Consistently Achieving Computed Tomography to Endovascular Recanalization <90 Minutes
Solutions and Innovations

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Time is brain. Recent data from the Intervventional Management of Stroke Trial 3 (IMS3) and other studies have provided further data to support this.¹⁻³ Data from IMS3 suggest that a 30-minute delay in recanalization reduces the average absolute rate of a good outcome by 11%.

Mazighi et al² have demonstrated a relationship between delays and increased mortality. A similar analysis from the Solitaire FR Thrombectomy for Acute Revascularization (STAR) Study data set suggests a 38% relative reduction in good outcome by a 1 hour delay in recanalization.² Rate of cell death has been estimated to be ≈2 million neurons/min in M1 occlusion.⁴ Currently in the United States, the mean time from symptom onset to groin puncture is 6 hours with an additional hour to achieve revascularization.⁵ It is clear that we as a collective need to improve overall workflow in endovascular management of acute large vessel ischemic stroke.

We have demonstrated that computed tomography (CT) head to reperfusion within 60 minutes is achievable.⁶ However, the process of achieving this metric requires some key processes to be in place. These include the presence of an organized emergency team to evaluate and stabilize vitals, secure airway, register the patient into the hospital information system, make a complete but quick clinical assessment, understand the patient’s premorbid status, expectations of outcome, advance directives, contraindications to treatment (and participation in trials), and need for ventilation/anesthesia support. Imaging needs to be geared up toward efficiency and rapid decision making. The key imaging components are rule out an intracranial bleed (and other intracranial conditions such as a tumor or subdural hemorrhage), identify that the patient has a small core of infarction and a proximal vessel occlusion on CT angiography. Other considerations may include anatomy (does the patient have aberrant anatomy or pathology that may influence endovascular access), presence of penumbras/collaterals. Intravenous tissue-type plasminogen activator (tPA) needs to be administered based on standard of care but without creating any delay in the effort toward achieving reperfusion. Assuming that the patient is suitable for the endovascular procedure (or an acute endovascular trial), the next steps include obtaining consent, getting the cath laboratory team together, organizing anesthesia if necessary, transporting the patient to the angiography suite, getting the angiography suite organized, having the patient prepared using standard antiseptic techniques, access the vascular system and the clot, and finally achieve optimal reperfusion. During this procedure, maintenance of the patient’s vitals and use medications as necessary to hold the patient still should help expedite the workflow and not delay it. After the procedure, the patient needs to be transferred to a monitored unit run by trained personnel (stroke unit, intensive care unit) for postprocedure care with planning toward rehabilitation. Below, we highlight innovations in the conduct and administration of this workflow that has helped us achieve our goal of quick and efficient reperfusion in patients with acute ischemic stroke.

Parallel Processing, Trust, and Teamwork
This, in our opinion is the single most important component of success.⁷,⁸ A single person or a group of individuals from 1 discipline cannot achieve successful endovascular treatment of stroke consistently. We have divided the team into 2 key components: the stroke team and the endovascular team. The anesthesia team is added as needed. The emergency room staff are a key component for the initial evaluation and stabilization. The stroke team on call is prenotified and they meet the patient at the door to the emergency. At this stage they take an expeditious history, a quick examination, quantify the National Institutes of Health Stroke Scale, get medical history, and establish a rapport with the family. In parallel, a member of the team notifies the CT scanner and the neurointerventionists. The teams converge in the CT suite as this is the point of decision making. Imaging acquisition and interpretation are streamlined (more details below). Intravenous tPA is administered in the imaging suite after the plain CT. In the meantime additional imaging is performed. The decision of eligibility for endovascular (or a trial) is taken collectively. At this stage, the stroke team gets consent, whereas the neurointerventionist moves to the angiography suite to plan and prepare for the procedure (they participate in the consent process as necessary). Members of the stroke team monitor and manage the patient during the procedure. The team manages...
complications, outcomes, and postprocedure care collectively. The diagnosis and treatment are performed in parallel by members of both teams to maximize the use of limited time. Trust and teamwork are essential.

