Comments and Opinions

Better Health, Less Spending
Delivery Innovation for Ischemic Cerebrovascular Disease
Lucy Kalanithi, MD; Waimee Tai, MD; Jared Conley, PhD, MPH; Terry Platchek, MD; Donna Zulman, MD, MS; Arnold Milstein, MD, MPH

Cerebrovascular disease is a leading cause of disability in the United States and results in $20.6 billion in annual direct medical spending, with ≈700,000 ischemic strokes yearly. Despite advances in stroke prevention and treatment, deficits persist in healthcare value (defined as improved population health and patient experience at lower per-capita cost). Initiatives including the American Heart Association and American Stroke Association’s Get-With-The-Guidelines-Stroke (GWTG) and Target:Stroke programs provide leadership to improve the quality of care. To add to these efforts, and in response to increasing healthcare spending, we designed a composite of prevention and treatment strategies that improve value in a short time horizon (1–3 years after implementation) by enhancing population health and experience of care while lowering total per-capita healthcare spending.

Methods
We used a healthcare delivery redesign method to develop a composite of care delivery strategies with potential to improve value for ischemic cerebrovascular disease. First, we conducted a medical literature review of epidemiology, intervention effectiveness and cost effectiveness, and clinical guidelines to identify opportunities for improvement. We subsequently conducted observations and interviews with patients and providers at 6 sites, adapting human-centered design methods from Stanford’s Biodesign Program. Our interviewers sought to identify frustrations, or disgusters, encountered by patients and providers to determine opportunities to improve the experience of care. Incorporating findings from these efforts, we listed unmet needs of patients, clinicians, and payers. Needs were ranked by expected impact of fulfillment on (1) health outcomes, (2) experience of care, and (3) total per-capita healthcare spending using a Likert scale–based system. To expand our thinking about higher-value stroke care, we observed or performed interviews at US and international sites nominated by health services and clinical experts for delivering high-quality care at relatively low cost. Finally, we studied processes used for other medical conditions and in other industries (the adjacent possible) with potential to improve value in cerebrovascular disease care. We refined a composite of care delivery strategies with the participation of expert advisors, including clinicians, social scientists, health services researchers, and business leaders. We estimated potential savings from the health system perspective, deducting operating costs of new care delivery strategies (for methods and calculations, see Tables I–V in the online-only Data Supplement). These methods were exempted from review by the Stanford Institutional Review Board.

Results
To fill value gaps (deficits in quality, experience, and cost effectiveness) in the care of ischemic cerebrovascular disease (Table 1), the composite we created (Figure) includes the following components: (1) reduce vascular risk by maximizing the use of cardioprotective medications, (2) relocate care for low-risk patients with transient ischemic attack (TIA) from hospital to outpatient settings, (3) improve efficiency of hospital-based care for mild ischemic stroke, (4) redesign emergency care to rapidly deliver intravenous tissue-type plasminogen activator (IV-tPA) to all eligible ischemic stroke patients, and (5) improve transition to posthospital care to reduce poststroke readmissions.

Reduce Vascular Risk by Maximizing the Use of Cardioprotective Medications
When combined, antihypertensive medications, statins, and antiplatelet therapy reduce stroke risk by more than half and are likely cost-saving in high-risk patients. However, these medications are underused for both primary and secondary prevention. Adherence is low: fewer than half of patients with vascular disease or at elevated risk take guideline-recommended cardioprotective medications. Causes of nonadherence include lack of information or understanding, polypharmacy, and cost. Health system factors also contribute: poor follow-up or unjustified discontinuation by a healthcare provider accounts for additional drop-off. Largely because of low prescribing and adherence, only 53% of Americans with hypertension in 2010 had achieved adequate blood pressure control.

To improve medication use, our program uses the following evidence-based techniques in the care of highest-risk patients: risk stratification, proactive outreach, medication protocols, health coaching, and copay reduction. The strategy

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Table 1. Value Gaps in Current Care of Ischemic Cerebrovascular Disease

