional disability from GWTG participating hospitals during early and sustained implementation (HR: 1.06 95%CI 1.00-1.12 P= 0.06), with mortality declining by 4.5% (HR

0.92, 95% CI 0.88-0.97, P=0.0005) (Song et al., 2016). These results reflect sound methodology and provide a framework for evaluating stroke systems of care, but the fact that the lower bound of the confidence interval for disability touches one emphasizes the need for additional research.

The benefit of stroke systems of care stems from the critical appraisal of each component of stroke care. Inefficiencies in stroke systems of care stem from everything from the availability of resources, geography and weather (Herpich & Rincon, 2020; Pulvers & Watson, 2017; Rai et al., 2016; Sheth et al., 2015). Hospitals participating in the AHA's GWTG program submit clinical output and outcome measures to an observational registry.[2]

The cost of implementing stroke systems of care is variable and data are limited by study methodology and reporting. The CDC sponsored Paul Coverdell National Acute Stroke Program (PCNASP) provides funding for state health departments to collect, measure, and track data to improve the quality of stroke care.[3] Estimates derived from program funded expenditures estimate that state health departments hire on average 2.5 full time equivalent employees when developing a state stroke system of care, with variation based on the number and resources of partner agencies. PCNASP funded expenditures during the funding period ranged from $790,123 to $1,298,160 (Yarnoff et al., 2019). Unfortunately, this data paint an incomplete picture, as it was collected as a convenience sample from participating health departments.

Maintaining a Deregulated Telemedicine Environment

Technologies that augment patient assessment such as telemedicine or artificial intelligence serve to enhance or improve stroke systems of care and the delivery of reperfusion therapy. Telestroke technologies are generally cost-effective, with the greatest benefit for patients that reside in remote areas. Historically, the expansion of telemedicine was hindered by a hostile regulatory environment that imposed strict guidelines on how, when and in what contexts telemedicine could be reimbursed. In response to the COVID19 pandemic, however, governments granted emergency exceptions to telemedicine regulations. Virginia was no exception, with Governor Ralph Northam signing Executive Order 57 which relaxes the rules healthcare providers must follow in regards to licensing and information security (Northam, 2020). Below I discuss current use cases for telemedicine in stroke before concluding with a recommendation for Virginia to maintain the deregulated telemedicine environment current in place due to the COVID19 pandemic.

Nelson et al found an incremental cost-effectiveness ratio of $108,363 per quality adjusted life year for patients presenting with stroke to hospitals without neurological services in-house but with access to telestroke compared to those that did not (Nelson et al., 2011). This study is helpful both for illustrating the promise of new technologies and providing a framework for using disability to calculate cost-effectiveness.

[2] See: https://www.clinicaltrials.gov/ct2/show/NCT02693223
[3] See https://www.cdc.gov/dhdsp/docs/PCNASP_one-pager_2020.pdf for one CDC one pager.

Several pilot programs expanding telestroke outside of the emergency department setting into the prehospital or outpatient settings are underway. While many of these programs met feasibility measures, their widespread adoption remains constrained by technology, regulation and funding (Pitchford et al., 2019).

Technology and Innovation

Research on stroke interventions is accelerating as effective treatments and modalities to select patients that will benefit from them expand. In this section I will review the historical and contemporary advancements in stroke treatment, as well as expected near-future innovations.

Several treatments for acute stroke can reduce disability but are necessarily time sensitive. Reperfusion therapy for ischemic stroke requires that enough brain tissue be salvageable, and the extent of injury be such that therapy not cause cerebral hemorrhage. The landmark NINDS trial that compared Tissue Plasminogen Activator (tPA) to placebo for patients with ischemic stroke with an onset of less than three hours found the tPA group had a 30% higher chance of a disability free outcome (GROUP, 1995). Later research found that some patients could safely receive and benefit from tPA up to four and a half hours after symptom onset (Peña et al., 2017). Efforts looking at further expanding the window for treatment using advanced imaging or new thrombolytic agents are ongoing, such at the Tenecteplase in Stroke Patients Between 4.5 and 24 Hours (TIMELESS) study (Genentech, 2018).

