Computed tomography perfusion–based selection of patients for endovascular recanalization

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Intravenous and intraarterial recombinant tissue plasminogen activator remains underutilized in the treatment of acute ischemic stroke, largely due to strict adherence to the concept of the therapeutic time window for administration. Recent efforts to expand the number of patients eligible for thrombolysis have been mirrored by an evolution in endovascular recanalization technology and techniques. As a result, there is a growing need to establish efficient and reliable means by which to select candidates for endovascular intervention beyond the traditional criteria of time from symptom onset. Perfusion imaging techniques, particularly CT perfusion used in combination with CT angiography, represent an increasingly recognized means by which to identify those patients who stand to benefit most from endovascular recanalization. Additionally, CT perfusion and CT angiography appear to provide sufficient data by which to exclude patients in whom there is little chance of neurological recovery or a substantial risk of postprocedure symptomatic intracranial hemorrhage. The authors review the current literature as it pertains to the limitations of time-based selection of patients for intervention, the increasing utilization of endovascular therapy, and the development of a CT perfusion-based selection of acute stroke patients for endovascular recanalization. Future endeavors must prospectively evaluate the utility and safety of CT perfusion-based selection of candidates for endovascular intervention. (DOI: 10.3171/2011.4.FOCUS10296)

Key Words • acute ischemic infarct • computed tomography perfusion • endovascular recanalization • recombinant tissue plasminogen activator

Despite the recent advances in imaging techniques and the evolution of endovascular intervention, stroke has remained the third leading cause of death within the US.7,45 Ischemic stroke also represents the leading cause of disability, as one-third of the 730,000–760,000 individuals who are afflicted each year will be left permanently disabled.7,45 In the 14 years following the approval of rt-PA for use in the treatment of acute stroke by the US FDA, approval has been granted in nearly every country.65 Unfortunately, underutilization of the drug has remained a persistent problem, with only 3%–8.5% of stroke victims receiving intravenous rt-PA.51 In a vast majority of patients, the primary barrier preventing the use of rt-PA is the narrow therapeutic time window within which the drug must be administered.2 Strict adherence to time limitations bars most patients from thrombolysis, as there is rarely sufficient time for symptom recognition, transport to a medical facility, diagnosis, evaluation of exclusion criteria, and intervention. Additionally, 16%–28% of patients with ischemic stroke awaken with their deficits, thereby preventing identification of the time of symptom onset.15,53 Unfortunately, in these patients, the time of symptom onset is equated with the time the patient went to sleep, the “time last seen well,” thereby excluding them from thrombolytic therapy.15,44,53

An exhaustive search of the existing literature suggests that successful vascular recanalization maximizes the opportunity to reduce mortality and improve functional outcome.52 Unfortunately, additional shortcomings of intravenous rt-PA include low rates of recanalization and high rates of vessel reocclusion. Angiographic evaluation of patients with an NIHSS score ≥ 10 revealed that more than 80% of patients have a persistent arterial occlusion after the administration of intravenous rt-PA, with only 10% of internal carotid artery and 25% of proximal middle cerebral artery occlusions partially or complete-
ly recanalizing. Furthermore, reocclusion occurs in as many as 34% of cases. In light of these persistent limitations of intravenous rt-PA therapy, research has focused on developing additional interventions to improve the outcome in acute ischemic stroke.

