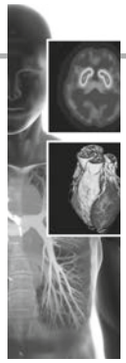

The role of urgent imaging in the diagnosis and management of patients with TIA and minor stroke

The diagnosis of patients with transient ischemic attack and minor stroke is challenging as patients have minimal or no neurological deficits related to their ischemic event on their clinical examination. Multiple clinical factors have been used in triaging these patients into high- and low-risk categories based on the estimated risk of having a recurrent ischemic event. However, the ability of clinical factors in isolation in predicting future ischemic events remains poor. The addition of urgent neuroimaging has substantially improved the diagnostic certainty and the accuracy of outcome prediction in this patient population. In this article, we briefly discuss the different forms of subsequent ischemic events that may occur in patients with transient ischemic attack and minor stroke. We review the role of different forms of parenchymal and vascular neuroimaging in the acute setting in establishing the correct diagnosis and predicting both radiographic and clinical outcomes in this patient population.

KEYWORDS: CT ■ disability ■ minor stroke ■ MRI ■ recurrent stroke ■ TIA

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Patients with transient ischemic attack (TIA) and minor stroke have similar clinical and radiographic characteristics and represent disorders on the same ischemic continuum [1,2]. Furthermore, TIA and minor stroke patients have similar prognoses for survival and recurrent vascular events [1]. Moreover, TIA is defined as neurological symptoms lasting less than 24 h and, as such, the distinction between the two conditions is further irrelevant in the acute setting and should be abandoned. It is well established that despite their mild presentation, these patients are at high risk for early deterioration and subsequent recurrent ischemic events. A retrospective review of two population-based studies and two randomized controlled trials have shown that between 18 and 26% of patients who presented with ischemic stroke had a history of a preceding TIA within the past 7 days [3]. Similarly, in-hospital studies have demonstrated that a substantial number of patients who acutely present with minor or rapidly improving ischemic symptoms are in fact dead or disabled by the time of their hospital discharge [4,5]. Therefore, there is considerable interest in improving the ability to make a timely diagnosis and implement treatment strategies during the short period of time between TIA/minor stroke and subsequent events [6].

However, time constraint is only one of the many challenges that clinicians face in the management of these patients. In fact, TIA/minor stroke mimics comprise some of the most common neurological etiologies for which patients are referred to the emergency department [7]. Multiple studies have shown that reliance on clinical characteristics alone has only moderate accuracy for making the correct diagnosis in this patient population [8,9]. Similarly, despite the fact that clinical characteristics are important for identifying high-risk patients [10], the sensitivity of clinical scoring systems, such as the ABCD [11] and ABCD^2 scores [10], in correctly predicting a recurrent event are far from perfect [12]. Therefore, over the past decade a number of studies have evaluated the ability of modern neuroimaging in isolation [13], or in combination with clinical features, in improving the accuracy of the currently used diagnostic tools in these patients [14,15].

In this article, the utility of different neuroimaging modalities in assessing patients with TIA and minor stroke and their value in accurately predicting outcome by differentiating high-risk patients with TIA/minor stroke from their low-risk counterparts is briefly discussed.

The role of parenchymal imaging in TIA & minor stroke

■ Brain CT scan

A noncontrast CT (NCCT) of the brain is the most widely available imaging modality for assessment of patients with suspected vascular events. It is fast, easily accessible and less

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expensive than all other imaging options. Despite this, NCCT has a relatively low sensitivity and inter-rater reliability in the detection of early infarct changes, even in patients with acute large ischemic syndromes [16]. Evidence of an acute infarct on NCCT alone has been shown to be predictive of recurrent stroke in TIA patients. However, the proportion of patients with evidence of acute infarcts was small (4%) [17]. A recent publication indicated that adding NCCT data increased the predictive value of the ABCD score [18]. These investigators rated a NCCT as abnormal if there was evidence of old or new infarction, or periventricular white matter disease. These abnormalities were assessed together and rated as present or absent. However, although there was a suggestion of improvement in the score with the addition of the NCCT information, the areas under the curves (AUCs) were similar to that of the ABCD score in this population (AUC: 0.76 for ABCD and 0.79 for ABCD + CT). This study has a number of limitations: there were no patients with evidence of an acute infarct on NCCT, which questions some of the radiological interpretation; the method of rating white matter disease on CT is not described; the exact timing of the NCCT related to the event is not clear; and diabetes was not included in the analysis.