Since 2015 mechanical thrombectomy has become the standard of care for patients with "large vessel occlusion" strokes (Nannoni et al., 2019). The DAWN trial led by Nogueira et al used a prospective multi-center randomized approach for patients presenting to United States stroke centers between six and twenty four hours of symptom onset (Nogueira et al., 2018). Patients assigned to the thrombectomy group had improved functional outcome scores by an adjusted difference of 33 percentage points (95% credible interval. 24%-44%, posterior probability of superiority, >0.999). The innovation here is not the thrombectomy procedure itself, but rather the development of imaging technology capable of measuring salvageable brain tissue called CT-Perfusion (Konstas et al., 2009). While the time limit to deliver reperfusion therapy is expanding, any delays in identification are still associated with significantly more disability (Rai et al., 2016).

Mobile stroke units are an attempt to effectively "bring the hospital to the patient" using large ambulances outfitted with computed tomography to directly respond patients and provide advanced imaging and treatment earlier in the disease process. The data on mobile stroke units are mixed, but a recent systematic review found that patients treated by mobile stroke units had shorter mean time-to-treatment windows (62 minutes vs 75 minutes; P=0.03) (Fatima et al., 2020). The review went on to find that patients treated with mobile stroke units had 1.46-folds higher likelihood of better clinical outcome than those in hospital (odds ratio: 1.46, 95% CI: 1.306 – 2.03, P=0.02). There was no significant difference in mortality (odds ratio 0.98, 95% CI: 0.81-2.32, P=0.8). Mobile stroke units seem to reliably reduce the time to treatment for stroke patients, but their cost-effectiveness remains questionable (Southerland & Brandler, 2017). A single mobile stroke unit costs about $1,000,000 to build and $500,000 to staff annually. In a

modeling study by Reimer et al mobile stroke units are cost-preferable to standard of care when they treat >391 patients a year, basing this assessment on the estimated number of interhospital transfers (by air and ground) and emergency department encounters avoided (Reimer et al., 2020). This analysis helps to identify areas where an MSU may be feasible but is a limited modeling study and not a comprehensive cost-effectiveness analysis.

Alternative One: Reform the VSSTF into a comprehensive stroke system of care, with a statewide registry.

This alternative would reform and further empower the VSSTF into a comprehensive stroke system of care. This alternative aims to fill information gaps between the different elements of the stroke continuum of care. In its current form the VSSTF offers a collaborative environment for stroke care experts, but that expertise is not necessarily or automatically shared outside of it. Developing stroke systems of care provide the most benefit for healthcare organizations like emergency medicals services agencies and smaller hospitals, with access to outcomes data, education and expertise that would be otherwise unavailable.

For example, emergency medical services are frequently the first point of medical contact for stroke patients, providing assessment, stabilization, and triage determinations. Prehospital personnel use abbreviated stroke assessments or "stroke scales". External validation of these prehospital stroke scales indicates that with typical use EMS providers will still miss approximately 20% of true strokes (Xirasgar et al., 2019). Contributing factors include provider training and education heterogeneity, and the relatively low volume of strokes that EMS providers encounter compared to the wide array of possible presentations (Pulvers & Watson, 2017). Complicating matters, most EMS agencies operate in parallel to the health systems they serve, with information sharing extremely variable throughout the state. Regional EMS councils and hospital EMS liaisons attempt to fill this gap but needs remain. The result of this fragmented information sharing system is that prehospital clinicians are simultaneously responsible for time-critical decisions for stroke patients, but receive inconsistent feedback and patient follow-up, hobbling quality improvement efforts.

During the 2008 Virginia General Assembly, § 32.1-111.3, the Statewide Emergency Medical Care System, was amended to add "as a component of the Emergency Medical Services Plan a statewide Prehospital and Interhospital Stroke Triage Plan designed to promote rapid access for stroke patients to appropriate, organized stroke care through the publication and regular updating of information on resources for stroke care and generally accepted criteria for stroke triage and appropriate transfer". VA Code § 32.1-111.15:1. Department Responsible for Stroke Care Quality Improvement; Sharing of Data and Information states that VDH shall make information contained in the state stroke system of care available to the VSSTF, but only provides this information to emergency medical services agencies, regional emergency medical services councils and the state emergency medical services advisory board "on request".

