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Recommendations

Mechanical Thrombectomy-Ready Comprehensive Stroke Center Requirements and Endovascular Stroke Systems of Care: Recommendations from the Endovascular Stroke Standards Committee of the Society of Vascular and Interventional Neurology (SVIN)

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Key Words

Acute ischemic stroke · Large vessel occlusion · Mechanical thrombectomy · Systems of care

Abstract

Five landmark multicenter, prospective, randomized, open-label, blinded end point clinical trials have recently demonstrated significant clinical benefit of endovascular therapy with mechanical thrombectomy in acute ischemic stroke (AIS) patients presenting with proximal intracranial large vessel occlusions. The Society of Vascular and Interventional Neurology (SVIN) appointed an expert writing committee to summarize this new evidence and make recommendations on how these data should guide emergency endovascular therapy for AIS patients.

Second-Generation Trials of Endovascular Therapy for Acute Ischemic Stroke

In the MR CLEAN [1], ESCAPE [2], EXTEND IA [3], SWIFT PRIME [4] and REVASCAT [5] trials, acute ischemic stroke (AIS) patients with proven large vessel occlusions (LVOs) were randomized to standard medical care [including treatment with intravenous tissue plasminogen

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Table 1. Summary of recent stroke trials

Trial	Patients	IV tPA	TICI 2B/3	90-day mRS 0–2	
				medical	endovascular
MR CLEAN	500	89%	59%	19%	33%
ESCAPE	315	75%	72%	29%	53%
EXTEND IA	70	100%	86%	40%	71%
SWIFT PRIME	196	100%	88%	36%	60%
REVASCAT	206	73%	66%	28%	44%

Table 2. Summary of the estimated effects of various interventions for heart attacks and stroke in terms of the NNT

a	*NNT to prevent 1 death or dependency at 1 year [32]*	
	Care of an AIS patient in a stroke unit	18
	Aspirin for AIS	83
b	*NNT to prevent 1 stroke at 1 year [32]*	
	Endarterectomy for symptomatic severe carotid stenosis	26
	Anticoagulation for nonvalvular atrial fibrillation	41
	Endarterectomy for asymptomatic severe carotid stenosis	100
c	*NNT to benefit functional outcome*	
	Mechanical thrombectomy in AIS [1, 4]	3–7
	IV tPA in 0- to 3-hour time window for AIS [33]	8
	IV tPA in 3- to 4.5-hour time window for AIS	14
d	*NNT to prevent 1 death at 1 month [34]*	
	IV thrombolysis in 0- to 6-hour time window for STEMI	43
	IV thrombolysis in 6- to 12-hour time window for STEMI	63

activator (IV tPA) for eligible patients] versus standard medical care combined with endovascular mechanical thrombectomy (MT), with favorable neurological outcome measured using the 90-day modified Rankin score (mRS). All trials were stopped early by the respective trials' data safety monitoring boards after interim analyses showed overwhelming efficacy of endovascular intervention.

These trials were conducted at high-volume cerebrovascular centers with extensive experience and proven capabilities in all aspects of the 24/7 care of the complex AIS patient, including expertise in emergency clinical and radiographic evaluation, neurointerventional experience with stent retriever-based MT, neurointensive care units with stroke neurologists, neurointensivists and stroke-trained nursing staff, and neurosurgical management of AIS-related complications. Such experience was critical to achieving the goals of (as stated in the ESCAPE Methods) 'fast treatment times and efficient work-flow' and expert postintervention management, criteria by which the enrolling centers in these trials were selected.