In a pooled analysis of data collected independently from 12 centers on patients with TIA, the odds ratio (OR) of recurrent infarct was 4.2 (2.6–6.9) in patients with a positive CT profile relative to those with a negative CT profile [18]. However, the predictive power of CT remained significantly lower than that of the diffusion-weighted imaging (DWI).

In summary, a normal NCCT is reassuring but does not rule out the diagnosis of an ischemic event and similarly does not carry a high prognostic value in determining positive or negative outcome in patients with TIA and minor stroke. In practice, the main value of normal NCCT in this group is mostly to rule out other etiologies (e.g., tumor and blood, among others) that may present with TIA-mimicking symptoms. More advanced imaging is often required to help identify the etiology of the presenting symptoms and to predict disability and recurrent events.

■ Brain MRI

In contrast to NCCT, MRI has a much higher yield for the detection of small ischemic lesions in patients with mild or transient ischemic events. DWI is highly sensitive to ischemic changes, even within the hyperacute period after the infarct [19]. Several studies have demonstrated evidence of acute ischemia on early DWI in over 50% of patients who had complete symptom resolution within 24 h of onset [20–22]. DWI is more sensitive than NCCT in specifically detecting small-volume infarcts, regardless of their clinical severity [23]. Multiple clinical factors, including symptom duration, have been correlated with the presence of parenchymal lesions on MRI. A pooled analysis of MRI data in 808 patients with TIA from ten centers has demonstrated a linear correlation between duration of clinical symptoms and acute ischemia on imaging [24]. Acute DWI is also an important tool for correct localization of ischemic symptoms, especially in differentiating anterior versus posterior circulation strokes in those with small ischemic lesions [23]. Therefore, MRI has implications in determining symptomatic versus asymptomatic carotid disease and the need for urgent carotid revascularization [25]. Evidence of ischemic injury on MRI not only changed the 'time-based' definition to a 'tissue-based' definition in TIA patients [26], but also has important implications in predicting outcome. A prospective imaging study of 126 patients with high-risk TIA and minor ischemic stroke (NIHSS ≤3) [13], showed that patients with acute DWI lesions on MRI performed within 24 h of symptoms onset, were 2.6-times more likely to have a new stroke compared with those with normal DWI at baseline. This risk significantly increased by 8.9-fold in the presence of intracranial occlusion. In this study, the combination of baseline DWI lesion and intracranial occlusion also significantly increased the risk of 90-day functional dependence, as measured by Rankin score ≥3. Similarly, a retrospective analysis of 601 consecutive patients with TIA, who had an MRI within 24 h of symptom onset, showed that both high-risk clinical characteristics ($ABCD^2 \geq 4$) and imaging characteristics (acute DWI lesions) were independent predictors of early recurrent stroke in this patient population [27]. In this study, the 7-day risk of recurrent stroke was 0% with no predictors, 2% with $ABCD^2 \geq 4$, 4.9% with acute DWI and 14.9% with both clinical and imaging predictors. Similar high recurrent stroke rates have been found in a separate study of patients with TIA who had acute DWI lesions within 24 h of symptom onset [28].

Acute tissue injury is also predictive of development of silent ischemic lesions on follow-up imaging. In a study of 143 patients with high-risk TIA and minor stroke (defined

as NIHSS <6) who had serial imaging, 9.8% showed evidence of new ischemic lesion on 30-day follow-up MRI [29]. It is important to note that close to half of these patients remained clinically asymptomatic. A trend to increased likelihood of new lesions at 30 days was seen with progressing baseline scan lesion number (none [2.2%], solitary [12.9%] and multiple [19.8%]; p = 0.046). Patients whose mechanism of stroke was large artery disease or cardioembolic were the most likely to have new lesions on 30-day follow-up MRI. Furthermore, the presence of multiple DWI lesions of varying ages (as defined by apparent diffusion coefficient maps) increased the risk of new lesion development on follow-up MR imaging (relative risk: 3.6; 95% CI: 1.9–6.8) [30]. Similarly, in an international multicenter collaborative study of patients with TIA, the OR of recurrent infarct was 18-fold higher in DWI-positive patients relative to DWI-negative patients [28]. Moreover, the extent of ischemic injury, as measured by the volume of acute DWI, has been shown to predict infarct progression in this population [31]. Furthermore, the presence of acute tissue injury can be used as an indicator of active ischemic process in patients with minor symptoms. In a prospective study of 693 patients with TIA and minor stroke, close to 50% of patients were classified as having cryptogenic events [32]. Follow-up imaging in these patients demonstrated a high rate of new ischemic lesions at day 30 (6.6%) and day 90 (14.5%), despite a very low clinical recurrent rate (1.2%) within 90 days. Therefore, the presence, the lesion volume and the number of acute DWI lesions all have positive predictive values in determining infarct progression and/or recurrence in this population.