The VSSTF is in a unique position to help bridge the gaps in communication between the links in the stroke continuum of care. The VSSTF could provide data to individual EMS agencies and regional stakeholders on the outcomes from stroke patients in their catchment area that may not be available otherwise. Providing access to this information will empower smaller healthcare service providers to identify and improve the stroke care they provide while connecting them to expert advice from VSSTF members.

Amending the statutory framework governing the VSSTF to provide it with additional authority would leverage the existing expertise present in the community while streamlining

stroke care across the Commonwealth. To do this VA code § 32.1-111.15:1 should be amended to expand beyond data sharing with the VSSTF to include the authority to determine and implement stroke standards of care. Under the existing statute healthcare facilities are obligated to share outcome and treatment data with the VSSTF, but after that data is shared there is no obligation to follow recommendations. The amended statute should include language granting authority for the VSSTF to produce data driven guidelines for state operated or funded healthcare programs as well as funding for at least 1 FTE for a program manager role. While this change would not completely impact hospital facilities, it would effectively allow the VSSTF to standardize all prehospital stroke assessments.

Alternative Two: Mobile Stroke Units

Several models exist that aim to reduce delays in stroke onset to reperfusion therapy by bringing treatment directly to the patient. Notable examples include mobile stroke unit ambulances equipped with advanced imaging and staffed by clinicians experienced in stroke care. These models contend with some of the disadvantages of telestroke networks in that they obviate the need for transferring a patient between facilities and can initiate treatment earlier. In the endovascular era there is increasing interest in implementing mobile teams staffed with interventional staff. In this model patients presenting with stroke like symptoms would have a mobile stroke unit dispatched capable of advanced imaging and initiation of reperfusion treatment at the site of first medical contact. In theory, this model would reduce delays in treatment associated with field transport and transfers between spoke and hub hospitals.

Mobile advanced intervention teams in the United States utilize a transportation-based model rather than a treatment in place model. This is reflected in the way that mobile intervention teams bill for their services, which requires that a patient be transported to qualify for reimbursement (Centers for Medicare and Medicaid Services, 2020). In Virginia, mobile critical care resources typically consist of a nurse and paramedic with advanced training and expanded scope of practice. These teams can be augmented depending on the mission with respiratory therapists, perfusionists, or physician members, but these compositions are the exception and generally constituted under ad hoc circumstances (12VAC5-31-1260. Supplemented Transport Requirements., 2012). Pilot MSU programs use similar staffing models, typically with the addition of a CT technologist (*Mobile Stroke Unit*, n.d.). Under this alternative, the mobile aspect of the intervention team is about brining advanced care to the patient, rather than bringing the patient to further definitive care with advanced clinical support en route.

The VSSTF is in a unique position to coordinate a regional intervention team pilot project. This alternative aims to leverage connections within the VSSTF to develop a pilot project for a regional mobile stroke unit.

Alternative Three: Targeted Hypertension Reduction Program

Stroke outcomes and incidence in Virginia are highly regional, and public education and outreach efforts must prominently include local considerations to be effective beyond the short term. As such the VSSTF members are uniquely suited to identify areas of greater need as well as champions that can provide local context. This alternative would make as part of the VSSTF's core mission to elicit feedback from members and stakeholders on unmet community education and outreach needs.

Risk behaviors frequently targeted for policy interventions to reduce the risk of stroke at the community level include diet, sedentary lifestyle, tobacco use, hyperlipidemia and hypertension, and delayed recognition of symptomatic disease (Pearson, 2011). Specifically, screening for hypertension and hyperlipidemia are among the more cost-effective preventive interventions according to the US Preventive Services Task Force. [4]

The VSSTF should develop a communication strategy and plan based on identified areas of highest need. These areas are most likely to be in the southwest corner of the state, where outcomes from cerebrovascular disease and the burden of hypertension is highest. The communication strategy requires a clear articulation of audience, clarity of message and choice of platform ("Making the Case for Stroke Communication," 2005). Essential, too, is an ongoing feedback relationship between stakeholders.

[4] https://www.annfammed.org/content/annalsfm/15/1/14.full.pdf

Criteria

Each policy option will be evaluated in terms of cost effectiveness (50%), t*he ability to* implement (20%), p*olitical feasibility* (15%)*, and Equity* (15%).