In summary, 5 studies, representing 1,287 randomized patients, provide level 1A evidence in support of endovascular treatment of LVO AIS patients in experienced high-volume stroke centers capable of performing stent-retriever-based MT therapy (summarized in table 1). Moreover, the powerful treatment effect of endovascular MT, as evidenced by a number needed to treat (NNT) of 3–7 for achieving an independent level of neurological functioning, is of a magnitude that few therapies in clinical medicine can claim. For comparison, the NNT for IV tPA in AIS is 8, while the NNT for percutaneous coronary intervention (PCI) compared to systemic fibrinolysis for preventing death in acute coronary syndromes is 30 (see also

table 2). Given the overwhelming benefit of endovascular therapy for LVOs in high-volume experienced centers, it is now imperative that as many patients as possible with this otherwise devastating condition be triaged to centers capable of providing this therapy in the shortest possible time frame. Our great public health challenge is to now translate these trial results into everyday practice while maintaining the high standards of the enrolling centers of these trials.

Impact of Level 1A Data and Unmet Needs

Approximately 700,000 AIS occur annually in the United States, of which 40–45% (280,000–315,000) are estimated to be due to LVOs [6]. In addition, the percentage of AIS due to LVOs is likely growing secondary to the increased prevalence of atrial fibrillation and cervical carotid disease in our aging population. By comparison, the annual volume of aneurysmal subarachnoid hemorrhage (aSAH) in the US is approximately 30,000, less than 10% of the number of LVO AIS patients. More analogous is the incidence of myocardial infarction in the US: approximately 915,000 cases occur annually, of which 30% (~275,000) are due to a disease process best treated with endovascular PCI – ST-segment elevation myocardial infarctions (STEMIs).

Several analyses, however, suggest that the percentage of LVO AIS patients that might currently qualify for endovascular MT in the US might at the most be 20,000 per year [7, 8]. Given the prevalence of LVO stroke in our society, and the availability of now proven interventions, this number is grossly inadequate. Why would less than 10% of all LVO AIS patients qualify for endovascular treatment (compared to approximately 70% of all STEMI patients receiving PCI or IV lytic therapy)? The answer is multifactorial but nonetheless simple: most patients do not currently reach capable endovascular centers before extremely time-sensitive irreversible brain injury has occurred. This delay is related to (1) persistent poor public understanding of life-threatening emergency stroke symptoms and (2) woefully inadequate systems of care. Increasing the number of LVO patients that will qualify for and thus benefit from endovascular therapy will require extensive work to educate the public and to create systems of care that facilitate fast and efficient triage of AIS patients to centers capable of providing comprehensive medical, endovascular and surgical care, including appropriate patient selection, endovascular MT therapy and expert postintervention management. Such systems are akin to those that have evolved for the management of acute trauma and acute myocardial infarction.

Recommendations

The Society of Vascular and Interventional Neurology (SVIN) guideline writing committee is making recommendations for effective application of AIS endovascular therapy using the framework of the '8 Ds' in the Stroke Chain of Survival endorsed in the AHA/ASA 2013 Guidelines for the Early Management of Patients with Acute Ischemic Stroke [9]: Detection, Dispatch, Delivery, Door, Data, Decision, Drug (or other intervention) and Disposition (table 3). Critical components of this effort will include: (1) public health education campaigns regarding stroke symptoms and the availability of highly effective treatment options that are critically time dependent; (2) education of first responders regarding in-field recognition and triage of stroke patients to MT-capable centers in a time-dependent fashion, and (3) continued evolution of the comprehensive stroke center (CSC) model to incorporate specific criteria for receiving and treating LVO AIS patients.

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Table 3. Stroke chain of survival (modified from 2013 AHA/ASA guidelines)

8D approach	
Detection	Patient or bystander recognition of stroke signs and symptoms
Dispatch	Immediate activation of 9-1-1 and priority EMS dispatch
Delivery	Prompt triage and transport to most appropriate stroke hospital and prehospital notification
Door	Immediate ED evaluation ideally by pre notified neurologists; if evaluation done at an outside hospital, direct transport to brain imaging or angiography suite or stroke intervention lab is encouraged
Data	Prompt ED evaluation, stroke team activation, laboratory studies and brain imaging
Decision	Diagnosis and determination of most appropriate therapy; discussion with patient and family
Drug	Administration of appropriate drugs or other interventions
Disposition	Timely admission to stroke unit or intensive care unit, or transfer