<table>
<thead>
<tr>
<th>Phase of Care</th>
<th>Value Gap Targeted for Improvement</th>
<th>Literature Review Findings and Observations</th>
</tr>
</thead>
</table>
| Stroke prevention   | Vascular risk factors inadequately controlled | • Less than half of patients at elevated vascular risk take all guideline-recommended medications to reduce risk  
  • Health system factors contribute: many do not receive necessary prescriptions  
  • Patient support is lacking: barriers to medication adherence are often unaddressed by health system |
| Care of TIA         | High rate of hospital admission for low-risk patients | • In the United States, most TIA patients are routinely admitted, although few have high risk of near-term stroke  
  • Rapid diagnostics and secondary prevention are needed post-TIA, but are not always completed during hospitalization |
| Care of mild ischemic stroke | Prolonged hospital stays | • Half of strokes result in no or minimal disability  
  • Nonetheless, most patients with stroke are hospitalized for multiple days |
| Care of disabling ischemic stroke | Underuse of IV-tPA | • Time-sensitive IV-tPA treatment reduces disability and is cost-saving when delivered early  
  • Fewer than 6% of patients with stroke receive IV-tPA, although 40% may be eligible  
  • Delays occur both before and after patients seek emergency care |
| Poststroke period   | High rate of readmission to hospital | • Many patients are readmitted poststroke because of recurrent vascular events or complications  
  • Up to half of poststroke readmissions may be preventable |

IV-tPA indicates intravenous tissue-type plasminogen activator; and TIA, transient ischemic attack.

is designed to generate additional savings by use of nurses rather than physicians to initiate and titrate medications (when needed) and medical assistants to support patient self-management, with the majority of outreach by telephone.

Proactive outreach and medication protocols can reduce vascular risk compared with usual care. From 2001 to 2009, Kaiser Permanente in Northern California increased its hypertension control rate from 43.6% to 80.4%, whereas national hypertension control rates hovered ≤60%. They attained a blood pressure control rate 11 percentage points higher than the state average.

Hypertension medication protocols for primary care are recommended by multiple professional societies. Protocols to support medication initiation and titration by nonphysicians have been successful in multiple settings, including via telephone by nurses and pharmacists.

Health coaches address obstacles rarely addressed by physicians, which constitute a disaggertor for patients. Telephonic coaching by nurses and dieticians improves both adherence and risk factor control in patients with vascular disease. Lower-cost personnel including medical assistants may also be effective health coaches, and telephonic coaching after minor stroke or TIA is satisfactory to patients.

Removing medication copays leads to modest improvements in adherence in high-risk patients. Such incentives show promise for reducing vascular events and healthcare spending in patients with heart attack and hypertension.

Approximately 15% of Americans are at high vascular risk (ie, ≥20% risk of major cardiovascular event <10 years) either because of existing vascular disease or high predicted risk using a tool such as the Framingham calculator. By increasing the use of blood pressure medication, statin, and antiplatelet therapy in this group, we estimate that our new care composite will reduce both ischemic strokes and heart attacks by as much as 15%. Factoring in the cost of care delivery, we estimate that net spending on acute ischemic stroke and heart attack will decline by ≤5% (Table I in the online-only Data Supplement).

Relocate Care for Low-Risk Patients With TIA From Hospital to Outpatient Settings

TIA is a harbinger of stroke, and early initiation of secondary prevention is critical. The risk of stroke <90 days of TIA is ≥10%, with half of subsequent strokes occurring in the first...
Secondary prevention medications reduce 90-day stroke risk by 80%.17

In the United States, admission practices vary for TIA. From 2006 to 2008, approximately two thirds of asymptomatic patients presenting to emergency departments after TIA were admitted.18 However, there is significant heterogeneity among patients with TIA. Hospitalization is cost-effective only for highest-risk patients, such as those with >20% 48-hour risk of stroke.19

For medically stable patients presenting with TIA and at low risk of near-term stroke, TIA clinics can achieve the same outcome as hospitalization at lower cost.20-22 TIA clinics may achieve cost savings of ≥$4000 per patient compared with hospital care.20,22 TIA clinics abroad safely reduced admission rates from 100% to 22% and from 63% to 17%.20,21 Pilot tests in the United States reduced admission rates to 20% to 30%,22,23 with subsequent strokes less frequent than predicted by ABCD2 (a clinical risk calculator of TIA defined by age, blood pressure, clinical features, and duration of symptoms) scores. Furthermore, TIA clinic protocols may result in better secondary prevention and fewer subsequent strokes compared with usual inpatient care.21,22

Triage tools seem to be key to TIA clinics’ success. Additional success factors include patient education, shared decision-making, immediate initiation of secondary prevention, and reliable, timely outpatient follow-up. Protocol-guided care by a neurologist-supervised advanced practice provider may allow additional savings realized through staffing efficiency.22,23

We estimate that admission can be avoided in >70% of patients with TIA, and that the cost of acute care for TIA in the United States could safely decline by as much as 60% (Table II in the online-only Data Supplement).