Cost-Effectiveness Analysis

To assess effectiveness, I first estimated the annual number of strokes for the base period of 2022 using 2015 population data from VDH. Given that the incidence of stroke remained stable as a proportion of population during that time, I then projected an estimated number of strokes for the 2022 – 2032 period using population projections from the Weldon Cooper Center. Taken together, I estimated an incidence of 44,525 strokes in 2022, rising to 48,348 by 2032. Once I established the total incidence of stroke, I stratified my projection by modified Rankin score using data from a large registry study by Olavarria et al., completing my base case outcome projection (Olavarría et al., 2017). I placed full outcome projections and tables in the appendix of this document.

To project the costs associated with each outcome projection I used data from Fattore et al, Baeten et al., and Hayes et al., to estimate the direct medical costs for each level of the modified Rankin scale. These three studies each used similar methodology, albeit in different regions. I normalized each rate before averaging them and converting them to 2022 dollars using historical currency exchange and inflation rates. I then created cost projections based on these estimates using the Federal Reserve's estimated rate of inflation for the 2022 through 2032 period. Figure 5 details the averaged and adjusted cost estimates by modified Rankin score, and full base case cost projections are in the appendix.

Average Cost by mRS	mRS 0	mRS 1	mRS 2	mRS 3	mRS 4	mRS 5
Fattore, 2012	$2,146.00	$2,146.00	$2,146.00	$5,722.00	$14,615.00	$14,615.00
Baeten, 2010	$2,014.00	$2,014.00	$4,798.00	$4,798.00	$20,380.00	$25,744.00
Hayes, 2008	$16,034.00	$13,598.00	$13,720.00	$24,983.00	$33,326.00	$30,805.00
Average and Conversion	$8,172.92	$7,187.02	$8,363.13	$14,368.77	$27,650.88	$28,801.49
Convert to 2022 $	$8,388.21	$7,376.34	$8,583.44	$14,747.29	$28,379.28	$29,560.21

Figure 5, Reported costs adjusted for 2015 Euro PPI, average of costs was converted to 2015 USD using Oanda.com historical currency converter web tool. Studies reported 12-month total direct costs for patients by mRS (Wilson et al., 2017).

Once I completed my base case projections, I created projections for each of my three policy alternatives. I began with the mobile stroke unit scenario by projecting the startup and operational costs. Estimates vary on the cost of operating and maintaining a mobile stroke unit, but the Cleveland clinic reported that initial vehicle purchase and outfitting costs approximately $1.2 million, and annual operating expenses amount to $500 thousand (*Mobile Stroke Unit*, n.d.). To account for estimated reimbursement from mobile stroke unit operations, I used estimates performed by Reimer et al that found mobile stroke units need a minimum patient volume of 392

a year in order to meet cost-effectiveness vs standard prehospital care (Reimer et al., 2020). Using these estimates, I redistributed 392 patients from my outcome projections into lower mRS categories using data from the BEST-MSU study, which is currently the only reliable data on patient-oriented outcomes from mobile stroke unit programs. They found that for every 100 patients treated with an MSU 27 will have less disability, and 11 more will be disability free (Grotta et al., 2021). This amounted to a total cost of $8,429,306,444.34 and a net present value of $220,275,783.80.

I then assessed alternative two, reforming the VSSTF into a more comprehensive stroke system of care. To estimate the costs, I assumed that the program would require one additional full-time equivalent project coordinator position with VDH, taking the mean reported salary for such a position ($50,328), adding a 30% premium for benefits and projecting over the analysis period using previous inflation estimates. I then added start-up costs for the first two years of the analysis period based off of the reported funding requests from the Florida Stroke Collaborative, which amount to $750,000 in the first year followed by $1,000,000 in the second year (*Florida Stroke Registry*, 2022). Outcome projections were based on an average of 1% improvement in disability both during the startup, implementation, and ongoing program period based on data from program assessments by the CDC (Centers for Disease Control and Prevention. Division for Heart Disease and Stroke Prevention, 2018). To model this, I assumed that 1% of patients with mRS scores of 5, 4, 3, 2, or 1, had a 1% downward reduction in scores. This amounted to a total cost of $8,330,556,182.71 and a net present value of $219,727,150.93.