Detection and Dispatch

The primary reason most AIS patients do not qualify for treatment (either with IV tPA or MT therapy) is delayed presentation from symptom onset. Public understanding of stroke is poor, with surveys showing that only about half of interviewees can identify common stroke symptoms [10]. Worse yet, identification of stroke symptoms is often not associated with an understanding of their time-sensitive emergency nature, with only about half of all stroke patients utilizing the 9-1-1 EMS system [11]. The most important step towards increasing the number of LVO AIS patients receiving treatment will thus likely involve continued aggressive public health education of stroke symptom recognition, their emergency nature and the availability of proven but time-sensitive treatment options. For example, educational efforts via primary care physicians or public health campaigns could be specifically targeted towards patients with a known increased risk of an LVO AIS (e.g., patients with atrial fibrillation, cardiac valvular disease, cervical carotid disease, or prior embolic stroke). Ultimately, increasing the number of AIS patients receiving treatment will be heavily dependent upon increasing the percentage of AIS patients who seek immediate emergency medical attention for stroke symptoms.

Recommendations

Public health campaigns regarding stroke symptoms, their emergency nature (necessitating use of the 9-1-1 EMS system) and the availability of time-sensitive treatments are needed.

Delivery

The AHA/ASA guidelines emphasize the importance of 'prompt triage and transport to the most appropriate stroke hospital and prehospital notification' of the patient's impending arrival by first responders [9]. Such in-field recognition and triage to specific hospitals has been central to optimizing care of the acute trauma patient and acute myocardial infarction patient. For example, guidelines for EMS evaluation of acute trauma patients stratify patients according to injury mechanism and severity, through which patients are routed to one of five levels of trauma care hospitals, bypassing lower-level trauma centers if necessary [12]. This approach has been noted to improve mortality following motor vehicle crashes [13, 14]. For patients with STEMI, AHA guidelines recommend direct transport to a PCI-ready facility, bypassing hospitals that do not offer that treatment [15]. These recommendations emphasize that the aim of bypass is to reduce times to treatment for PCI and also suggest this method is preferable in patients with a transport time of under 30 min. These guidelines were adopted based on the DANAMI-2 trial that showed the benefit of PCI despite longer travel distances [16].

Table 4. Summary of the prehospital stroke severity scales used for prehospital triage of LVO AIS patients to the most appropriate stroke facility

Name of scale	Initial study location	Sample size, n	Components	Score (cutoff for triage)	Sensitivity/ specificity	PPV/PLR/ NPV/NLR
3-Item Stroke Scale (3I-SS) [35]	Frankfurt am Main, Germany	171	level of consciousness gaze motor: arm and leg	0–6 (>4)	0.67/0.92	PPV 0.74 NPV 0.89
Los Angeles Motor Scale (LAMS) [36]	Los Angeles, Calif., USA	119	face droop arm drift grip strength	0–5 (>4)	0.81/0.89	PLR 7.36 NLR 0.21
Texas Stroke Intervention Prehospital Stroke Scale (TSI-PSS or LEGS score) [37]	Dallas-Fort Worth, Tex., USA	174	leg strength eye fields gaze speech/language (also called LEGS score)	0–16 (>4)	0.66/0.76	PPV 0.52 PLR 2.73 NPV 0.85 NLR 0.45
Rapid Arterial Occlusion Evaluation Scale (RACE) [38]	Barcelona, Spain	654	face droop motor: arm and leg gaze language/aphasia agnosia	0–9 (>5)	0.85/0.68	PPV 0.42 NPV 0.94

PPV = Positive predictive value; NPV = negative predictive value; PLR = positive likelihood ratio; NLR = negative likelihood ratio.

Similar triage systems for AIS patients, with an emphasis on improved in-field stroke recognition and transportation of LVO AIS patients to the 'most appropriate stroke hospital' (a high-volume MT-capable facility described below) rather than the 'nearest stroke hospital', are now necessary. Though stroke triage may be more challenging due to the absence of an objective test in the field (e.g., an EKG for STEMI), simple clinical examination skills may help to triage the more severe strokes. Such basic clinical examination skills have been standardized as part of several prehospital stroke severity scales (summarized in table 4), and have been studied or utilized by different EMS agencies across the world. Most of these scales allow for a relatively high sensitivity of detecting an LVO AIS patient in the field.