Perhaps no advancement in any area has been as significant as the development of endovascular intervention and intraarterial thrombolysis. Using cerebral angiography, neurosurgeons and interventionalists have developed both pharmacological and mechanical interventions for the treatment of major vessel occlusion. Endovascular intervention offers clear advantages in the management of stroke, including direct assessment of the occluded vessel, focused delivery of thrombolytics to the point of occlusion, and the ability to directly evaluate the result of treatment. In addition to balloon angioplasty and stent placement, advances in technology have led to the development of multiple mechanical devices that use agitation, aspiration, and snaring of the thrombus to recanalize large caliber vessels. Most importantly, the evolution of endovascular surgery has extended the therapeutic window for intervention (http://clinicaltrials.gov/ct2/show/NCT00359424?term=IMS+III&rank=1).27,28

Current Guidelines for Intravenous and Intraarterial Thrombolysis

Current guidelines for intravenous and intraarterial thrombolysis are centered around the concepts of the therapeutic window of intervention and the risk of hemorrhagic complications after thrombolysis. The National Institute of Neurological Disorders and Stroke study strictly established a 3-hour period from the time of symptom onset as the therapeutic window within which intravenous rt-PA could be administered. Due to the limited practicality associated with such a narrow window for drug administration, significant research efforts explored the possibility of extending the time interval.

The results of a pooled analysis of 6 individual studies, published in 2004, suggested that the beneficial effect of rt-PA could be observed beyond 3 hours. In 2008, The Safe Implementation of Thrombolysis in Stroke Treatment Registry (SITS-ISTR) retrospectively compared outcomes between patients treated with rt-PA under 3 hours with those treated in the 3–4.5-hour window. The analysis showed the groups to display no significant differences in symptomatic intracranial hemorrhage, mortality rate, or independence at 3 months, thus suggesting intravenous thrombolysis could be used safely beyond the 3-hour window. Although earlier randomized prospective trials evaluating the effectiveness of intravenous thrombolysis beyond the 3-hour window failed to show benefit, the results of the European Cooperative Acute Stroke Study (ECASS) III demonstrated a significant improvement in outcome when rt-PA was administered in the 3–4.5-hour window. These findings prompted the American Heart Association and American Stroke Association to revise the guidelines in 2009, thereby extending the treatment window from 3 hours to 4.5 hours from the onset of symptoms.

The concept of a therapeutic window is not limited to intravenous administration of rt-PA, and the time window limiting endovascular intervention continues to be a source of debate. One of the greatest limitations to endovascular intervention resides in its relatively low availability within the community, as the vast majority of providers are most commonly found in large tertiary academic centers. In addition to the initial evaluation and diagnosis, a significant amount of time may also be lost in transport to a facility with endovascular capabilities, thereby limiting the utility of intraarterial interventions. Currently, the American Heart Association guidelines have established a 6-hour therapeutic window for intraarterial thrombolysis. This time limit was derived from data emanating from the prospective, randomized, placebo-controlled Prolyse in Acute Cerebral Thromboembolism (PROACT II) study in which patients treated with intraarterial prourokinase within 6 hours of symptom onset experienced improved outcomes (40% vs 25%, respectively) and higher rates of vessel recanalization (66% vs 18%, respectively) when compared with the control population.

The therapeutic window for endovascular mechanical recanalization is less defined and embolectomy via clot retrieval device has only been studied in 2 prospective nonrandomized trials. The Mechanical Embolus Removal in Cerebral Ischemia (MERCi) trial enrolled patients ineligible for intravenous rt-PA who presented within 8 hours of symptom onset and with large-vessel occlusions. The multicenter MERCi trial examined a similar patient population treated with various clot retrieval systems, while also including patients who had not improved with the administration of intravenous rt-PA. When compared with the rates of recanalization in the PROACT II study, mechanical thrombolysis resulted in higher rates of recanalization within 8 hours of symptom onset. Based on this finding, the FDA approved the use of the Merci Retriever in cases of acute stroke, but the benefit of the device on clinical outcome remains unknown.

Thus, the advent of mechanical recanalization has potentially extended the therapeutic time window in which revascularization can be safely performed.