For alternative three, a targeted public hypertension reduction campaign, I used cost and effectiveness estimates from Victor et al.'s Black Barbershop hypertension reduction program. I used program cost estimates, adjusting for the average difference in salary between Virginia and California (Victor et al., 2018). I then assumed that a well-funded and implemented program would reach approximately 1% of stroke patients each year, and then that 75% of that group would have a stroke outright prevented, moving from an mRS score of 5, 4, 3, 2, or 1 to 0. These estimates are based on the risk reduction associated with hypertension control from several studies (Arnett et al., 2019; Diener & Hankey, 2020; Howard et al., 2016). This amounted to a total cost of $7,832,743,848.53 and a net present value of $219,724,316.42.

Year	Base Case	Mobile Stroke Unit	Hypertension Reduction	Reforming VSSTF
2022	$ 655,133,771.17	$ 656,833,771.17	$ 655,387,334.41	$ 652,775,663.36
2023	$ 669,622,890.58	$ 675,738,596.59	$ 667,177,238.27	$ 672,107,205.40
2024	$ 695,927,450.41	$ 696,454,324.22	$ 677,170,510.82	$ 690,757,479.89
2025	$ 716,648,344.86	$ 717,186,332.62	$ 687,313,476.37	$ 710,463,793.54
2026	$ 734,319,904.83	$ 734,869,211.64	$ 697,608,377.43	$ 727,616,459.07
2027	$ 761,412,511.43	$ 761,973,991.84	$ 708,750,984.21	$ 752,938,778.90
2028	$ 786,753,348.19	$ 787,328,361.53	$ 721,480,719.23	$ 777,027,722.20
2029	$ 812,937,562.22	$ 813,526,435.21	$ 734,439,100.75	$ 801,895,101.03
2030	$ 833,145,007.83	$ 833,748,019.43	$ 747,630,235.89	$ 821,734,121.73
2031	$ 860,873,198.96	$ 861,490,745.65	$ 761,058,305.52	$ 848,041,146.51
2032	$ 889,524,221.73	$ 890,156,654.45	$ 774,727,565.64	$ 875,198,711.09
NPV	$220,275,783.80	$221,094,069.97	$219,724,316.42	$219,727,150.93
Outcome Measure	105482	104069	91058	102839
Result	**2088**	**2124**	**2413**	**2137**

Figure 6, Cost-Effectiveness analysis outcomes table

The result of my analysis is that each alternative is cost-effective compared to my base case projection, but the hypertension reduction program is more so than either reforming the VSSTF or implementing a mobile stroke unit. The results of this assessment are unsurprising given that reducing the overall incidence of stroke completely nullifies the burden of stroke, whereas a mobile stroke unit and reformation of the VSSTF promotes marginal improvements in those that have already suffered a stroke.

Equity

Equity is a criterion for assessing the degree to which a policy distributes services and economic benefits fairly across society. Equity considerations are paramount in reducing the burden of disability from stroke. I will consider the equity implications of policy alternatives for rural as opposed to urban populations. Stroke outcomes are dependent on the availability of prevention resources and emergent treatment options, and rural areas have a higher burden of stroke than urban areas.

Political Feasibility

I will assess political feasibility for each alternative by evaluating the necessary steps for adoption. For each alternative I will assess the primary stakeholders and decisionmakers whose buy-in would be required for any program. I will also describe relevant state or municipal agencies whose support is required.

Implementation

Each suggested alternative requires substantial buy-in at the local level and across a fragmented health system, so assessing the likelihood of sustained, and programmatic buy-in is important. I will also include staff ownership in execution. Finally, I will determine the staffing burden of each alternative.

Evaluation Criteria

Each policy option will be evaluated in terms of effectiveness (25%), c*ost effectiveness* (25%), t*he ability to* implement (20%), p*olitical feasibility* (15%)*, and Equity* (15%).

Evaluation

Status Quo

Cost-Effectiveness

My base case projections indicate that the total summed modified Rankin scale scores for the 2022 – 2032 period will amount to 105,482, the highest among each alternative.