The goal is to identify and triage as many LVO AIS patients rapidly to the 'most appropriate facility' with comprehensive stroke care, including endovascular MT. The strict analogy to the acute trauma and STEMI patient suggests that these more evolved triage systems provide an ideal template for one focused on the acute stroke patient.

Recommendations

The American Heart Association's 'Mission Lifeline' project [17] states that one of its main goals is 'to create STEMI systems of care and improve existing ones to ensure prompt, seamless, effective treatment to STEMI patients'. A similar multisociety collaborative approach should be created to drive development of LVO AIS systems of care. A reasonable model would be to consider a triage system based upon the severity and duration of symptoms: all patients within the time window for IV tPA treatment might best be delivered to the nearest stroke center unless the added transport time to an endovascular capable hospital is less than 30 min, whereas all patients ineligible for IV tPA due to symptom duration might best be triaged directly to the nearest endovascular-capable hospital.

Door, Data, Decision, Drug and Disposition

Door, data, decision, drug and disposition encompass the critical management steps that begin once the AIS patient arrives at the receiving hospital. These include immediate emergency department (ED) triage to a high-acuity area (Door), prompt ED evaluation, 24/7 stroke team activation, laboratory studies and advanced brain imaging (Data), diagnosis and determination of the most appropriate therapy (Decision), administration of appropriate drugs or other interventions (Drug, and now mechanical endovascular reperfusion), and timely admission to a stroke unit or intensive care unit (Disposition).

The recently completed endovascular stroke trials have clearly demonstrated that high-volume stroke centers are best suited to provide this complex care quickly and efficiently. With regard to acute stroke management, existing criteria for such CSCs by accreditation bodies such as The Joint Commission (TJC), Der Norske Veritas (DNV) or Hospital Facilities Accreditation Program (HFAP) have to date focused on the treatment of AIS patients with IV tPA. Given the level 1A data supporting endovascular therapy for LVO AIS patients, these guidelines should now be revised to incorporate specific criteria pertaining to endovascular management of AIS.

The current eligibility requirements for CSCs (for example, based on current TJC criteria) include seven criteria: patient volume, advanced imaging capabilities, posthospital coordination, dedicated neurointensive care, a peer review process for quality control, participation in stroke research and reporting of performance measures.

Volume

Patient outcomes in disease processes such as acute trauma [18], STEMI [19] and aSAH [20, 21] have been shown to be superior at high-volume facilities. Similarly, higher-volume endovascular stroke centers have lower times to reperfusion and better outcomes with MT [22]. Accordingly, TJC requirements for annual patient volume at CSCs include 20 patients with subarachnoid hemorrhage and 25 AIS patients treated with IV tPA. Given these TJC recommendations for aSAH and IV tPA treatment volumes, along with the prevalence of AIS compared to aSAH, where 85% of all strokes are ischemic in nature, a minimum requirement of 25–30 MT-treated patients per year is recommended. Also, given the association of operator volume and outcomes, each CSC-affiliated neurointerventionalist should have a minimum of 10 MT procedures per year.

Advanced Imaging Capabilities

Current imaging criteria for CSCs include 24/7 availability of CT and CT angiography, MR and MR angiography, and catheter angiography, along with the ability to perform routine carotid duplex ultrasound, transcranial Doppler ultrasonography, extracranial ultrasonography, transesophageal echocardiography and transthoracic echocardiography. All are critical for the management of the LVO AIS patient. In addition, CSCs performing endovascular AIS interventions need the capacity to triage and treat two simultaneous LVO AIS patients, thus necessitating the 24/7 availability of 2 neurointerventionalists, 2 stroke interventional labs and all associated support staff (e.g., radiology technicians, nursing staff).