Prenotification
We have helped organize and train local Emergency Medical Services staff to first, recognize major strokes; second, prenotify the stroke team through a centralized paging system; and finally, to bring all such patients directly to the Foothills Hospital irrespective of their location within the city. As such, we uncommonly see any drip and ship patients. Delays introduced by the drip and ship paradigm have been shown within the IMS3 data.9 Prenotification allows for better preparedness of the emergency room staff.

Fast Minimalist Clinical Examination
From a decision-making perspective, we have found that a quick and focused neurological examination is all that is needed especially in severe strokes because of large vessel occlusion. We continue with our examination as the patient is moving from door to emergency department and to CT. We use the provincial electronic medical record system to gather past information about the patient while the patient is getting imaged. This method of acquiring clinical information while patient is moving along the workflow path saves time. Whether the patient has an National Institutes of Health Stroke Scale score of 17 or 19, in our experience does not influence decision making. Of course, from the perspective of studies and trials it is important that there be precise quantification of National Institutes of Health Stroke Scale. As such we find that these can be completed in parallel before or after the CT scan as other things are going on. We do recognize that there is a cost to fast minimalist clinical exams; we may occasionally miss important diagnosis. Nonetheless, such alternative diagnoses are epidemiologically rare. In addition, our imaging paradigm (detailed below) makes this a unlikely scenario especially in the presence of a proximal vessel occlusion on a CT angiogram. In addition, we have instituted a active quality assurance process where the entire team meets once a week to discuss all cases including a detailed discussion on workflow, imaging, errors, and potential improvements, and also use this as an opportunity to teach and learn.

Fast, Minimalist Imaging Based on a Decision-Based Paradigm; No Complex Post Processing of Imaging
Our imaging protocol includes a noncontrast CT head and a multiphase CT angiography (patent pending). It is important to optimize CT head quality to be able to appreciate early ischemic changes. It is imperative to view the images on a high-quality screen with narrow window width and appropriate window level (usually a window width of 50; window level of 35 is a good starting point). The head CT allows for exclusion of hemorrhage and extensive early ischemic changes (large core). These are viewed on the CT console and a decision to treat with intravenous tPA is taken. Although intravenous tPA is being administered (if appropriate), we proceed with a multiphase CT angiogram. The multiphase CT angiography allows for detection of proximal vessel occlusion, allows for discriminating carotid occlusion from a 99% stenosis (identify a slow trickle of contrast in the second phase), determine the precise length of thrombus (proximal end in first phase; distal end in later phases), and finally evaluate collateral circulation. Collateral evaluation is useful in quick determination of degree of flow to the ischemic brain.10-13 In addition, the presence of good collaterals correlates well with the Alberta Stroke Program Early CT Score (ASPECTS) score. Patients with good ASPECTS score (small core) have good collaterals (this makes intuitive sense as well).14,15 Nonetheless, ASPECTS interpretation becomes less reliable in the early presenters or when the CT image is marred by movement or other artifact.16 Collateral interpretation therefore serves as a check on ASPECTS interpretation. The 2 modalities together help us make the decision. We have derived an easy intuitive collateral scoring system (http://www.aspectsinstroke.com/collateral-scoring/introduction/). An additional advantage of this approach is that there is no need for transfer of images to another workstation or need for complex postprocessing. In our experience, CT angiogram is not significantly affected by patient motion and it does not suffer from the variability of CT perfusion based on vendor, arterial input function, imaging protocol, and postprocessing software.11 Evidence suggests that the CT angiogram can be done quickly (consistently within 5 minutes in our opinion), allowing significant time saving and expediency.9,17 We use the following paradigm: small core based on head CT (good ASPECTS score), proximal vessel occlusion, and good collaterals and use a Bayesian approach to decision making.18 The probability of salvageable brain tissue among patients with a blocked proximal artery, favorable noncontrast CT scan, and good collaterals on multiphase CT angiogram is high. Therefore, because the post-test probability after an additional diagnostic test such as computed tomography perfusion or MRP is unlikely to change, these tests may not be needed for decision making. This Bayesian approach emphasizes that in this clinical situation of major ischemic stroke, only semiquantitative/qualitative information is needed to make a treatment or trial-enrollment decision. We acknowledge that other imaging paradigms including those based on perfusion imaging (CT and MRI) are useful in selecting the right patients for therapy; it is important that such imaging paradigms align well with the principle of fast imaging, post processing, and decision making.