These temporal guidelines are based on clinical criteria, neurological examination, and the potential for symptomatic intracranial hemorrhage following the administration of thrombolytics. Unfortunately, the underlying pathophysiology of stroke and an evaluation of tissue salvagability are not included in these treatment protocols. As the pharmacological and technological evolution of endovascular neurosurgery continues to expand the therapeutic window, reliable identification of appropriate candidates for intervention has become increasingly important. With the widening time window, the risk of symptomatic intracranial hemorrhage also has the potential to increase. Furthermore, in the absence of vascular imaging, patients that have no possibility of benefiting from thrombolysis, such as those with “stroke mimics” and completed infarcts with no salvageable tissue, receive intravenous rt-PA or undergo an endovascular procedure. Concurrently, those with salvageable tissue and the potential of receiving the greatest benefit from thrombolysis go untreated due to their presentation outside of the window. This time window varies with each patient and depends mainly on the presence of salvageable tissue.
and quality of the collateral vessels, which will determine the size of the penumbra compared with the core infarct. As a result, rapid evaluation of the acute stroke patient has evolved to include noninvasive imaging techniques to assist in the prediction of clinical outcome, the determination of tissue viability upon presentation, and the estimation of ultimate infarct size. Central to this effort has been the increasing sophistication of CT scanning, particularly in the field of CT angiography and CT perfusion.

**Radiological Evaluation of the Acute Stroke Patient**

The relatively wide availability of modern CT scanners within the community and the relatively short acquisition time needed to generate meaningful data renders CT the ideal modality for imaging the acute stroke patient. The use of CT perfusion in the management of acute stroke was first described in 1980 by Axel, yet its practical application to patient care was not possible due to the limited technology of those early imaging systems. The technological evolution that has occurred now makes it possible to identify the location of a thrombus within the vasculature while also evaluating the viability of the brain tissue. These advances have led to the development of imaging protocols by which acute stroke patients are emergently evaluated upon admission. Briefly, we discuss a commonly described protocol for the incorporation of CT angiography and CT perfusion data into the diagnosis and management of the acute stroke patient.

Prior to any intervention, a noncontrast CT scan is routinely obtained to identify hemorrhage, chronic ischemic disease, and intracranial mass lesions that may have induced a seizure, thereby representing a "stroke mimic." At present, a noncontrast CT scan remains the only imaging study required for the selection of candidates for thrombolysis. The noncontrast CT scan should be performed within 1 hour of thrombolytic therapy to avoid the development of hemorrhage and infarction that may occur between the time of imaging and intervention. The identification of any intracerebral hemorrhage on the noncontrast CT scan immediately excludes the patient as a candidate for thrombolysis.

The fact that the patient is already in the CT scanner allows for rapid acquisition of CT angiography and CT perfusion images. A CT angiogram should include the vasculature from the aortic arch through the intracranial circulation to identify the site of vessel occlusion and sources of thromboembolism, while also evaluating for the potential presence of collateral circulation. Finally, CT perfusion is used to assess the volumes of the infarct core and penumbra. The data from these 3 studies is interpreted and, along with the neurological examination results, used to determine candidacy for intraarterial thrombolysis.

Within the community there is undoubtedly resistance to the use of iodinated contrast for the acquisition of CT angiography and CT perfusion images. It should be noted that the newer generations of CT scanners are capable of generating high quality images with lower doses of contrast. Additionally, the incidence of contrast-induced nephropathy has been shown to be extremely low, with a recent study of 481 patients undergoing CT angiography, cerebral angiography, or both, identifying only 7 (3.3%) of 244 eligible patients with evidence of mild nephropathy.

**Computed Tomography Perfusion: Technical Considerations**

The term cerebral perfusion refers to the blood flow within the capillary networks of the brain. Computed tomography perfusion, a dynamic imaging modality, captures quantitative data pertaining to the measurement of CBF and CBV. This advantage is derived from the linear relationship between contrast concentration and attenuation in CT imaging. As a result, the volume of contrast agent within a vascular distribution may be calculated by imaging the related transient increase in attenuation as it passes through the tissue. Modern imaging systems interpret this data, create time-versus contrast-concentration curves based on the selection of an "input artery" and "vein," and quantify cerebral perfusion in terms of 3 parameters: CBF, MTT, and CBV. Cerebral blood flow represents the volume of blood that passes through a volume of brain tissue within a given unit of time (ml of blood per 100 g of brain tissue per min). Mean transit time measures the average amount of time that it takes blood to flow through a region of brain (seconds), while CBV is defined as the total volume of blood in a region of brain (ml of blood per 100 g of brain tissue).