Stroke centers have traditionally been focused on providing resources and optimizing processes to improve delivery of thrombolytic medications, namely IV tPA. With the advent of cutting-edge clot retrieval devices and recent landmark endovascular stroke trials showing the functional outcome and mortality benefit of stroke intervention, the need for standardization of stroke intervention labs within stroke centers across the country has become paramount. The SVIN has compiled Stroke Interventional Laboratory Consensus (SILC) criteria to help standardize stroke intervention labs within stroke centers in an effort to promote high quality and rapid stroke care. The required elements of a stroke interventional lab are summarized in table 5.

Table 5. Required elements for a Stroke Interventional Lab within a Stroke Center (SVIN-SILC: Stroke Interventional Laboratory Consensus criteria)

8M approach	
Manpower	Essential personnel including medical director, physicians, nurses and radiology technicians
Machines	Appropriate angiographic equipment and facility level resources
Materials	Medical device inventory, angiography room supplies and medications
Methods	Standardized protocols for stroke workflow optimization within hospital and within the stroke interventional lab
Metrics, volume	Annual volume criteria for facilities as well as stroke interventionists to obtain as well as maintain certification or credentials
Metrics, quality	Benchmarks for performance improvement and quality assurance with meaningful measures within the stroke interventional lab
Metrics, safety	Radiation and procedural safety practices
Money	Fair market value compensation standards for physician manpower needs to provide 24/7 coverage of stroke interventional labs

Posthospital Care Coordination

Many LVO AIS patients currently treated at high volume stroke centers are patients transferred from outside hospitals. This system will likely evolve in the future towards direct transport of the suspected AIS patient to a CSC. In either scenario, CSCs need a monitored system that ensures adequate communication with the patient's discharge facility (e.g., to an acute rehabilitation facility) and the patient's local physicians to coordinate long-term care (e.g., acute rehabilitation needs, treatment plan for secondary prevention of stroke). Centers would be best served by cooperative protocols or transfer agreements to transition patients earlier to rehabilitation. Stroke centers should ensure that acute in-patient rehabilitation facilities that receive their patients be adequately resourced and trained in standardized outcome scales. In addition, stroke centers should encourage acute in-patient rehabilitation facilities to obtain appropriate certifications such as TJC stroke rehabilitation certification or Commission for Accreditation of Rehabilitation Facilities (CARF) certification.

Dedicated Neurointensive Care Unit and Expert Neurointensivist and Neurosurgical Management

The TJC requirements for CSC management of aSAH patients and post-IV tPA AIS patients include a dedicated neurointensive care unit and 24/7 in-house expertise in cerebrovascular disease management. The medical management of the LVO AIS patient is equally complex, involving the prevention or management of secondary brain injury (e.g., ischemia-related cerebral edema and/or hemorrhagic conversion), reocclusion and the identification and treatment of the underlying etiology of the patient's presenting LVO. Integral components of such expert management also include early mobilization and aggressive physical, occupational and speech/swallow therapy services. Given the potential for complications (intracerebral hemorrhage, perforation with subarachnoid hemorrhage, etc.) that in some cases require emergent neurosurgical intervention (e.g., external ventricular drain placement, hematoma evacuation, hemicraniectomy) immediate availability of neurosurgical expertise on a 24/7 basis is also critical to the management of these patients.

As with previous studies showing improved outcomes for acute myocardial infarction patients treated in dedicated coronary care units [23], treatment of AIS patients [24], aSAH patients [25] and head trauma patients [26] in a dedicated neurological intensive care unit by a neurointensivist has been associated with improved neurological outcomes. These observations suggest that expert postoperative management of endovascular-treated LVO

AIS patients is a critical aspect of achieving a favorable neurological outcome [27]. 24/7 immediately available in person expertise in cerebrovascular disease management by teams of vascular neurologists or neurocritical care specialists should be required for all endovascular AIS centers.

