New Insight into Transient Contrast Enhancement on Computed Tomography after Endovascular Treatment of Stroke

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Summary

Transient contrast enhancement on computed tomography following endovascular treatment of stroke is a recognized entity that has been previously reported. Technological advances in brain imaging now have the potential to explore and refine its proposed etiology. We describe three patients in whom the location of contrast enhancement correlates with decreased cerebral blood volume on pre-therapeutic CT perfusion studies and with restricted diffusion on MRI. In this regard, contrast enhancement demarcated areas of completed cerebral infarction. The diagnostic and etiological implications are discussed.

Introduction

Cerebrovascular accidents are the third leading cause of death in the United States, and approximately 795,000 people experience a stroke each year¹. As a majority of these cases are ischemic in etiology, the main therapeutic goal is the prompt restoration of cerebral blood flow. Regardless of the chosen treatment modality, a feared complication is hemorrhage. The rates of hemorrhagic transformation in the treatment arms of several large studies range from 35-43%²⁻⁴. For this reason, most stroke centers obtain an immediate post-treatment nonenhanced head CT. However, several studies have demonstrated that hyperdense foci on these scans do not necessarily reflect blood products⁵⁻¹³. Yoon et al. characterized non-hemorrhagic hyperdensities on post-therapeutic CT scans into two distinct

entities: contrast enhancement and contrast extravasation⁸. Contrast enhancement was defined by rapid clearance of the hyperdensity without residual mass effect or hematoma cavity. Contrast extravasation was noted to have a higher density, persist on serial scans, and be associated with a higher rate of hemorrhagic transformation and clinical deterioration. This distinction, while logical, is based solely on post-treatment imaging. To our knowledge, there have been no studies relating these findings to pre-intervention CT perfusion data. Moreover, there has been a relative paucity of correlative MR data. We present a series of three patients who demonstrated CT contrast enhancement immediately following endovascular therapy. The goal of this study is to correlate this finding with the results of CT perfusion and MR imaging. Given the small number of patients and the retrospective design, an IRB exception was granted.

Case Reports

Patient 1

This 82-year-old woman presented to the emergency room with a two-hour history of aphasia, right hemiparesis, and a baseline NIHSS score of 22. A CT angiogram demonstrated occlusion at the left M1/M2 junction. CT perfusion demonstrated increased time to peak throughout the left MCA distribution, with areas of completed infarction manifest by decreased cerebral blood volume. There were additional areas with preserved blood volume,

Figure 1 An 82-year-old female with aphasia, right hemiparesis, and a left M1/2 occlusion. CT perfusion images demonstrate increased time to peak (TTP) throughout the left MCA territory (A) with focally decreased cerebral blood volume (CBV) in the left frontal region and along the left posterior cortical surface (B). Immediately following endovascular thrombus aspiration, a noncontrast CT (C) demonstrates enhancement in these same regions. This finding had resolved on a CT obtained 48 hours after treatment. MRI (D) demonstrates restricted diffusion (confirmed on ADC map) in the regions demarcated by decreased CBV on the CT perfusion study.

indicating salvageable penumbra. While initial intravenous t-PA did not result in clinical improvement, subsequent endovascular thrombus aspiration resulted in complete recanalization of the primary occlusion, consistent with an Arterial Occlusive Lesion (AOL) recanalization score of III (Table 1)¹⁵. Following treatment, all MCA branches were noted to be widely patent except for a persistently occluded inferior M4 branch. As treatment resulted in significantly improved perfusion of the ischemic area, the post-treatment Mori et al recanalization grade was 3 (Table 2)¹⁶. A post-treatment CT demonstrated hyperdense foci in areas of the left MCA territory. The location of these foci correlated with sites of decreased blood volume on initial CT perfusion. An MRI obtained 12 hours later demonstrated restricted diffusion in

the same areas. A repeat CT obtained 48 hours later demonstrated resolution of the enhancement without evidence of hemorrhagic transformation. The patient was discharged to a nursing home one week later with a dramatic improvement in her right hemiparesis and mild improvement in her aphasia. Of note, an MRA obtained five months later demonstrated persistent left MCA recanalization without evidence of reocclusion (Figure 1).