In the setting of acute stroke, this model, in conjunction with an understanding of the concept of cerebral autoregulation, can be used to differentiate between the irreversible core of infarction and the ischemic penumbra. Infarcted tissue, which lacks autoregulation, demonstrates decreased MTT and CBV, while vessels within the salvageable penumbra maintain autoregulation of blood flow. In these areas, MTT is increased, while CBV is also preserved. Clinically, this distinction is of the utmost importance, as emerging evidence suggests that the mismatch between core and penumbra may exist as long as 12–24 hours from the onset of symptoms, thus extending the therapeutic window far beyond the current limitations.

**Computed Tomography Perfusion: Identification of the Candidate for Thrombolysis**

The predominant flaw in treating acute stroke patients based on the concept of a strict therapeutic window is the inability to evaluate for the presence of a salvageable ischemic penumbra. There is great variability in the volume of penumbra among individual stroke patients due to the percentage of vessel lumen occlusion, the caliber of the obstructed vessel, and the presence or absence of collateral circulation. Thus, patients presenting within 1 hour of symptom onset may have no penumbra, while others presenting at much later time points may have a large volume of viable tissue. Accurate identification of each population is paramount to successful treatment.

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of acute stroke, to both maximize the number of salvageable patients receiving intervention and to exclude those who would only inherit the risk of intracranial hemorrhage without the prospect of improvement.

In light of recent efforts to extend the length of the therapeutic window, it has become even more critical to determine the effectiveness of CT perfusion in identifying those who remain thrombolysis candidates beyond the current time limitations. Of the 3 variables described above, the size of the infarct core on CT perfusion appears to be the strongest predictor of clinical outcome in patients receiving intraarterial thrombolysis. Gasparotti et al.,17 in their retrospective review of 42 patients receiving endovascular recanalization within 3–6 hours of symptom onset, found infarct core size to be a more relevant determinant of clinical outcome than penumbra and total perfusion deficit volume.

In a study of 22 consecutive patients treated with intraarterial thrombolysis for a middle cerebral artery stem occlusion within 6 hours of symptom onset, Lev et al.19 showed that the volume of the infarct core on CT perfusion significantly correlated with the final infarct volume. This correlation was strongest in those patients in whom complete recanalization was achieved. Furthermore, infarct volume on admission CT perfusion was found to correlate with clinical outcome as measured by the mRS score, but not with the initial NIHSS score. For those patients presenting with a CT perfusion infarct core > 100 ml, the predictive value for a poor clinical outcome was 100%, while those with an infarct core < 100 ml had a 77% positive predictive value for a good clinical outcome. Although further analyses are needed, these results suggest that the volume of infarct core on CT perfusion is a more accurate predictor of clinical outcome than the NIHSS score.

Wintermark et al.62 investigated the prognostic accuracy of CT perfusion in a study of 22 acute stroke patients (8 of whom were status post thrombolytic therapy) by examining the correlation between admission CT perfusion data and diffusion-weighted MR imaging performed at an average of 3 days postinfarct. Where postinfarct MR angiography demonstrated persistent arterial occlusion, the total volume of ischemia on admission CT perfusion (infarct and penumbra) correlated with the average volume of diffusion restriction on diffusion-weighted MR imaging. In cases of recanalization, infarct volume on admission CT perfusion was greater than or equal to the infarct volume on diffusion-weighted MR imaging, while the volume of diffusion restriction was significantly smaller the total area of ischemia on CT perfusion. Importantly, the admission NIHSS score correlated with the size of the ischemic lesion on CT perfusion, thus providing insight into the clinical prognosis. These studies suggest that CT perfusion reliably assesses the volume of irreversible infarction and accurately predicts the clinical outcome in potential candidates for endovascular recanalization. (Figs. 1 and 2)