Peer Review Process

The current JC guidelines require that 'the hospital will have a peer review process to review and monitor the care provided to patients with ischemic stroke, subarachnoid hemorrhage and administration of tPA'. CSCs performing MT interventions for LVOs should incorporate into this process specific performance measures related to the fast and efficient endovascular treatment of these patients (see below). In addition to an internal peer review process, a national database for endovascular performance measures akin to the AHA Get with the Guidelines registry for IV tPA treatment metrics would be useful to gauge individual centers' quality outcomes and identify potential performance improvement measures.

Participation in Stroke Research

The current JC eligibility criteria for CSCs state 'the CSC will participate in Institutional Review Board-approved patient-centered stroke research'. The level 1A data generated by the MR CLEAN, ESCAPE, EXTEND IA, SWIFT PRIME and REVASCAT trials will stimulate numerous future clinical trials focused on optimizing endovascular therapy for LVO AIS patients (e.g., the use of advanced imaging for patient selection especially beyond the conventional time window, the evaluation of novel MT devices, the use of procedural sedation, the impact of preoperative neuroprotective strategies). Experienced high-volume CSCs will remain the optimal setting for such stroke research and provide another important reason for directing AIS patients to CSCs. As part of the performance improvement process within stroke centers, it is essential for a CSC to have a coordinator tasked with maintenance of an endovascular stroke registry or database that would serve not only as a means of quality improvement but also as a source of meaningful clinical data analysis.

Performance Measures

A primary emphasis of the MR CLEAN, ESCAPE, EXTEND IA, SWIFT PRIME and REVASCAT trials was measurement and implementation of fast treatment times and efficient workflow. Performance measures of all aspects of endovascular therapy for LVO AIS patients will be critical for identifying and correcting institutional barriers to fast and safe treatments for these patients. The recent January 2015 JC CSC core performance measures (CSTKs) incorporate some but not all of these variables. Of the 8 core performance measures for CSCs, 3 overlap with all AIS patients (CSTK-01, documentation of presenting NIHSS; CSTK-02, documentation of the 90-day mRS outcome, and CSTK-05, documentation of the overall rate of hemorrhagic transformation of an AIS). Two are unique to CSC performance of endovascular therapy of LVOs: CSTK-07, the median time to revascularization, and CSTK-08, the postintervention TICI reperfusion score.

CSTK-07 requires documentation of the time from hospital arrival to the time of initial MT therapy (e.g., first pass with a mechanical reperfusion device). More granular procedural details, however, would be even more helpful in identifying steps associated with significant delays to treatment, and minimize door to revascularization times. Required documentation of the following procedural metrics is thus recommended:

- First medical contact to hospital arrival
- Time from hospital arrival to stroke team evaluation
- Time from hospital arrival to imaging (if necessary)
- Recommended less than 10 min

– Time from imaging study to groin puncture
• Recommended less than 60 min
– Time from hospital arrival to groin puncture
• Recommended less than 90 min
– Time from groin puncture to first MT attempt
• Recommended less than 30 min
– Time from groin puncture to TICI 2B or better or conclusion of procedure
• Recommended less than 60 min

Other critical procedural data not captured in the current JC CSC performance measures include the following:

– Preoperative ASPECTs score and core infarct volume (on baseline CT or MR)
– Location of LVO on preoperative vascular imaging and initial diagnostic cerebral angiogram
– Preintervention TICI score
– Use of procedural general anesthesia versus conscious sedation
– Postintervention infarct volume
– Endovascular complications
• Intracranial vessel perforation
• Embolization to previously uninvolved territory
• Arterial dissection
• Groin hematoma requiring transfusion or surgical repair

Most importantly, key clinical outcome measures must be obtained and documented, including the following:

– NIHSS at 24 h and hospital discharge
– Symptomatic intracranial hemorrhage
– Discharge destination
– mRS and NIHSS at discharge and 90 days
– Hospital and 90-day mortality

Ongoing peer review of these performance measures should be conducted both internally in any hospital performing MT interventions and against other institutions via a national database, all in an effort to drive continued workflow quality improvement, with the goals of minimizing door to revascularization times and of ensuring safe and effective use of MT therapies. Specific goals for procedural success and procedural safety, along with metrics for clinical outcomes, should be determined, and a peer review process (including both internally and those by accrediting bodies) should be triggered when institutions fail to achieve these goals on an annual basis. Fundamental criteria would include the following:

