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# Carotid siphon calcification impact on revascularization and outcome in stroke intervention

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ABSTRACT

*Objective:* The degree of coronary artery calcification has been shown to predict outcomes in coronary artery disease. The impact of intracranial carotid artery calcification on the prognosis of acute ischemic stroke (AIS) is unknown. The authors sought to examine if the degree of intracranial carotid artery calcification influences reperfusion or outcomes in AIS intervention.
*Methods:* All anterior circulation large vessel occlusion AIS cases that underwent intra-arterial therapy from January 2009 to July 2012 were reviewed. Clinical and radiographic data were collected. Non-contrast brain CT scans were assigned a Calcium Extent Score (degree of calcification of the carotid wall circumference), Calcium Thickness Score (thickness of the calcified plaque), and total Carotid Siphon Calcium (CSC) Score (8-point scale).
*Results:* One-hundred seventeen patients met inclusion criteria. The mean age was 65.4 ± 15.6 years and 36% were male. Calcification was present in the intracranial carotid artery of 84 patients (71%). Inter-rater agreement for total CSC score was strong (Spearman's rho = 0.883, $p < 0.001$). The mean Calcium Extent Score was 1.5 ± 1.3, Calcium Thickness Score 1.3 ± 1.0 and total CSC Score 2.8 ± 2.2. Reperfusion and mRS were not associated with CSC. Multivariate linear regression analysis revealed that older age, history of coronary disease and cervical internal carotid occlusion/near-occlusion were independently associated with higher total CSC scores.
*Conclusion:* Extensive calcification on the intracranial carotid artery does not have impact on reperfusion or clinical outcomes in AIS patients undergoing endovascular therapy. Higher CSC scores are associated with coronary artery disease, increasing age and cervical internal carotid artery occlusion/near-occlusion.



## 1. Introduction

The presence of coronary artery calcium on fluoroscopy has been shown to predict coronary artery disease (CAD) and poor clinical outcome [1,2]. Computer tomography has validated these findings with more accurate quantification of the extent of coronary artery calcium [3]. Subsequently, the extent of coronary artery calcification has been consistently demonstrated to predict coronary stenosis [4,5] and clinical outcomes in asymptomatic [6–8] and symptomatic patients [9,10], independent of established risk factors.

The impact of the presence of intracranial carotid artery calcium on reperfusion and clinical outcomes of acute ischemic stroke (AIS) is not clear. We hypothesized that the presence and extent of carotid siphon calcification (CSC) on plain multi-detector CT may influence revascularization rates and correlate with worse clinical outcomes in AIS patients undergoing endovascular therapy (ET).

## 2. Materials and methods

A retrospective review of all anterior circulation AIS cases at our institution from January 2009 to July 2012 identified 143 consecutive patients that received intra-arterial therapy (IAT) for AIS. This study was approved by the local Institutional Review Board.

Inclusion criteria included National Institute of Health Stroke Scale (NIHSS) score ≥ 7 or aphasia, time from symptom onset (or last time seen well) to intervention ≤ 12 h, no evidence of

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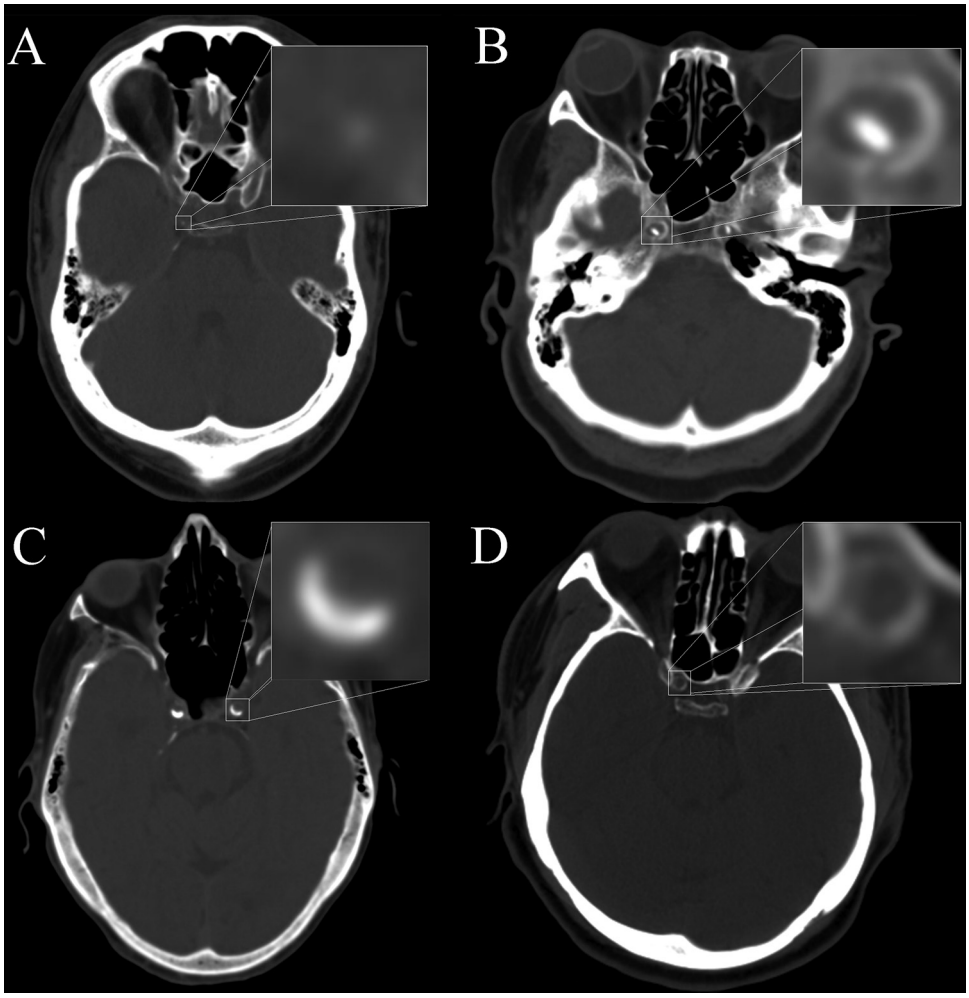