Performing MRI studies in patients with TIA may increase the detection of unexpected brain abnormalities, such as tumors and cerebral aneurysms. Interestingly, the most common incidental finding on brain MRI is silent ischemia [33]. The presence of silent ischemia is a marker of vascular disease and has implications in prediction of future ischemic events [34]. Furthermore, there is growing evidence that links subclinical infarcts to cognitive and functional decline [35]. Therefore, new silent infarcts should not merely be considered as an epiphenomenon. In addition, the development of new silent ischemia can be used as a surrogate marker for inadequate secondary prevention measures and warrant more aggressive medical or surgical interventions in patients who remain clinically asymptomatic.

The role of perfusion imaging in TIA & minor stroke

Approximately one-third of patients with minor stroke and TIA have evidence of tissue hypoperfusion on CT perfusion or perfusion-weighted MRI performed within 24 h of symptom onset [36–38]. Mismatch between a large perfusion deficit and a smaller ischemic core (demonstrated by DWI) is referred to as the ischemic penumbra. Penumbra is thought to represent a hypoperfused region that is at risk for infarction, but is also potentially amenable to salvage [39]. The most commonly used perfusion parameters to define ischemic penumbra are relative cerebral blood flow, relative cerebral blood volume and T_{max} (the time to maximum residue function obtained by deconvolution) maps [40].

In the ABCD^2 + MRI study [14], presence of ischemic penumbra was determined by assessment of relative sizes of mean transit time delay versus DWI lesions. Patients with mismatch (mean transit time >DWI) were significantly more likely to have recurrent stroke (27 vs 7%; p = 0.003) or functional impairment (29 vs 7%; p = 0.001) as compared with those without mismatch. Similarly, tissue hypoperfusion was predictive of both clinical and radiographic deterioration in the subgroup of patients with lacunar stroke [37]. In a prospective study of TIA and minor stroke patients who underwent serial imaging, tissue hypoperfusion (defined as regions with T_{max} delay of ≥2 s) was identified in 34% of patients [31]. Those with baseline perfusion deficit were much more likely to develop new ischemic lesions on early follow-up MRI at day 7. All new ischemic lesions developed within the originally hypoperfused regions and, as such, represent infarct progression rather than infarct recurrence. A CT perfusion study in 65 patients with anterior circulation TIA, demonstrated that 33.8% of patients had focal perfusion deficit at baseline. Subsequent in-hospital events occurred more frequently in those with perfusion deficit compared with those without. Similarly, a detailed volumetric analysis of mismatch (defined as areas with T_{max} delay of ≥4-s DWI) in 137 patients with TIA and minor stroke was found to be predictive of infarct growth in the originally hypoperfused regions of the brain on day 30 follow-up scans [41]. In this study, a 10-ml mismatch was found to have the highest sensitivity and specificity for predication of infarct growth on follow-up imaging at day 30. Therefore, a mismatch volume of ≥10 ml was therefore referred to as 'critical mismatch'. To further validate these findings, the presence of critical mismatch (T_{max} ≥4-s DWI ≥10ml) as a poor prognosticator of outcome was validated

in a large consecutive cohort of 281 patients with minor stroke and TIA [42]. In this study, presence of critical mismatch at baseline was highly predictive of further infarct growth on follow-up imaging (OR: 10.3; 95% CI: 3.5–30.2) [42].

The role of vascular imaging in TIA & minor stroke

Accurate imaging of intra- and extra-cranial arteries is important in establishing the correct diagnosis, planning appropriate treatment strategies and prognosticating the recurrent ischemic rates in patients with TIA and nondisabling stroke. Noninvasive vascular imaging methods, now widely available, are replacing the need to perform the invasive intra-arterial angiography (IAA) as the screening method for detection of vascular abnormalities in this population. Doppler ultrasound (DUS), trascranial Doppler (TCD), CT angiography (CTA) and MR angiography are currently available and are reasonable methods for initial vascular assessment in patients with a transient or minor neurological deficit.