– Door to groin puncture times of less than 90 min in >75% of patients
– TICI 2B or 3 reperfusion greater than 50% of the time
– Symptomatic intracranial hemorrhage rate of less than 10%
– 90-day mortality rate of less than 25%
– 90-day mRS of 0–2 in greater than 30%

The Necessary Evolution of the CSC Model

The current model for CSCs envisions a single facility with high volumes of both hemorrhagic and ischemic stroke patients. The prevalence and treatment acuity of these two subsets of stroke, however, suggest the need for a divergence in triage and care. Hemorrhagic stroke is less common than ischemic stroke, accounting for only 15% of all stroke. As a general rule, the endovascular or surgical treatment for hemorrhagic stroke (e.g. ruptured cerebral

Table 6. Required elements for AIS Comprehensive Stroke Centers

1	24/7 stroke neurology team available within 15 min either in person or via telemedicine (telephone or telecamera)
2	24/7 neurointerventionalists available within 30 min
3	Advanced imaging capabilities, including 24/7 availability of CT and CT angiography, MR and MR angiography and catheter angiography
4	24/7 neurosurgery coverage available within 30 min
5	24/7 NeuroICU and neurointensivists available within 30 min
6	Capacity to handle two simultaneous acute LVO patients 2 NeuroIR suites or stroke intervention labs (including associated teams of RNs, techs, etc.) 2 available neurointerventionalists
7	Minimum volume requirements Minimal of 30 endovascular MT cases/year Minimum of 10 MT cases per operator per year Minimal of 25 IV tPA cases/year

aneurysm, ruptured arteriovenous malformation) is urgent but not emergent, and such interventions are typically performed within 24 h of arrival to the treating facility. These two factors (uncommon, not requiring immediate treatment) might favor transfer of patients needing highly specialized expertise in aspects of hemorrhagic stroke treatment not available at some endovascular MT-capable centers to centers with added expertise in hemorrhagic stroke management (e.g., surgical clipping), even if the transfer were to require several hours [28]. Relatively few such added expertise hemorrhagic stroke facilities are likely necessary given the overall low volume of these patients.

Ischemic stroke, however, is extremely common, accounting for 85% of all stroke patients. In addition, treatment with either IV tPA or endovascular therapy is extremely time sensitive, and treatment delays (including those associated with patient transfer) need to be minimized as much as possible. While in-field evaluation and triage to an endovascular-capable hospital is one important way to minimize treatment delays, the availability of more MT-capable hospitals that can directly receive acute stroke patients from EMS (e.g., within 30–45 min of EMS triage) will prove central to effective treatment of these patients.

Given the rare nature of aneurysmal SAH, however, it is unlikely that all MT-capable hospitals with sufficient AIS volume could also meet aSAH volume criteria for CSC status as currently defined. The concept of the CSC should thus evolve to accommodate the emerging need for more regional MT-capable hospitals that will not have substantial aSAH volume. One possible model would be to designate CSCs capable of fulfilling endovascular AIS and all other aspects of ischemic and hemorrhagic stroke treatment criteria, but not those for aneurysmal SAH clipping, and CSCs capable of fulfilling criteria for both aneurysm clipping and endovascular AIS treatments. EMS transport to the nearest MT-capable CSC stroke center could then most efficiently triage ischemic stroke patients; patients found to have aSAH in which surgical clipping is deemed necessary could be stabilized and then transferred to the nearest CSC facility with aneurysm clipping capabilities (see table 6 for a summary of the proposed necessary elements for all AIS comprehensive stroke centers).