**Improve Efficiency of Hospital-Based Care for Mild Ischemic Stroke**

Mild stroke also offers an opportunity to avoid traditional inpatient care. Observation status was first defined by the Centers for Medicare and Medicaid Services as outpatient care ordered for Medicare and Medicaid Services as outpatient care ordered for inpatient care.24 In 2013, Centers for Medicare and Medicaid Services regulated that observation status apply to patients staying <2 midnights.24 Centers for Medicare and Medicaid Services policy states that observation services are usually needed for ≤24 hours; private payers are following a similar pattern.26 Care provided in observation units guided by evidence-based protocols shortens length of stay and lowers healthcare costs 27% to 42% compared with inpatient care,24 particularly when length of stay is <24 hours.24,26

Although several centers in the United States have lowered costs and improved outcomes by using observation units for patients with TIA,27,28 none has yet reported their use in the care of mild strokes.

We hypothesize that an expedited protocol for inpatient care of mild stroke (examination, imaging, laboratory testing, rehabilitation assessment, education, secondary prevention, and referrals) could safely shorten length of stay without compromising quality. This approach could apply, for example, to patients with National Institutes of Health Stroke Scale score <5 who (1) are not treated with thrombolysis or carotid or other intervention; (2) present with minimal disability (including no significant swallowing or ambulatory difficulty) for which outpatient rehabilitation is suitable; and (3) have adequate social support. Benefit redesign may be needed to insulate patients from higher out-of-pocket costs, which in a few cases are higher for observation stays than for inpatient care.25,26 Feasibility of an observation care pathway is bolstered by a recent report of safe same-day outpatient care of 61% of minor stroke patients (40% of all stroke patients) in the United Kingdom.29

Mild strokes account for more than half of all strokes20,30 and expedited observation care for mild strokes could lower hospitalization costs for mild stroke by >20% while maintaining or improving quality (Table III in the online-only Data Supplement).

**Redesign Emergency Care to Rapidly Deliver IV-tPA to All Eligible Ischemic Stroke Patients**

IV-tPA for ischemic stroke is supported by a level A recommendation in national guidelines.31 Despite the risks of thrombolysis, IV-tPA results in a complete or near-complete recovery in significantly more patients compared with placebo.31 However, its efficacy is time-sensitive: the sooner the IV-tPA is delivered, the better the chance of survival to hospital discharge, independent ambulation, and discharge to home, particularly when given within the Food and Drug Administration–indicated time frame of 3 hours from symptom onset (off-label use ≤4.5 hours receives a level B recommendation).31,32 When given <3 hours, IV-tPA lowers total healthcare spending within 1 to 5 years.33 Process improvements to improve the timeliness of thrombolysis likely improve outcomes and save costs.34

Nonetheless, IV-tPA is understated and often delayed. Half of patients with ischemic stroke could receive IV-tPA if access to care were optimized.35 However, as of 2009, at most 5.2% of patients hospitalized for stroke in the United States received it.1 Hospitals participating in the GWTG initiative delivered IV-tPA <3 hours of symptom onset to 7% of patients presenting with acute ischemic stroke.2 Less than a third of patients were treated <60 minutes of arrival, as recommended by guidelines; median door-to-needle time in 2011 was 72 minutes in GWTG hospitals.2

The performance shortfall is because of 2 factors: patients not presenting for care soon enough and delays in care. Fewer than half of individuals with acute ischemic stroke arrive within the IV-tPA treatment window.2,36 Of those, roughly half are ineligible for or refuse treatment.36 Of the remainder, the majority do not receive IV-tPA because of inefficiency or lack of access to a physician willing to give it.36

To address these shortfalls, we propose a new approach to improving patient self-management and emergency care. The California Acute Stroke Pilot Registry investigators predicted that interventions motivating patients to seek treatment sooner would have a larger impact than health system improvements.36 Ambulance transfer is associated with shorter delay to hospital arrival and IV-tPA delivery,32,36 but only half of stroke patients arrive by ambulance.2 Public knowledge of stroke warning signs and treatment availability is low. A 2005 survey found that only 15.7% of high-risk patients could name 3 stroke warning signs, 3.6% could independently identify IV-tPA as a treatment for stroke, and 9% understood the ideal
treatment window of <3 hours. The majority of patients want IV-tPA; in our interviews, lack of awareness of its benefits and time-sensitivity emerged as a dissuader for stroke survivors who lost the opportunity to benefit from disability-reducing treatment. However, population-wide stroke education campaigns have shown negative or modest results and may lack specifics. Therefore, promotion of an action plan—calling 911 immediately and seeking IV-tPA in case of stroke—may be necessary. We embed such training of patients and family members into the self-management component of our proposed stroke prevention strategy for high-risk patients. Borrowing from the adjacent possible, we propose practicing a stroke drill, analogous to fire drills.