I assess the net present value of the status quo for the 2022 – 2032 period as $220,275,783. This ranks the lowest among each alternative. I calculated a score of 2088 in my cost-effective analysis.

Equity

Stroke outcomes in Virginia are extremely inequitable across the rural and urban divide and is therefore low (see figure 1).

Political Feasibility

The status quo necessarily benefits from high political feasibility, as it requires no action on the part of stakeholders or decisionmakers.

Implementation

Similarly, to political feasibility, the status quo requires no additional effort to implement and therefore ranks high.

Alternative 1: Reform the VSSTF Into a Comprehensive Stroke System of Care, With a Statewide Registry

Cost-Effectiveness

I project the total summed modified Rankin scores over the 2022 - 2032 period at 102,839.

The cost-effectiveness of this alternative is similarly medium, with net present value of $219,727,150 and a calculated cost-effectiveness score of 2137.

Equity

This alternative ranks high for equity, as the implementation of a registry program would focus its efforts on regions of the state that do not traditional have access to the kind of data analysis and information provided by the registry.

Political Feasibility

The political feasibility of this alternative is assessed as low. Of each proposed alternative, this would require the largest legislative lift, both by reforming Virginia statutes relating to the purpose of the VSSTF and for initial startup funding.

Implementation

I rank the implementation potential of this program as medium. This alternative would require the expansion of organizations required to report data to the state for analysis, but most of the structures required to do so already exist. For hospitals and health systems the American Heart Association's Get with The Guidelines program provides an appropriate framework. Unfortunately, this alternative suffers from requiring individual emergency medical services agencies to report stroke specific data to the state of Virginia. While technically required under current regulations, the Office of Emergency Medical Services has consistently fallen short in attempts to standardize and improve data collection and dissemination. [5]

[5] See: https://roanoke.com/news/state-and-regional/judge-finds-virginia-agency-violated-foia-by-not-releasing-overdose-data/article_227d63ea-8b24-5d1e-8245-2296924b2391.html

Alternative 2 Mobile Stroke Units.

Cost-Effectiveness

Mobile stroke units highly likely improve outcomes for patients treated by them, but they are limited by geography, call volume and the availability of specialty staffing. I projected the total summed modified Rankin scores for a mobile stroke unit program as 104,069, which is lower than the status quo but higher than all other alternatives.

I therefore assess the cost-effectiveness of a mobile stroke unit program as low, with a net present value of $221,091,069 and a cost-effectiveness measure of 2124. While this number is not lower than that of reforming the VSSTF, it is likely an overestimate. My model assumed that a mobile stroke unit would reach over 390 patients each year and would recreate the beneficial effects of the BEST-MSU study. Any MSU in Virginia would be hard pressed to obtain such high call volumes.

Equity

The equity of a mobile stroke unit program in Virginia is low. A mobile stroke unit is premised on the idea that dropping critical care resources at the site of illness improves outcomes, which provides notable individual benefit but severely limits the reach of the program. Additionally, the specialty staffing requirements of a mobile stroke unit mean that the only places capable of developing the program would already be associated with a large, academic medical center. Patients with access to large academic medical centers are typically in higher income, more urbanized settings, which would box out rural residents from any benefit.

Political Feasibility

The political feasibility of a mobile stroke unit program in Virginia is high as it would not require any substantial change to Virginia regulation or legal frameworks. Additionally, large health systems must be the sponsors and collaborators for any program, and mobile stroke units have been used effectively for marketing and distinguishing care provided in areas like Houston and Cleveland.

Implementation

The feasibility of implementation for a mobile stroke unit program in Virginia is medium. The most difficult part of implementing a mobile stroke unit program in Virginia is finding qualified staffing for the unit itself. This again relies on the ability of a large health system participating in the project, as they would be the only supplier of emergent neurological expertise. Additionally, cooperation with a local fire/rescue department may be necessary to supply individuals qualified to drive the unit, which is much larger than a traditional ambulance and requires a specialty driving certification.

Alternative 3: Targeted Hypertension Reduction Program

Cost-Effectiveness

The projected sum of mRS scores amounts to 91058, which is less than all other alternatives. While my projections rely on several assumptions, the results are consistent with other preventative medicine research and programs. Preventing even a few severe strokes (defined as mRS of four or above) portends substantial benefits in terms of costs to the individual, society, and health systems.