**Perfusion-Based Identification of Endovascular Candidates: Long-Term Outcomes**

There are multiple measures of outcome following endovascular thrombolysis of the acute stroke patient. Recanalization rate, the development of intracranial hemorrhage, improvement in the NIHSS or mRS score, and mortality rates are among the most commonly evaluated variables within the literature. In light of efforts to extend the therapeutic window for endovascular therapy, it has become necessary to compare results between studies utilizing strict time window criteria and those relying on perfusion imaging.

The PROACT I and II studies represent two of the first randomized, prospective trials evaluating intraarterial recombinant prourokinase (r-proUK) treatment within a 6-hour therapeutic window.9,16 Patient selection for intervention was dependent upon presentation within the therapeutic window and perfusion imaging data were not included in the decision-making process. The PROACT I data shows a 57.7% recanalization rate and 30.8% of patients to have an mRS score < 2. Symptomatic intracerebral hemorrhage was found in 15.4% of patients and 26.9% of patients had died at 3 months. The PROACT II study found a slightly higher rate of recanalization (66%) resulting in a greater percentage (40%) of patients exhibiting an mRS score < 2 at 3 months. The patients in the PROACT II study also experienced a lower rate of symptomatic intracerebral hemorrhage (10%) and virtually identical mortality rate at 3 months (26%).16

Natarajan et al.,44 using CT perfusion data as the primary inclusion criteria for endovascular intervention, published their retrospective analysis of 30 patients who underwent endovascular intervention ≥ 8 hours after the onset of stroke symptoms. All patients selected for intervention were chosen based on CT perfusion findings of > 30% relative CBV within the affected hemisphere compared with the unaffected hemisphere. The authors reported a recanalization rate of 66.7%, a value consistent with the results published in the PROACT I and II studies. The fact that only 20% of patients possessed an mRS score < 2 at 3 months, a value considerably lower than those published in the aforementioned studies, may be explained by the expected loss of viable tissue that occurs as time from stroke onset elapses. Furthermore, it is important to note that patients in this study also experienced a 3.5-point decrease in their NIHSS score, a value not measured in the other studies. Finally, the rates of symptomatic postintervention intracerebral hemorrhage (10%) and mortality at 3 months (33.3%) were comparable to the rates observed in patients presenting at least 2 hours earlier, but treated strictly based on time of presentation. Supporting these findings is the retrospective analysis of About-Chebl1 in which the safety and efficacy of intraarterial thrombolysis was compared between patients presenting < 6 hours (early group) and > 6 hours (late group) from symptom onset. All patients were selected for endovascular intervention based on the presence of perfusion mismatch on CT perfusion or MR imaging. Similar rates of symptomatic intracerebral hemorrhage were found between the groups (8.8% early vs 9.5% late), while 30-day mortality was not statistically significant between the groups (29.4% early vs 23.8% late). Perhaps most importantly were the relatively similar functional outcomes between the groups at 3 months as measured by the mRS score (41.2% mRS score ≤ 2 early vs 42.9% mRS...
Selection for endovascular recanalization based on CT perfusion

Fig. 1. Computed tomography perfusion-based selection of an appropriate candidate for endovascular thrombolysis. A 36-year-old woman presented to the emergency room 5 hours after the acute onset of right-sided hemiplegia. Her NIHSS score on admission was 22. The patient received intravenous t-PA and was transferred to our institution without resolution of symptoms. Computed tomography perfusion on arrival exhibited decreased CBF (A) and increased MTT (B) with minimal decreased CBV (C) in the left basal ganglia. A cerebral angiogram (D) showed proximal left-sided M1 occlusion. Two attempts to retrieve the thrombus were made with the Merci retriever, at which point angiography revealed recanalization of the middle cerebral artery (E). The patient was found to have 4/5 motor strength in the right upper and lower extremities after the procedure (NIHSS score = 3).

score ≤ 2 late). These findings demonstrate the utility of perfusion imaging in determining the true salvageability of tissue, regardless of timing of symptom onset.