■ DUS & TCD

Timely detection of carotid disease is arguably the most important step in secondary prevention of recurrent ischemic stroke in patients with TIA/minor stroke arising from carotid artery stenosis. Different methods of measuring carotid stenosis have been used [43]. Carotid endarterectomy has been shown in randomized controlled trials to reduce the risk of ipsilateral ischemic stroke due to significant carotid stenosis (70–99%) and in some cases with moderate stenosis, if the surgery is performed quickly after the index event [44,45]. The endarterectomy trials measured the degree of carotid stenosis from IAA, an invasive and expensive procedure that may also cause further delays in the care of these patients. Multiple noninvasive techniques, including carotid DUS, are now available and have largely replaced the need for performing IAA as the screening test for detection of carotid disease in patients with minor or completely resolved neurological symptoms. Carotid Doppler ultrasonography assesses the velocity changes in blood flow associated with stenosis in the carotid arteries using either a continuous wave, a single-gated pulsed wave or directional color modes [46,47]. Carotid DUS is less accurate than IAA, particularly at 50–69% stenosis; however, it does reduce the investigation risk and the time from clinical diagnosis to imaging, and ultimately surgery, in most cases [48]. Apart from reduced accuracy, carotid DUS has multiple other limitations including operator dependency and providing limited or no information on the posterior circulation and intracranial vascular status of the patients [49].

Therefore, addition of TCD ultrasound is useful in the setting where DUS is the only available vascular imaging modality. TCD ultrasound is a noninvasive and reliable method for the detection of intracranial occlusion or stenosis through measurement of blood flow [50,51]. Increased flow velocities, as detected by TCD, have been shown to be strongly related to vascular risk factors including hypertension, hypercholerstolemia and diabetes [52]. The presence of intracranial stenosis, as detected by TCD, is associated with vascular risk factors, such as hypertension and diabetes. In a prospective study of 598 patients with recent TIA and nondisabling stroke, the mean flow velocity, the pulsitility index and their ratio, detected by TCD, showed strong prognostic value for recurrent vascular events [53]. An analysis of TCD findings on 1881 patients presenting with an acute TIA to the TIA-SOS clinic (a TIA clinic with round-the-clock access), showed presence of intracranial occlusion/stenosis in 8.8% of patients [54]. After 1-year follow-up on best preventative therapy, the incidence of recurrent vascular events was significantly higher in patients with baseline TCD abnormalities than those without. Apart from detection of intracranial stenosis and occlusion, TCD monitoring can identify asymptomatic microembolic signals (MESs). Emboli backscatter and appear as high-intensity short-duration signals on continuous TCD monitoring [55]. In the acute phase of TIA/minor stroke, MESs have been reported between 9.3 and 71% of patients with a variety of arterial or cardiac embolic sources [56,57]. Multiple studies have shown that MES is an independent predictor of recurrent ischemic events in patients with TIA and and in stroke of all severity [58,59]. Furthermore, treatment with anti-thrombotic therapy has been shown to reduced MESs [60] and reduce the risk of early recurrence [61].

In summary, both carotid DUS and TCD monitoring are reliable and feasible vascular techniques in the assessment of TIA and minor stroke patients, and can be used as an alternative method in centers with limited access to other vascular imaging modalities.

■ MR angiography

It is well recognized that patients with mild or rapidly resolving neurological symptoms who do not receive thrombolytic therapy can have poor

outcomes related to early deterioration [4]. The role of acute MR angiography in the detection of those potentially at risk for early deterioration has been studied. Minor stroke patients with documented large vessel occlusion are at the highest risk of deterioration when thrombolysis is withheld [4,62,63]. Together these studies report outcomes for only 241 patients in total, with 34 (14%) having evidence of large artery occlusion. A total of 44% (15 out of 34) of patients with occlusion had poor outcome versus 21% (44 out of 207) of patients with no occlusion (relative risk: 2.1; 95% CI: 1.3–3.3; p = 0.0085 Fisher's exact test). All of these studies have used MRI to document large artery occlusion. The small number of patients is explained by the fact that it is challenging to obtain acute stroke MRI quickly and routinely.

■ CT angiography

The advantages of CT over MRI include its wider availability, lower cost, shorter scanning time intervals and better patient tolerability. CTA is a safe and feasible technique for vascular imaging and can be performed in most emergency departments in conjunction with NCCT as the initial imaging in acute stroke [64]. Intracranial large vessel occlusion identified by CTA was an independent factor to predict poor neurological outcome in a consecutive cohort of patients with stroke and TIA [65]. In a large consecutive cohort of patients with TIA and minor ischemic stroke, the utility of CT/CTA findings was assessed within 2 h of symptom onset [66].