Predictably, then, this alternative ranks high for cost-effectiveness, with a net present value of $219,724,316 and the highest cost-effectiveness measure of 2413. This is consistent with the colloquialism "an ounce of prevention is worth more than a pound of cure". The costs of a severe, disabling stroke are enormous, and preventing them outright is extremely cost-effective.

Equity

The equity of this program ranks as high, as it is modeled off a program whose specific goal was to reach populations traditionally left behind from medical resources. Indeed, the design of this program emphasizes the need to work from the local level up and provide resources directly to at-risk and vulnerable populations.

Political Feasibility

The political feasibility of this program is high, as it would not require any substantial regulatory or legislative change on the part of the state of Virginia. Additionally, the localized nature of the program will ease pressures typically associated with the state attempting to bring programs to communities they do not have a positive relationship with.

Implementation

The implementation feasibility of this program is medium. The local nature of the program and the requirement that a healthcare worker be present to perform the interventions means that the success of the program is dependent on relationships between health systems and targeted communities.

Outcomes Matrix

Criteria	Base Case	Reforming VSSTF	Mobile Stroke Unit	Hypertension Reduction Program
Cost-Effectiveness (50%)	1	2	1	3
Equity (15%)	1	3	1	3
Political Feasibility (15%)	3	1	3	3
Implementation (20%)	3	2	2	2
Final Score	**1.7**	**2**	**1.5**	**2.8**

Each outcome was assigned either a 3, 2, or 1 based on receiving either a high, medium, or low score. The number was then multiplied by the weight of each criterion and summed to create a one to three scale.

Recommendation

Based on the above analysis I recommend the development and implementation of a hypertension reduction program. Out of each alternative assessed, the hypertension reduction program was by far the most cost-effective, and equitable. These benefits are such that even if the program faces unexpected difficulties in implementation, it will remain the recommended course of action to reduce the burden of stroke disability in Virginia.

Implementation, Stakeholder Discussion, Potential Roadblocks

Several steps are required to implement a hypertension reduction program in Virginia, primarily the coordination of stakeholders and decisionmakers. The primary stakeholders for a program like this would be local health systems, community organizations that represent target communities, and the target communities themselves. Communities most at risk from stroke due to hypertension are also liable to be skeptical of the healthcare system, and creating personal networks based on trusted actors within each group is imperative for success. The first step would be to identify areas of higher need, and partner health systems with established public outreach programs. Public outreach and education is a core part of stroke care and a requirement of stroke treatment center designations, the limitation is on the availability and bandwidth of individual programs to support new efforts, or augment and reform old ones into the new model.

The next step is identifying community leaders and organizations that have connections to the target populations. This analysis relies on the program assessments of the Black Barbershop Hypertension Reduction program, making this step the key to an effective program. Community partners will vary from location to location, and it is obviously not a requirement that the program partner with barbershops. Examples of community organizations could also include churches, Rotary or Lion's clubs, local emergency medical services and fire departments, or even coffeeshops. So long as the organization has a positive relationship with the target population and the healthcare partners are willing to invest in community partnerships, the program should be effective.

To assist in bridging the gap between healthcare system and community stakeholders, the VSSTF should partner with the Virginia Chronic Disease Preventive Collaborative Network (CDPVN), an agency under the VDH whose mission is to provide information, outreach and a

collaborative enviornment for programs like this. The CDPVN possesses expertise on the development and implementation of public outreach programs. Their inclusion in a cooperative or even advisory capacity will save VSSTF stakeholders substantial labor.

Conclusion

Too many Virginians suffer long-term disability from stroke, but there are a number of viable alternatives at reducing this burden at an individual and population level. Implementation of a targeted hypertension reduction program would save the state of Virginia and society at large a substantial amount of these costs, and likely create positive externalities. Other alternatives like a mobile stroke unit, or reformed stroke system of care would benefit stroke patients, but no matter how you measure it, preventing a stroke outright is more effective than marginally improving care once one has occurred.