To reduce health system delays once patients seek emergency care, our composite includes 5 strategies piloted at innovative centers around the world: (1) hospital prenotification by emergency medical services; (2) clinical evaluation by a neurologist via secure telecommunication while patients are en route; (3) bypassing the emergency department and delivering patients directly to a computed tomographic scanner from the ambulance (not currently part of the American Heart Association/American Stroke Association Stroke recommendations); (4) point-of-care laboratory testing; and (5) IV-tPA delivery by a specialized team immediately after computed tomography excludes a hemorrhagic stroke. Helsinki University Central Hospital in Finland reduced median door-to-needle time from 105 to 20 minutes using these strategies, treating 31% of stroke patients with IV-tPA. Ninety-four percent of those were treated ≤60 minutes of arrival. The process was successfully replicated in Australia for a 4-month period. A similar intervention at Washington University in St Louis, with immediate computed tomography on arrival, parallel workflow, and point-of-care laboratory testing, reduced door-to-needle time from 60 to 39 minutes. Cost-effectiveness modeling of interventions to improve IV-tPA delivery suggests that immediate computed tomography is the strategy offering the greatest potential cost savings.

Evidence-based care strategies could improve IV-tPA delivery 3- to 4-fold. Cost savings would accrue if the majority of patients were treated ≤3 hours of symptom onset (Table IV in the online-only Data Supplement).

**Improve Transition to Posthospital Care to Reduce Poststroke Readmissions**

The final feature of our composite addresses the transition to posthospital care after ischemic stroke. Over 40% of patients with stroke are readmitted ≤1 year and 14% ≤30 days. Under the Hospital Readmissions Reduction Program of the Affordable Care Act, hospitals with high readmission rates are subject to a Medicare penalty. Common reasons for readmission are stroke sequelae (eg, pneumonia, hip fracture) and vascular events (eg, recurrent stroke and myocardial infarction). Estimates of preventable readmission range from 11.8% to 53%. Older age, vascular disease, greater stroke severity, and index length of stay >10 days are associated with readmission.

For patients vulnerable to readmission, our composite includes health coaching before and after hospital discharge and a process to ensure timely outpatient follow-up, including entry into a program for secondary prevention. Although no single intervention is regularly associated with reduced readmission and few studies focus on reducing poststroke readmissions, multicomponent programs have been successful in general medical patients. A systematic review identified transitions coaching beginning before discharge, patient-centered discharge instructions, and follow-up telephone calls as commonalities among successful interventions, reducing relative risk of readmission up to a third and lowering poststroke healthcare costs. For poststroke patients, a transitional care model by nurse navigators reduced readmissions at 1 hospital from 9% to 3% in patients discharged home, ensuring outpatient follow-up was a key component.

We conservatively estimate that improving posthospital care for ischemic stroke patients discharged to home would reduce 30-day readmissions by ≤14%, reducing healthcare spending on readmissions by ≤5% when accounting for the cost of intervention (Table V in the online-only Data Supplement).

An overall summary of the 5 primary strategies of cost-saving redesign of cerebrovascular disease can be seen in Table 2, including their key components and the subsequent impact on patient experience, population health, and per-capita cost of care.

**Discussion**

Using a method incorporating medical evidence and observation, we designed a composite strategy to improve healthcare value for patients with ischemic cerebrovascular disease. This strategy could form a template for implementing care delivery strategies ranging from prevention to acute and postacute care of TIA and ischemic stroke. Themes include patient education and support, avoiding hospitalization, process improvement, and more efficient staffing. Societal impact may be even greater than projected. We estimated only direct costs, and our cost savings may be underestimated: many of our data sources relied on published Medicare claims data, which may reflect lower spending than that of private payers.