In this cohort, persistent symptoms, CT/CTA abnormalities and DWI all positively predicted recurrent stroke. However, in the multivariable analysis, the only factor predictive of recurrent ischemic events was acute CT/CTA. CT/CTA abnormalities also predicted disability in this study, even in the absence of recurrent events [67].

The utility of brain imaging in outcome definition in TIA/minor stroke

The definition of recurrent events in patients with ischemic stroke is challenging [68]. Infarct growth or development of a *de novo* ischemic lesion can occur on follow-up imaging with or without a change in patient's clinical status. Furthermore, clinical deterioration can occur in the absence of apparent radiographic alterations. It has been well demonstrated that unlike infarct recurrence that occurs over time and almost at a linear rate, infarct progression commonly occurs early on, within a few days, after the index [69]. More importantly, the different outcomes are probably each correlated with separate etiologies, which may warrant different therapeutic measures. Therefore, it is important to develop a standardized event classification scheme that could both guide clinicians in day-to-day practice and perhaps be utilized in future research studies and clinical trials. Thus, we used baseline and follow-up MRI as a surrogate marker for disease activity in combination with clinical findings to create an event classification system that categorizes patient outcomes in six different groups (**Box 1**) [70]. In this substudy, most events in minor stroke and TIA patients were due to progression of the presenting event (either clinical or radiological progression) and were not secondary to an actual recurrence.

The clinical outcome of either recurrent TIA versus stroke at 1 year was assessed in a subgroup of VISION patients with high-risk TIA [71]. High-risk TIA patients who were DWI negative on their baseline scan were 4.6-times (27.4 vs 5.9%; p < 0.05) more likely to have a subsequent TIA at 1 year than patients with a DWI lesion, but were 4.3-times (2.1 vs 9.1%; p = 0.19) less likely to have a subsequent stroke. The implication that DWI-negative patients have recurrent transient events rather than recurrent strokes suggests that some of these patients have an alternative pathophysiological explanation than ischemia (e.g., migraine, epilepsy and somatiform disorder, among others) [71]. However, the question remained as to what proportion and what type of patients were falsely DWI negative on baseline imaging. In an analysis of 403 patients of all stroke severity who were enrolled in the VISION study, 103 (25.6%) were DWI negative [72]. In this group, the final diagnosis was stroke in 26 (25.2%), TIA in 63 (61.2%) and nonischemic in 14 (13.6%) patients (seizures and migraine, among others). Of the stroke patients, six out of 26 (23.1%) had infarcts on 30-day follow-up MRI on fluid attenuated inversion recovery (FLAIR) sequences in clinically relevant regions (four lacunar syndromes and two posterior circulation syndromes). The majority of patients with a final clinical diagnosis of stroke, but no evidence of infarction on follow-up imaging (13 out of 26, 65%) had either brainstem or lacunar strokes as the clinical diagnosis.

Prediction of outcome in TIA & minor stroke

Previous work in TIA has used the ABCD^2 score [10] to predict recurrent stroke. The ABCD^2 score uses clinical and ischemic event details to predict

Box 1. A combined clinical and radiographic classification of outcomes in patients with transient ischemic attack and minor stroke.

New symptomatic infarct
- Infarct outside of the initial perfusion abnormality with new functional deficit. If no baseline perfusion abnormality is visualized, then the new infarct must be geographically separate from the original infarct

New symptomatic stroke without infarct
- New clinical stroke deficits not referable to the initial infarct territory without evidence of a new infarct on imaging

Symptomatic infarct growth
- Clinical functional deterioration with evidence of a new infarct within baseline perfusion abnormality or directly extending from initial infarct if no perfusion abnormality was seen on baseline imaging

Stroke progression without infarct growth
- Functional deterioration without infarct growth

Silent infarct growth
- New infarct within baseline perfusion abnormality without functional deterioration. New diffusion-weighted imaging lesion can be separate from original lesion if contained within original perfusion abnormality

New silent infarct
- New infarct on imaging outside the area of original perfusion abnormality without new functional deficit

Reproduced from [70].