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Appendix

Reference	2018 Average Costs	2018 Virginia Incidence and Cost	2019 Costs Adjusted for Inflation	2019 Population Incidence	2020 Costs Adjusted for Inflation	2020 Population Incidence
Emergency Department Care	$ 1,938.00		$ 2,013.98		$ 2,100.57	
Home Health Visits	$ 11,462.00		$ 11,911.40		$ 12,423.50	
Inpatient Stays	$ 25,722.00		$ 26,730.51		$ 27,879.72	
Office-Based Events	$ 1,063.00		$ 1,104.68		$ 1,152.17	
Prescription Medication Costs	$ 578.00		$ 600.66		$ 626.49	
Ambulance Costs*	$ 516.00		$ 536.23		$ 559.29	
Estimated Population Incidence		*43691*		*43782*		*44046*
Estimated Total Direct Costs		***$ 98,199,652***		***$ 102,263,521***		***$ 107,302,988***

Reference	2015	2016	2017	2018	2019	2020*
Total Population Estimate	**8,382,993**	**8,411,808**	**8,470,020**	**8,517,685**	**8,535,519**	**8,586,967**
Stroke, Previous Stroke 2015	26000					
Percent of Total Virginia Population	0.31%	0	0	0		
Estimated Prevalence Stroke with Previous Stroke		26089	26270	26418	26473	26633
Stroke, No Previous Stroke 2015	17000					
Percent of Total Virginia Population	0.2%					
Estimated Prevalence Stroke with *No* Previous Stroke		17058	17176	17273	17309	17414
Total Stroke Incidence	**43,000**	**43148**	**43446**	**43691**	**43782**	**44046**

Projected Distribution of mRS Scores	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
0	9107	9193	9272	9306	9441	9527	9613	9621	9708	9796
1	12868	12990	13101	13148	13340	13461	13583	13594	13717	13842
2	5346	5397	5443	5463	5543	5593	5643	5648	5699	5751
3	4803	4848	4890	4907	4979	5024	5070	5074	5120	5166
4	4848	4894	4936	4954	5026	5071	5117	5122	5168	5215
5	7974	8050	8119	8148	8267	8342	8417	8424	8501	8578
Projected 10 Year Stroke Incidence	44946	45372	45762	45926	46595	47017	47444	47483	47914	48348

Mobile Stroke Unit Scenario	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
0	9379	9468	9549	9583	9723	9811	9900	9908	9998	10089
1	13140	13264	13378	13426	13622	13745	13870	13881	14007	14134
2	5288	5338	5383	5403	5481	5531	5581	5586	5637	5688
3	4740	4785	4826	4843	4914	4958	5003	5007	5053	5098
4	4786	4831	4872	4890	4961	5006	5051	5056	5101	5148
5	7938	8013	8082	8111	8229	8304	8379	8386	8462	8539
Projected 10 Year Stroke Incidence	**45309**	45738	**46131**	**46296**	**46971**	**47397**	**47826**	**47866**	**48300**	**48738**

Hypertension Reduction Scenario	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
0	8995	8942	8889	8837	8785	8733	8681	8630	8579	8529
1	12709	12634	12560	12486	12412	12339	12266	12194	12122	12050
2	5281	5250	5219	5188	5157	5127	5096	5066	5037	5007
3	4744	4716	4688	4660	4633	4605	4578	4551	4524	4498
4	4788	4760	4732	4704	4676	4649	4621	4594	4567	4540
5	7876	7830	7784	7738	7692	7647	7602	7557	7512	7468
Projected 10 Year Stroke Incidence	44394	44132	43871	43612	43355	43099	42845	42592	42341	42091

VSSTF Reform/Registry Scenario	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
0	9107	9193	9272	9306	9441	9527	9613	9621	9708	9796
1	12868	12990	13101	13148	13340	13461	13583	13594	13717	13842
2	5346	5397	5443	5463	5543	5593	5643	5648	5699	5751
3	4803	4848	4890	4907	4979	5024	5070	5074	5120	5166
4	4848	4894	4936	4954	5026	5071	5117	5122	5168	5215
5	7974	8050	8119	8148	8267	8342	8417	8424	8501	8578
Projected 10 Year Stroke Incidence	44946	45372	45762	45926	46595	47017	47444	47483	47914	48348