Patient 2

This 75-year-old woman presented to the ER with a six-hour history of left hemiparesis and a baseline NIHSS score of 9. A CT angiogram demonstrated occlusion of the right M2 poste-

Figure 2 A 75-year-old female with left hemiparesis and occlusion of the right M2 posterior division. CT perfusion images demonstrate focally decreased CBV in the right insular and frontotemporal cortices (A,B). Following IA t-PA and endovascular aspiration, a noncontrast CT demonstrates enhancement in these same regions (C,D). These findings had resolved on a CT obtained 24 hours after treatment. MRI (E) demonstrates restricted diffusion (confirmed on ADC map) correlating with the areas demonstrating decreased CBV on the presenting CT perfusion study.

rior division. Perfusion analysis demonstrated increased time to peak with focal areas of decreased cerebral blood volume in the right insular and frontotemporal cortices. The remainder of the right MCA distribution demonstrated preserved cerebral blood volume and flow. As she was outside of the IV t-PA treatment window, she was taken immediately to the endovascular suite. A combination of intraarterial t-PA and thrombus aspiration yielded complete recanalization of the primary occlusion, consistent with an AOL recanalization score of III. More distally, there was dramatic improvement in perfusion with residual occlusion of an inferior M4 branch vessel, consistent with a Mori et al reperfusion grade of 3. A post-procedure CT scan demonstrated focal small areas of enhancement in the right insula and in the right fronto-tempo-

ral cortex correlating with the foci of decreased cerebral volume seen on the CT perfusion study. An MRI demonstrated restricted diffusion in these same regions. By 24 hours, the CT contrast enhancement had resolved without evidence of hemorrhagic transformation. A CT angiogram performed on post-treatment day 1 revealed persistent right MCA recanalization with no evidence of reocclusion. The patient was discharged home three days later with resolution of her presenting symptoms and a discharge NIHSS score of 0 (Figure 2).

Patient 3

This 81-year-old man presented to the ER with a four-hour history of left hemiparesis and a baseline NIHSS of 17. A CT angiogram dem-

Figure 3 An 81-year-old man with left hemiparesis and occlusion of the right M1/M2 junction. CT perfusion demonstrates focally decreased CBV in the right basal ganglia (A: arrow). Following mechanical thrombolysis, a noncontrast CT demonstrates enhancement in this location (B). There was no residual enhancement on a CT obtained 24 hours after treatment. MRI (C) demonstrates restricted diffusion (confirmed on ADC map) in the basal ganglia correlating with the initial focus of decreased CBV. Additional areas of restricted diffusion are apparent more distally in the right MCA territory reflecting either the development of completed infarction in this region (subsequent to the initial CT perfusion) or the sequela of distal propagation of emboli during thrombolysis.

onstrated occlusion of the right M1/M2 junction. CT perfusion demonstrated increased time to peak in this distribution. There was focally decreased cerebral blood volume in the right basal ganglia but preserved volume in the rest of the right MCA territory. He was immediately taken to the interventional radiology suite where mechanical thrombolysis yielded complete recanalization of the primary occlusion, consistent with an AOL recanalization score of III. More distally, there was significantly improved perfusion of the right MCA territory with small areas of persistent decreased perfusion. Overall, the findings were consistent with a Mori et al. recanalization grade of 3. An immediate post-procedure CT demonstrated hyperdensity in the right

basal ganglia, matching the region of decreased cerebral blood volume on CT perfusion. Follow-up CT scans demonstrated resolution of enhancement at 24 hours without evidence of hemorrhagic transformation. An MRI revealed restricted diffusion in the right basal ganglia correlating with the region of contrast enhancement. Additional foci of signal abnormality were present in the distal right MCA territory, reflecting either progression of initial ischemia to completed infarction or distal propagation of emboli following thrombolysis. Unfortunately, despite improvement in his hemiparesis, the patient had a complicated hospital course, suffered a myocardial infarction, and died seven weeks after therapy (Figure 3).

Table 1 **AOL Recanalization Score** ¹⁵.

Score	AOL Recanalization Score
0	No recanalization of the occlusive lesion.
I	Incomplete or partial recanalization of the primary occlusive lesion with no distal flow.
II	Incomplete or partial recanalization of the primary occlusive lesion with any distal flow.
III	Complete recanalization of the primary occlusion with any distal flow.

Table 2 **Mori et al. Reperfusion Grading System** ¹⁶.