Utilizing diffusion-weighted MR imaging, and not CT perfusion, to identify potential candidates for endovascular intervention, Janjua et al.29 were still able to show benefit from intervention in patients presenting more than 8 hours after the onset of stroke symptoms. The authors reported a decrease in the NIHSS score of more than 4 points in 72% of the patients selected for intervention. Once again, none of the patients undergoing endovascular recanalization suffered a postprocedure intracranial hemorrhage.

Recently, Hassan et al.24 performed a retrospective evaluation of the efficacy of CT perfusion-guided selection of candidates for endovascular thrombolysis. The multicenter analysis compared outcomes and complications between patients selected for endovascular therapy by CT perfusion criteria versus patients selected based on time elapsed from symptom onset. The authors reported a decrease in the NIHSS score of more than 4 points in 72% of the patients selected for intervention. Once again, none of the patients undergoing endovascular recanalization suffered a postprocedure intracranial hemorrhage.

The DAWN trial (DWI/PWI and CTP Assessment in the Triage of Wake-Up and Late Presenting Strokes Undergoing Neurointervention) is an ongoing multicenter study evaluating the safety and efficacy of perfusion-based endovascular therapy in patients presenting more than 8 hours after symptom onset or in cases of “wake-up” strokes.47 Although not completed, preliminary data emanating from the study has produced results similar to those observed in endovascular intervention occurring within 8 hours of symptom onset. In a stroke population with a mean time of 16.3 hours from last-seen-well to treatment, successful recanalization was achieved in 73% of cases and 161 (83%) of 193 patients had an mRS score < 3 at 3 months. Again, the rates of symptomatic intracerebral hemorrhage (10.4%) and mortality (22%) were comparable to those in patients treated within the 6-hour time window based on timing of symptom onset alone.

Although the existing literature appears to support the utility of perfusion imaging in the selection of candidates for endovascular therapy, the data has been largely generated from retrospective analyses. Future research endeavors must include prospective randomized trials to better evaluate the true effectiveness of therapy, incidence of complications, and long-term outcome of endovascular revascularization in the ischemic stroke population presenting outside of the traditional therapeutic window.
a significant ischemic penumbra and a large area of completed infarct. An unfavorable CT perfusion. A 79-year-old man presented to the emergency room 6 hours after the acute onset of right-sided hemiplegia. An emergency CT perfusion exhibited decreased CBF (A) and increased MTT (B), as well as loss of CBV (C) in the distribution of the left middle cerebral artery. Coronal CT angiography (D) revealed a thrombus in the proximal left middle cerebral artery (arrow). The patient was considered an unsuitable candidate for endovascular intervention due to the lack of a significant ischemic penumbra and a large area of completed infarct.

Institutional Protocol for CT Perfusion–Based Management of Acute Stroke

The effective utilization of CT perfusion requires, in part, implementation of an established protocol to ensure prompt evaluation, diagnosis, and intervention. At Thomas Jefferson University–Jefferson Hospital for Neuroscience, the acute stroke protocol is initiated immediately upon notification from the outside institution. If the patient is a candidate for intravenous thrombolysis, the treating physicians are encouraged to initiate therapy. Patients are transferred via helicopter or ambulance directly to the endovascular suite where the initial neurological examination is performed and noncontrast CT, CT angiography, and CT perfusion can be acquired. The decision to initiate endovascular intervention is made based on the neurological examination and the results of the imaging studies. If CT perfusion data reveals a “mismatch” between infarct core and salvageable penumbra, the patient immediately undergoes intervention, regardless of the time from symptom onset. In cases of completed infarction, the patient is transferred to the intensive care unit for supportive care.