Our unique method incorporated available medical evidence from multiple sources. As a result, our conclusions are dependent on the quality of those sources. Additionally, although the components of our composite were refined by those with considerable expertise in stroke care, suggestions including expedited care of mild stroke and promotion of IV-tPA via health coaching extend beyond published evidence, relying instead on plausible information for related interventions and conditions. The other strategies have evidence of clinical and economic benefit, although not all studies reported costs; cost was usually a secondary outcome, and intervention resources were not always reported. We included nonrandomized studies, introducing additional potential confounders, and studies performed in multiple countries and healthcare payment structures, which may limit generalizability. Our cost estimates used a range of published values, many from public payors, thus possibly underestimating the cost savings gained by private payors. Our cost savings did not include multifactorial sensitivity analysis. We selected strategies suitable for implementation in a single health system; therefore, some potentially cost-saving interventions (eg, telesstroke networks) are not discussed. Other lifestyle interventions such as exercise.
and diet were also not discussed because of lack of cost-effectiveness data. Applicability and reproducibility may be sensitive to local factors such as organizational culture and payment structure. We recognize that implementation support for these cost-saving strategies have inherent adoption costs. Start-up costs for implementation support are not included in the net cost savings calculations (see the online-only Data Supplement), but continued ongoing costs of personnel or other infrastructure were included. We were challenged by the wide range of potential implementation costs, most of which are unique to each delivery system and dependent on the types of resources available at the time of implementation. In our experience, for some healthcare systems, such costs are only opportunity costs, because relevant leaders and support

| Table 2. Strategies to Improve Value of Care for Cerebrovascular Disease |
|--------------------------|--------------------------------|------------------|
| Strategy                  | Components of Successful Interventions | Impact on Patient Experience, Population Health, and Per-Capita Cost of Care |
| Population targeted: patients at elevated risk of stroke, MI, or both | Select patients at elevated risk of stroke, MI, or both6,8,11,15 | ↑ Patient satisfaction13 |
| Reduce vascular risk by maximizing the use of cardioprotective medications | Population management with proactive outreach6,8,15 | ↑ Medication prescribing in up to additional 45% of patients6,15,50 |
|                          | Evidence-based physician-prescribed medication protocols5,6,10,13 implemented by nurses6,15,50 | ↑ Medication adherence in additional 6–11% of patients11,14 |
|                          | Health coaching to address barriers to medication adherence1,13,15 | ↑ Blood pressure control in additional 11–27% of patients6,11,15 |
|                          | Nonphysicians (nurses and medical assistants) working at top of license/certification with supervision6,8,15 | ↑ Cholesterol control in additional 30% of patients51 |
|                          | Telephone-based care6,11,13 | ↓ Stroke 31%14 |
|                          | Remove copays for highest-risk patients6,7,14,15 | ↓ Vascular events ≤11%5,14 |
|                          |                               | ↓ Hospitalizations6 |
|                          |                               | ↓ Healthcare spending ≤8%14,15 |
| Population targeted: patients with TIA or mild stroke not treated with IV-Ipa | Triage near-term stroke risk in emergency department via risk calculators21,22 and imaging21,23 | ↑ Quality of care: greater provision of guideline-recommended diagnostic testing21,22 and secondary prevention21 |
| Relocate care for low-risk patients with TIA from hospital to outpatient settings | For low-risk patients, offer TIA clinic; initiate secondary prevention before emergency department discharge20–25 | ↓ Stroke risk 54%21 or no increased risk compared with hospitalized patients20,22,23 |
|                          | Shared decision-making tool to ensure TIA clinic option aligns with patients’ preferences6 | ↓ Hospitalization rate21–22 |
|                          | Reliable, timely TIA clinic access20–25 | ↓ Healthcare spending ≤74% per patient treated in TIA clinic20,22 |
|                          | Standardized care by advanced practiced providers20,23 | ↓ Healthcare spending likely, based on demonstrated success when applied to TIA patients20,22 |
|                          |                               | ↓ Length of stay likely, based on demonstrated success when applied to TIA patients20,22 |
| Improve efficiency of hospital-based care for mild ischemic stroke* | Select patients with mild stroke and minimal functional disability* | ↓ Healthcare spending likely, based on demonstrated success when applied to TIA patients20,22 |
|                          | Dedicated, protocol-guided observation unit27,28 | ↓ Healthcare spending likely, based on demonstrated success when applied to TIA patients20,22 |
|                          | Expedited diagnosis and treatment, as demonstrated for TIA patients21,28 | ↓ Healthcare spending likely, based on demonstrated success when applied to TIA patients20,22 |
|                          | Observation rather than inpatient billing, as demonstrated for TIA patients21,28 | ↓ Healthcare spending likely, based on demonstrated success when applied to TIA patients20,22 |
| Population targeted: patients with moderate to severe stroke or with mild stroke treated with IV-Ipa | Health coaching for high-risk patients to prompt immediate contact of EMS in case of stroke* | ↓ Door-to-needle time to as low as 20–39 min30,41 |
| Redesign emergency care to rapidly deliver IV-Ipa to all eligible patients with ischemic stroke | Hospital pretreatment by EMS41 | ↑ Proportion of patients treated with IV-Ipa to ≤31% of ischemic stroke patients admitted40 |
|                          | Clinical evaluation by neurologist via secure telecommunication while patients are en route40 | ↑ Proportion of IV-Ipa–treated patients treated <60 min to 74–94%36,40 |
|                          | Bypass emergency department for immediate computed tomographic scan39–41 | ↓ Healthcare spending likely, based on cost-effectiveness studies33,34 |
|                          | Point-of-care laboratory testing39–41 | ↓ Healthcare spending likely, based on cost-effectiveness studies33,34 |
|                          | Designated IV-Ipa delivery team39–41 | ↓ Healthcare spending likely, based on cost-effectiveness studies33,34 |
| Improve transition to posthospital care to reduce poststroke readmissions | Select patients vulnerable to readmission45 | ↓ Readmissions by relative 14–33%45,48–49 |
|                          | Health coaching spanning transition to posthospital care45,49,66 | ↓ Hospitalization costs47,48 |
|                          | Patient-centered discharge instructions45,49,66 | ↓ Healthcare spending40 |
|                          | Post-discharge telephone calls45,48 | ↓ Healthcare spending40 |
|                          | Timely outpatient medical follow-up45,49 | ↓ Healthcare spending40 |