clinical outcome and does not include brain imaging. We proposed that brain imaging may be a way of improving the prediction of outcome. The new score $ABCD^2$ + MRI was created by adding evidence of acute infarct on DWI to the $ABCD^2$ score. The predictive accuracy of the $ABCD^2$ + MRI score was significantly higher than $ABCD^2$ (AUC: 0.88 vs 0.78; p = 0.01). Those with a high score (7–9) had a 90-day recurrent stroke risk of 32.1%, a moderate score (5–6) had a risk of 5.4% and a low score (0–4) had a risk of 0.0%. Unlike the $ABCD^2$ score (p = 0.33), the $ABCD^2$ + MRI score (p = 0.02) predicted functional impairment at 90 days. Interestingly, in the multivariate analysis, vessel occlusion and perfusion (see 'The role of perfusion imaging in TIA & minor stroke' section for discussion on perfusion) were substitutable in the model, and in the final model only occlusion was chosen, as it is more widely applicable [14]. When considering evidence of acute infarct on either CT or MRI ($ABCD^2$ I score) given the wider accessibility of CT scan, the prognostic yield of the score also improved. Pooled AUC improved from 0.66 (0.53–0.78) for the $ABCD^2$ score to 0.78 (0.72–0.85) for the $ABCD^2$ I score. This was confirmed in a multicenter study that included 4574 patients with TIA and demonstrated a significant improvement in the yield of $ABCD^2$ score in predicting recurrent strokes at day 7 and 90 with addition of brain infarct on NCCT or DWI [12]. To further increase the yield of scoring system, the $ABCD^3$ I score was developed that considered two points for dual TIA, two points for acute infarction on DWI and two points for carotid stenosis of at least 50% [15]. Considering these high-risk features, the predictive value of $ABCD^2$ score significantly improved in the $ABCD^3$ I score for early recurrent events by day 30 (0.90 at day 2; p = 0.035, 0.92 at day 7; p = 0.001, 0.85 at day 28; p = 0.028 and 0.79 at day 90; p = 0.073).

Conclusion

A significant proportion of patients with minor or completely resolved neurological symptoms show evidence of vascular or tissue abnormalities on acute neuroimaging studies. These factors have been proven to be invaluable in risk stratification, treatment planning and outcome prediction in these patients. Furthermore, despite best medical management, approximately one-third of these patients have evidence of radiographic deterioration on sequential MRI. The majority of these patients remain clinically unchanged. This not only emphasizes the dynamic pathophysiologic changes that occur in the brain of patients with TIA and minor ischemic stroke, but also argues that more sensitive surrogates (such as serial MRI scans) should be used both at baseline and follow-up assessment of these patients in conjunction with clinical and functional outcome measures.

Future perspective

The presence of infarct progression on follow-up assessments (in both symptomatic and asymptomatic patients), despite implementation of best medical therapies, raises the question of whether alternative therapies are required for these patients. Are certain patients with TIA/minor stroke potential candidates for acute revascularization treatments such as intravenous

thrombolytics? The safety of thrombolysis in these patients with intracranial occlusion is currently under investigation in the TEMPO-1 trial [101]. The early use of dual antiplatelet agents (aspirin and plavix) is currently being tested in the POINT trial [102]. Hopefully the results of these trials will provide further evidenced-based treatment options for TIA and minor stroke patients in the near future.

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Executive summary

- Parenchymal imaging should be performed as soon as possible in every case of transient ischemic attack (TIA) and minor stroke. There is growing evidence that over half of these patients have tissue injury on their initial scan, and the sensitivity of diffusion-weighted imaging sequence in identifying these lesions is by far superior to that of the noncontrast CT of the brain. The presence of tissue injury not only confirms the diagnosis, but also has prognostic value in predicting future events in this population.
- Infarct progression is the most common etiology for early neurological deterioration in this population. Over one-third of patients with high-risk TIA and minor stroke have evidence of tissue hypoperfusion on early perfusion imaging. The presence of perfusion deficit is highly predictive of further infarct growth and may warrant implementing aggressive therapeutic measures in this subgroup.
- Vascular imaging should be performed as soon as possible and preferably in conjunction with the initial noncontrast CT in all cases of TIA and minor stroke. Early identification of intra- and extra-cranial cerebral vasculature predicts subsequent ischemic events as well as clinical outcome in patients with TIA and minor stroke. Clinicians should note that Doppler ultrasound can only assess the extracranial vasculature and should only be used in situations where alternative vascular imaging (CT angiography and MR angiography) is contraindicated or inaccessible.
- The addition of brain infarction and vessel occlusion, detected on early vascular and parenchymal imaging, to the original ABCD^2 score improved the predictive power of this score in determining future cerebral ischemic events. Neuroimaging should be used in conjunction with clinical factors in all patients with TIA and minor stroke to help improve outcome prediction in this population.

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