Limitations of CT Perfusion

There is little doubt that in the vast majority of cases, CT perfusion confirms the clinical diagnosis of acute stroke and reliably assesses the volume of infarcted tissue and salvageable penumbra. However, in its current state, CT perfusion technology is limited by interobserver variability, inconsistencies between different software programs, and a lack of standardization in diagnostic criteria. Multiple investigations have attempted to define the values of CBF and CBV most sensitive for penumbra and infarct. Murphy et al. prospectively analyzed data from 41 patients presenting with acute stroke. Using CT perfusion, the authors determined the permeability–surface area product, a measure of the rate of contrast extravasation from the intravascular to the extravascular space through a disrupted blood-brain barrier. In the hemorrhagic transformation group, the mean permeability–surface area product (0.49 ml x min⁻¹ x [100 g]⁻¹) was significantly higher than for the permeability–surface area product for the group that did not hemorrhage (0.09 mL x min⁻¹ x [100 g]⁻¹). These findings translated into a 77% sensitivity and 94% specificity for the prediction of hemorrhagic transformation when the PS threshold was set at 0.23 ml x min⁻¹ x (100 g)⁻¹. Clearly, further investigation may reveal CT perfusion to be a useful tool in better defining the risk of hemorrhage.

There are a number of scenarios in which the utility of CT perfusion and its contribution to patient care have become the subject of debate. In many instances, CT perfusion reveals information pertaining to infarct and penumbra volume that clearly assists in the decision to intervene. In patients presenting with a small area of completed infarct and a large penumbra, the decision to proceed with thrombolysis is considered to have a favorable risk-benefit ratio. Likewise, patients with large infarcts and relatively little or no penumbra would be considered poor candidates for intervention. The controversy arises in scenarios in which the difference in infarct and penumbra volumes is less dramatic. For example, there are currently no guidelines for patients presenting with a small infarct core and...
small penumbra, nor is there data to define the appropriate treatment for patients with large infarcts and penumbra. As there is currently no classification scheme for CT perfusion volumetric data, decisions in these circumstances must be made based on neurological examination and clinical acumen. Furthermore, the ability of CT angiography to identify the site of vessel occlusion in these circumstances is a key component of the decision-making process. Thrombus in a large-caliber proximal vessel on CT angiography may be amenable to endovascular therapy, whereas distal vessel disease is unlikely to improve with endovascular intervention.

There is no doubt that CT angiography plays an essential role in the diagnosis of posterior circulation ischemic stroke through its rapid identification of thrombus within the vertebral or basilar arteries. Unfortunately, the utility of CT perfusion in the evaluation of brainstem and cerebellar ischemia is extremely limited and data generated from these studies are less reliable predictors of outcome.

Conclusions

The obvious limitations of intravenous thrombolysis have driven the need to develop effective endovascular techniques to better treat acute ischemic stroke. The evolution of endovascular therapy has been mirrored by the need to lengthen the therapeutic window for potential pharmacological and mechanical revascularization. Evidence is now emerging that supports the need for treatment protocols based on the pathophysiology of each individual stroke patient. Computed tomography perfusion, used in conjunction with noncontrast head CT and CT angiography, appears to reliably distinguish between infarcted and salvageable tissue, thus providing important data when deciding upon intervention. Due to the relatively recent introduction of this technology into clinical practice, lack of widespread use, and longstanding reliance on the concept of the therapeutic time window, prospective randomized trials assessing the utility of CT perfusion will be needed. At present, the existing data appears to support the safe and effective implementation of endovascular intervention beyond the traditional therapeutic time windows and future advances in imaging offer the potential of expanding the possibility of intervention to an even larger number of patients.

Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

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