Grade	Mori et al. Reperfusion Grade
0	Unchanged.
1	Movement of thrombus not associated with any improvement in perfusion.
2	Partial recanalization with reperfusion in less than 50% of the ischemia-related area.
3	Partial recanalization with reperfusion in more than 50% of the ischemia-related area.
4	Complete or near complete recanalization with full return of perfusion.

Discussion

We describe three patients who demonstrated transient hyperdensities on unenhanced CT scans immediately after endovascular treatment of stroke. On serial CT scans this resolved without hemorrhagic conversion. As such, the findings are most accurately classified as areas of contrast enhancement based on the scheme put forth by Yoon et al.⁸. Review of additional imaging studies demonstrates that foci of contrast enhancement correlated with areas of decreased cerebral blood volume on presenting CT perfusion studies. Moreover, these areas also demonstrated restricted diffusion on subsequent MRI. As such, post-treatment contrast enhancement demarcated areas of non-salvageable, completed infarction. Prior studies have speculated that disruption of the blood-brain barrier represents the etiology of post-treatment contrast enhancement⁵⁻¹³. The results of this study are complementary and provide supporting objective imaging data. Contrast enhancement was limited to documented areas of infarcted parenchyma, where focal disruption of the barrier would be expected to produce such findings. This represents a logical extension, now supported by perfusion data, of the findings of Nakano et al.^{7,14}. Following endovascular therapy for MCA occlusion, there was a higher incidence of contrast enhancement in patients whose pre-therapy CT scans demonstrated early signs of infarction. These signs, including obscuration of the margins of the lentiform nucle-

us, loss of insular ribbon, and cortical effacement, likely reflect more advanced ischemic changes. In our series, the primary occlusive sites were successfully and completely recanalized with an AOL score of III. More distally, post-treatment angiograms demonstrated greater than 50% reperfusion of the ischemic territory yielding a Mori et al. score of 3. Two of the three patients had follow-up angiographic imaging documenting the absence of delayed reocclusion. These results differ from those of several prior studies that explored the relationship of contrast enhancement and degree of vessel recanalization. Two larger studies deserve particular attention. Yoon et al. reported that patients with contrast enhancement, but not extravasation, had significantly worse Mori et al. recanalization grades (defined as grades 0, 1, or 2) than controls⁸. Nakano et al. demonstrated no significant difference in recanalization — classified as good, poor, or none — between groups with and without hyperdense foci⁷. While not specifically distinguishing between contrast enhancement and extravasation, Nakano et al. identify a subset of patients in whom hyperdense areas disappeared by the next day, and who all demonstrated neurological improvement. This subset meets the definition of contrast enhancement as proposed by Yoon et al. Whether the positive clinical outcome seen in this particular subset of patients reflects an increased rate of recanalization is speculative but possible. Notably, neither of these studies included CT perfusion data. In our series, contrast

enhancement was seen in areas corresponding to regions of completed infarction. This would suggest that the underlying status of the brain parenchyma is the primary etiological factor in contrast enhancement. While successful recanalization may allow contrast to reach this area, the underlying compromised blood brain barrier is ultimately responsible for contrast enhancement. In short, the extent of vessel recanalization may be less important than the nature of territory it supplies. Interestingly, the persistence of distal occlusion, remote from the sites of contrast enhancement, was noted in each patient in our series. This distal occlusion may have altered the proximal perfusion facilitating the passage of contrast through the abnormal blood brain barrier in the infarcted parenchyma. Our findings may prove useful in the evaluation of post-therapy CT scans. Interpreting a hyperdensity on these studies can be challenging, with critical diagnostic and therapeutic implications. If the hyperdense focus correlates with a region of completed infarction on CT

perfusion, it may well represent contrast enhancement. Nonetheless, repeat CT scans to document resolution are essential to delineate between contrast enhancement, contrast extravasation, and hemorrhagic conversion. There are several limitations to our series. These include its small size and retrospective design. Additionally, there is a lack of long-term follow-up. It should be noted that our aim is not to attribute prognostic value to a finding, but rather to relate the presence of contrast enhancement to the underlying status of the brain parenchyma. As CT perfusion is increasingly utilized in the setting of acute stroke, larger prospective studies could be readily designed and performed to further investigate these findings and to document their clinical relevance. Finally, there are undoubtedly patients who have CT perfusion evidence of completed infarction who do not demonstrate post-therapeutic CT contrast enhancement. Future studies could be designed to investigate the differences between these subgroups of patients.

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