EMS indicates emergency medical service; IV-Ipa, intravenous tissue-type plasminogen activator; MI, myocardial infarction; and TIA, transient ischemic attack.

*Novel interventions to be tested, borrowing from adjacent possible.
staff already exist. Furthermore, although including certain implementation support costs may reduce potential net savings early on in the adoption of these strategies, our overall cost savings may have been underestimated because of use of public payor data rather than a more realistic mix of public and private payor claims.

Despite these uncertainties, we think that the accumulated evidence is sufficiently robust, and the expense of ischemic cerebrovascular disease so burdensome, that a convincing case exists to demonstrate and disseminate this care composite. We are beginning partnerships with healthcare systems to pilot-test the strategies’ impact on health and healthcare value.

In conclusion, we used diverse sources of information to design a composite strategy to improve healthcare value for ischemic cerebrovascular disease. We estimate that the proposed strategies, if combined, could potentially lower the cost of healthcare for stroke and TIA by $1.6 billion within a year after implementation (depending on the costs of implementation support), with additional savings of ≤$800 million in the first year accruing from preventing myocardial infarction and improving IV-tPA use.

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Disclosures

None.

References


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to
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Estimated Cost Savings

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SUPPLEMENTAL METHODS

We estimated direct cost savings from the US health system perspective based on risk factor prevalence, vascular event incidence, current care methods, effect sizes in successful pilots, and costs of conditions and interventions (eTables 1-5). The measure of cost savings is reduced spending by payers. Cost estimates derive from medical literature and national databases including both public and private US payers. In two instances (eTables 3 and 5) for which admission rates and cost of admission were not available in the medical literature, data from the Healthcare Cost and Utilization Project (HCUP) Nationwide Emergency Department Sample\(^1\) and HCUP Nationwide Inpatient Sample\(^2\) were used, respectively; these costs represent hospitals’ costs to provide services, and they provide a proxy for payer spending. Discounting was not applied; studies of the cost-effectiveness of intravenous tPA (eTable 4) already discounted savings, and the rest realize savings within a year. All estimates have been brought up to date (to reflect the value in 2012) using a consumer price index (CPI) inflation calculator\(^3\) and then rounded. Calculations in each table stand alone and do not link strategies.