**Fig. 1.** Carotid siphon calcification extent. (A) Dot of calcification in the carotid wall. (B) Crescentic area of calcification measuring less than 90° of the carotid wall circumference. (C) Calcification involving 90–270° of circumference. (D) Calcification encompassing 270–360° of the circumference.

hemorrhage on baseline CT, large artery occlusion (internal carotid or middle Cerebral Artery M1 or M2 trunks, infarct size <1/3 the Middle Cerebral Artery territory and core to perfusion qualitative mismatch ratio >1:1.2 on MR perfusion/CT perfusion scan [11]. In patients beyond 6 h from symptom onset, advanced imaging was required. Twenty-six patients met exclusion criteria of posterior circulation occlusion ($n = 18$), time from symptom onset >12 h ($n = 4$), distal branch occlusion ($n = 2$), and no attempt at intracranial reperfusion ($n = 2$), leaving 117 patients for the primary analysis.

The modified treatment in cerebral ischemia (mTICI) scale was utilized as reperfusion criteria [12]. Reperfusion hemorrhages were defined by the European Cooperative Stroke Study (ECASS) criteria on post-procedure CT within 48 h [13–15]. Good outcomes were defined by Modified Rankin Scale (mRS) $\leq 2$ at 3-months [16]. Ipsilateral proximal cervical internal carotid artery occlusion or near-occlusion was defined during angiography [17].

All non-enhanced CT examinations were performed with a 64-section multidetector – Somatom; Siemens (Malvern, PA), 5 mm slices, 120 KVP, 37 mAs. Image data was transferred to a workstation for the evaluations. A Calcium Extent Score was determined utilizing a scale based on the circumferential extent of calcium deposition in the intracranial segment of the internal cerebral artery (Table 1) [18]. The petrous, cavernous, ophthalmic and communicating internal carotid segments were considered in the analysis, and the section with the most conspicuous disease was graded. The Calcium Thickness Score was determined by the point of maximum thickness of the calcified wall of the intracranial carotid. After assessing the 234 carotid siphons in 117 subjects, the vessel in either side with the highest Calcium Extent Score (Fig. 1) and highest thickness score were utilized for grading. The total CSC Score (8-point scale) was established by a sum of the extent and thickness scores. The threshold used to determine the presence of a calcific lesion was set at a density of 130 Hounsfield units having an area $\geq 1\ mm^2$ [3]. All the CT images were retrospectively reviewed

**Table 1**
Grading scale for Carotid Siphon Calcification Score.

| | | |
|---|---|---|
| *Extent of calcification of carotid artery siphon*: | | |
| Grade | 0 | No calcification |
| | 1 | Dot of calcification |
| | 2 | Crescentic area of calcification <90° of wall circumference |
| | 3 | Calcification involving 90–270° of wall circumference |
| | 4 | Calcification involving 270–360° of wall circumference |
| *Thickness of calcification of carotid artery siphon*: | | |
| Grade | 0 | No calcification |
| | 1 | Calcification 1 mm thick |
| | 2 | Calcification 2 mm thick |
| | 3 | Calcification 3 mm thick |
| | 4 | Calcification >3 mm thick |