Conclusions

Twenty years have passed since IV tPA was first shown to provide benefit to AIS patients, becoming the first and only approved treatment for AIS. Despite disappointment with initial clinical trials that failed to show benefit in unselected patients treated with intra-arterial

Table 7. Summary of recommendations

1	Endovascular MT, in addition to treatment with IV tPA in eligible patients, is recommended for anterior circulation large vessel occlusion ischemic strokes in patients presenting within 6 h of symptom onset (level 1A evidence)
2	Public health campaigns regarding stroke symptoms, their emergency nature (necessitating use of the 9-1-1 EMS system), and the availability of time-sensitive treatments are needed
3	Systems of care focused upon the out-of-hospital triage and transport of patients to specialized treatment centers are now required for ischemic stroke, analogous to systems that have evolved for STEMI and trauma patients; a multisociety collaborative approach akin to the American Heart Association's 'STEMI Mission Lifeline' project [17] could help drive development of such LVO AIS systems of care
4	Endovascular MT-capable hospitals should meet specific requirements regarding AIS and endovascular case volume, infrastructure, 24/7 imaging and clinical expertise, efficient workflow and procedural and clinical outcomes, all followed with specific performance measures as outlined
5	The CSC model must evolve given the marked differences in both the prevalence and treatment acuity of acute ischemic stroke compared to aSAH; the number of MT-capable hospitals necessary to treat LVO AIS patients will likely be far greater than the number of centers required to treat the relatively low volume of aSAH patients; two categories of CSCs are thus likely necessary: those centers that have high volumes of AIS patients alone and those centers that remain referral centers of hemorrhage stroke as well

lytics and/or first-generation endovascular devices [29–31], several prospective randomized trials have now provided powerful level 1A evidence of overwhelming efficacy of endovascular MT with stent retriever devices in LVO AIS patients at experienced high-volume stroke centers. Endovascular acute stroke therapy has thus changed almost overnight from a treatment with unclear benefit to a patient's best opportunity for avoiding death or major neurological disability, a treatment now becoming the standard of care.

This patient population, however, currently remains dramatically underserved, with fewer than 10% currently receiving this powerful intervention. To substantially increase the percentage of patients receiving endovascular therapy for their LVO stroke will require significant public health and infrastructure investments, from patient education to creation of regional triage systems of care with more endovascular MT-capable hospitals (see table 7 for a summary of these recommendations). While an enormous challenge, such efforts have the potential to dramatically impact the lives of numerous patients facing a terrible disease associated with significant death and disability.

Disclosure Statement

J.D.E. reports consulting work with Stryker Neurovascular, Medtronic and Silk Road Medical. D.R.Y. reports consulting work with Aldagen/Cytomedix and Medtronic, is a steering committee member for the SWIFT Prime Trial, a DSMB member for the ESCAPE trial, and a co-principal investigator for the RECOVER-Stroke trial. R.G. reports consulting work with Stryker Neurovascular, Medtronic, Rapid Medical, and Penumbra, and royalties from UpToDate. He is also the Associate Editor of the *Journal of Neurointerventional Surgery*, the *Journal of Neuroimaging*, and *Interventional Neurology*. He receives grant support from Zoll, Penumbra, Medtronic, Stryker Neurovascular and the Wellstar Foundation. O.O.Z. reports consulting work with Stryker Neurovascular, Penumbra, and Medtronic, is on the steering committee for THERAPY and DEFUSE 3 clinical trials, is an NIH STROKENET endovascular committee co-chair, and is the PI for ARISE II embotrap stent retriever trial and the PI for the ATLAS aneurysm stent study. R.G.N. is Trevo-2 and DAWN Trials Principal Investigator for Stryker Neurovascular; he is also on the SWIFT and SWIFT Prime Trials Steering Committee and the STAR Trial Angiographic Core Lab of Covidien, in the 3D Separator Trial Executive Committee of Penumbra Inc. and is a member of the Stroke Trial DSMB of Rapid Medical. Furthermore,

he is Editor-In-Chief of the journal *Interventional Neurology*. T.G.J. reports consulting work with Silk Road Medical, Blockade Medical and Codman Neurovascular, is an advisory board member with Medtronic, and a PI of the Styrker Neurovascular-sponsored DAWN clinical trial. V.J., A.R.X. and J.F.K. report no relevant disclosures.

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