For suggested strategies requiring new healthcare job roles (e.g., health coach) or significant reallocation of staff (eTables 1 and 5), we offset savings by an estimated steady-state intervention cost, which we expect to be ongoing on an annual basis. These costs were estimated from published costs of related interventions. We did not estimate implementation costs (e.g., quality improvement staff). We are working with pilot sites to test the strategies and determine such resource requirements.
# Table I. Reduce vascular risk: estimated cost savings

<table>
<thead>
<tr>
<th>US adults at high vascular risk(^b)</th>
<th>Full use of protective medications(^a)</th>
<th>Annual acute ischemic strokes and myocardial infarctions (MIs)</th>
<th>Mean acute and post-acute care cost per vascular event in first year</th>
<th>Estimated annual national spending and savings on acute stroke and MI in high-risk patients (range and %)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Status quo</strong></td>
<td>240,144,250 adults in US(^4) (-15% at high vascular risk(^5,6)</td>
<td>36,021,650 adults</td>
<td>48.6(^\prime) (345,825) ischemic strokes (based on incidence reported by Go, et al.(^6))</td>
<td>$31,360(^6,3)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>360,000 MIs (based on incidence reported by Go, et al.(^5))</td>
<td>$45,980(^10)</td>
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<tr>
<td><strong>Suggested higher-value strategy</strong></td>
<td>240,144,250 adults in US(^4) (-15% at high vascular risk(^5,6)</td>
<td>36,021,650 adults</td>
<td>78.6(^\prime), (293,950) ischemic strokes (\text{with 50% estimated reduction in vascular events via medication adherence,}(^11)</td>
<td>$31,360(^6,3)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>306,000 MIs</td>
<td>(\text{resulting in 15% fewer events})</td>
<td>$45,980(^10)</td>
</tr>
</tbody>
</table>

\(^a\)American Heart Association/American College of Cardiology Foundation guidelines for secondary prevention: antiplatelet agent(s), statin, and antihypertensive medication(s)\(^13\)

\(^b\)High risk group: vascular disease or Framingham score >20\% absent known vascular disease

\(^c\)based on successes of published interventions reported in Table 2
Table II. Outpatient care of transient ischemic attack (TIA): estimated cost savings

<table>
<thead>
<tr>
<th>TIA patients presenting to US ERs annually</th>
<th>Admission rate (range)</th>
<th>Mean cost per patient (range)</th>
<th>Estimated annual national spending (range) and savings (range and %)</th>
</tr>
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<tbody>
<tr>
<td>Status quo</td>
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<td></td>
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</tr>
<tr>
<td>271,000 TIAs(^{14,15})</td>
<td>63.5%(^{16,17}) admitted</td>
<td>172,100 patients</td>
<td>$5,400-6,530(^{16,17}) inpatient care cost $985,219,000 to $1,242,493,000</td>
</tr>
<tr>
<td></td>
<td>36.5%(^{14}) outpatient care</td>
<td>98,900 patients</td>
<td>$565-$1200(^{16,17}) outpatient care cost</td>
</tr>
<tr>
<td>Suggested higher-value strategy</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>271,000 TIAs(^{14,15})</td>
<td>17.4-30%(^{16,19}) admitted</td>
<td>47,150 to 81,300 patients</td>
<td>$5,400-6,530(^{16,17}) inpatient care cost $381,085,000 to $758,529,000 (savings range $483,964,000 to $604,134,000 = 40-60% savings compared with status quo)</td>
</tr>
<tr>
<td></td>
<td>70-82.6%(^{16,19}) outpatient care</td>
<td>189,700 to 223,850 patients</td>
<td>$565-$1200(^{16,17}) outpatient care cost</td>
</tr>
</tbody>
</table>

\(^{a}\)consistent with HCUP Nationwide Emergency Department Sample admissions
### Table III. Improve efficiency of acute care for mild ischemic stroke: estimated cost savings

<table>
<thead>
<tr>
<th></th>
<th>Mild ischemic strokes in US annually</th>
<th>Inpatient admission rate</th>
<th>Mean cost per patient (range)</th>
<th>Estimated annual national spending on mild ischemic stroke hospitalizations and savings (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Status quo</strong></td>
<td>691,650 ischemic strokes&lt;sup&gt;6&lt;/sup&gt;</td>
<td>56% mild (Paul 2013, Reeves 2013)&lt;sup&gt;20,21&lt;/sup&gt;</td>
<td>85.2% inpatient&lt;sup&gt;a&lt;/sup&gt; (HCUP NEDS 2010)</td>
<td>330,000 mild ischemic strokes admitted</td>
</tr>
<tr>
<td><strong>Suggested higher-value strategy</strong></td>
<td>691,650 ischemic strokes&lt;sup&gt;6&lt;/sup&gt;</td>
<td>56% mild (Paul 2013, Reeves 2013)&lt;sup&gt;20,21&lt;/sup&gt;</td>
<td>39% inpatient (Paul 2013)&lt;sup&gt;25&lt;/sup&gt;</td>
<td>151,050 mild ischemic strokes admitted</td>
</tr>
<tr>
<td></td>
<td>387,300 mild ischemic strokes</td>
<td>387,300 mild ischemic strokes</td>
<td>178,950 mild ischemic strokes moved to observation care</td>
<td>$5,680 (40% savings, based on successes reported by Nahab, et al. [Nahab J Stroke 2012]&lt;sup&gt;23&lt;/sup&gt; and Ross, et al. [Ross 2013]&lt;sup&gt;24&lt;/sup&gt;)</td>
</tr>
</tbody>
</table>