Use the CT Angiography to Plan the Procedure
We use the CT angiography for planning of the endovascular procedure. An analysis of the arch allows a precise determination of what kind of catheter would be needed to access the carotid. An evaluation of the carotid bifurcation can be used to determine where the balloon guide catheter should be placed. An assessment of the circle of Willis and tortuosity can be used to determine the need for a distal access catheter and length and size of the stentriever, and the possibility of using direct thrombus aspiration as the primary intervention.19 A combination of the early ischemic changes, distribution of collaterals, and size of the relevant M2 branches can help determine which M2 would be the preferred one to access.
Consent for Procedure and Trials

A standardized approach of going through the natural history and summarizing known knowledge and results of recent trials helps the process. We practice the consent process with our trainees so that they are well versed with it. We have additionally created a training module for our trainees that also covers answers to the commonest questions from the patient’s family. The key components in this training are (1) a brief summary of the results of recent randomized controlled trials. For expediency, we limit these results to IMS3. (2) A brief summary of evidence-based standard of care based on current guidelines. (3) If needed, a brief description of why randomized controlled trials are necessary. We often encourage the use of examples. The most commonly used example is to quote the randomized controlled trial that led to the approval of intravenous tPA and how 20 years ago, patients agree to participate in the trial.
Anesthesia

We rarely use general anesthesia for multiple reasons. First, it saves time. Second, there are data to suggest that general anesthesia may be potentially harmful. Third, we find that with the current generation of stroke devices and with pre-existent knowledge of the vascular anatomy from the CT angiogram, we are able to successfully and safely open vessels in spite of some degree of patient motion. Finally, performing these procedures awake allows patient evaluation and examination during the procedure. This is especially useful if the thrombus breaks and after the M1 is open, one finds that a distal MCA branch is still occluded. Doing a physical examination halfway through the procedure can help in determining whether it is worthwhile to go after it. Because the stroke team stays with the patient throughout the procedure there is always a neurological expert available to evaluate the examination.

Setting Up the Angiography Room

We have a standardized stroke kit that is ready to go. As such we have a stroke table laid out with all the necessary materials such as cleaning solution, drapes, and puncture set. In addition, we have standardized, as much as possible, the catheters and devices that are used. We find that in nearly all anterior circulation strokes, we use an 8F sheath, a balloon guide catheter, an inner catheter in a coaxial fashion to access the arch, a 021 microcather and a stentriever. Using this standardized approach saves time not only for the operator but also for the technologists who do not have to search for materials (catheters, wires, etc) for the procedure.

Cross Training of Angiography Staff

We do most of our procedures with the help of a technologist and a nurse. We found that cross training of the staff as much as possible helps especially after hours. As an example, we have trained our nurses about various catheters so that they can pull them off the shelf and trained our technologists how to set up the pressure bags.

Take Safe Short Cuts When You Can

At the time of endovascular procedure, we keep restoration of blood flow in the brain as the highest priority. We have taken many short cuts. For example, we no longer shave the groin. We often do not put in a Foley’s catheter (especially in older male patients) till after the stentriever has been deployed. In our typical aneurysm coiling patients we add heparin to male patients) till after the stentriever has been deployed. We often do not put in a Foley’s catheter (especially in older many short cuts. For example, we no longer shave the groin. We often do not put in a Foley’s catheter (especially in older

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