<sup>a</sup>admission rate for first-listed ICD-9 codes 434.11, 434.91 and 436<sup>25</sup> in HCUP Nationwide Emergency Department Sample<sup>1</sup>

<sup>b</sup>cost of hospitalization for stroke without thrombolysis
Table IV. Rapidly deliver intravenous tPA (IV-tPA) to all eligible patients: estimated cost savings

<table>
<thead>
<tr>
<th></th>
<th>Ischemic strokes in US annually</th>
<th>IV-tPA treatment rate</th>
<th>Mean lifetime direct cost of ischemic stroke per patient</th>
<th>Estimated lifetime total spending (range) and savings (range and %)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Status quo</strong></td>
<td>691,650 ischemic strokes$^6$</td>
<td>5.2%$^{27}$ treated with IV-tPA</td>
<td>35,950</td>
<td>$159,800$</td>
</tr>
<tr>
<td></td>
<td>94.8%$^{27}$ not treated with IV-tPA</td>
<td>655,700</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Suggested higher-value strategy</strong></td>
<td>691,650 ischemic strokes$^6$</td>
<td>25%$^{27}$ treated with IV-tPA</td>
<td>172,900 patients (136,950 above status quo)</td>
<td>78%$^6$ within 3 hours$^{27}$</td>
</tr>
<tr>
<td></td>
<td>22% in 3-4.5 hour range$^{27}$</td>
<td>30,150 patients above status quo</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>75% not treated with IV-tPA</td>
<td>518,750 patients</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

$^{a}$estimate based on demonstrated success by Meretoja, et al.$^{27,30}$ and predicted effects of specific improvements by California Acute Stroke Pilot Registry Investigators$^{31}$

$^{b}$conservative estimate, as 86.5% are treated within 3 hours at Get With the Guidelines-Stroke hospitals$^{32}$
Table V. Improve transition to post-hospital care to reduce readmissions: estimated cost savings

<table>
<thead>
<tr>
<th></th>
<th>Ischemic stroke admissions in US annually</th>
<th>30-day readmissions (range)</th>
<th>Mean cost per readmission (range)</th>
<th>Estimated annual national spending (range) and savings (range and %)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Status quo</strong></td>
<td>691,650 ischemic strokes&lt;sup&gt;6&lt;/sup&gt;</td>
<td>85.2% admitted&lt;sup&gt;a&lt;/sup&gt;</td>
<td>45% discharged home&lt;sup&gt;6&lt;/sup&gt;</td>
<td>265,000 patients</td>
</tr>
<tr>
<td><strong>Suggested higher-value strategy</strong></td>
<td>691,650 ischemic strokes&lt;sup&gt;6&lt;/sup&gt;</td>
<td>85.2% admitted&lt;sup&gt;a&lt;/sup&gt;</td>
<td>45% discharged home&lt;sup&gt;6&lt;/sup&gt;</td>
<td>265,000 patients</td>
</tr>
</tbody>
</table>

<sup>a</sup>admission rate for first-listed ICD-9 codes 434.11, 434.91 and 436<sup>25</sup> in HCUP Nationwide Emergency Department Sample<sup>1</sup>  
<sup>b</sup>consistent with HCUP Nationwide Inpatient Sample<sup>2</sup> 30-day readmission rate after index stay for acute cerebrovascular disease (CCS 109)  
<sup>c</sup>conservative estimate of intervention success based on proportion of readmissions judged preventable<sup>33</sup> and success of published interventions (Table 2)  
<sup>d</sup>mean cost of readmission within 30 days after index stay for acute cerebrovascular disease (CCS 109), using HCUP Nationwide Inpatient Sample data<sup>2</sup>
SUPPLEMENTAL REFERENCES


