Diagnosing carotid near-occlusion with phase contrast MRI

ONLINE DATA SUPPLEMENT

METHODS

CTA

CTAs were performed at the Department of Radiology at University hospital of northern Sweden or at referring hospitals as part of routine practice. Consequently, several machines and routine practice protocols were used. All CTAs covered aortic arch to vertex. Thin sliced axial images and standard reformats were 3mm slabs of mean intensity projections.

All CTA measurements were made by one observer with window adjusted for good separation between contrast and tissue. Distal ICA was assessed well beyond the bulb, usually in/near C2 vertebra level. Diameters were measured on axial source images with a software using 0.1 mm steps, caliper was placed in the middle of the fuzzy edge and short axis measured when artery was oblique to the plane. As artery cross-section was sometimes oblique, distal ICA area was calculated by the diameter assessment: $(Diameter/2)^2*\pi$.

MRI

A 3T MRI scanner (GE Discovery MR 750; Waukesha, WI) with a 32-channel head coil was used. Using 4D PCMRI, blood flow velocities were obtained for the cerebral arteries. The scan time for the 4D sequence was approximately 9 minutes. Two different velocity encoding sensitivities were used, 110 cm/s for investigation of the cerebral arteries and 40 cm/s for investigation of arteries with low velocity, such as the ophthalmic artery. Parameters were 16000 radial projections, 300×300×300 acquisition resolution, 220×220×220 mm imaging volume, 320×320×320 mm reconstruction resolution, 0.7×0.7×0.7 mm3 voxel size, 6.5-6.9/2.7-3.1 ms repetition time / echo time, 8° flip angle and 166.67 kHz bandwidth. The image lower border was a few centimeters below skull base, i.e. including distal extracranial ICA, but not the ICA stenosis.

Image post-processing entailed selecting a seed point in the ICA from which a perpendicular cross-section of the artery was automatically segmented [1]. Using this segmentation the flow rate was calculated. An example of the output of the in-house display is presented in online figure 1.

RESULTS

There was no overlap in ICA flow or relative ICA flow between the groups (online table 1 and online figure 2). Please refer to online figure 3 for receiver operating characteristic curve, online figure 4 for scatterplots and online figure 5 for comparison between MRI observers.

DISCUSSION

Ten studies have assessed ICA flow in carotid stenosis with phase contrast MRI, all neglected to assess near-occlusion [2-11]. Seven did so despite claiming NASCET grading use [2-8]. As near-occlusions are common (27% of symptomatic ≥50% carotid stenosis [12]), many near-occlusions misinterpreted as conventional stenoses were likely included in these studies. Almost all previous studies found a correlation between percent degree of stenosis and ICA flow [2-11]. Our findings differ as we found no correlation between percent degree of stenosis in flow among conventional stenoses. The most reasonable explanation for this difference is that we performed the NASCET-method mandated separation of near-occlusion omitted by the other studies.

REFERENCES

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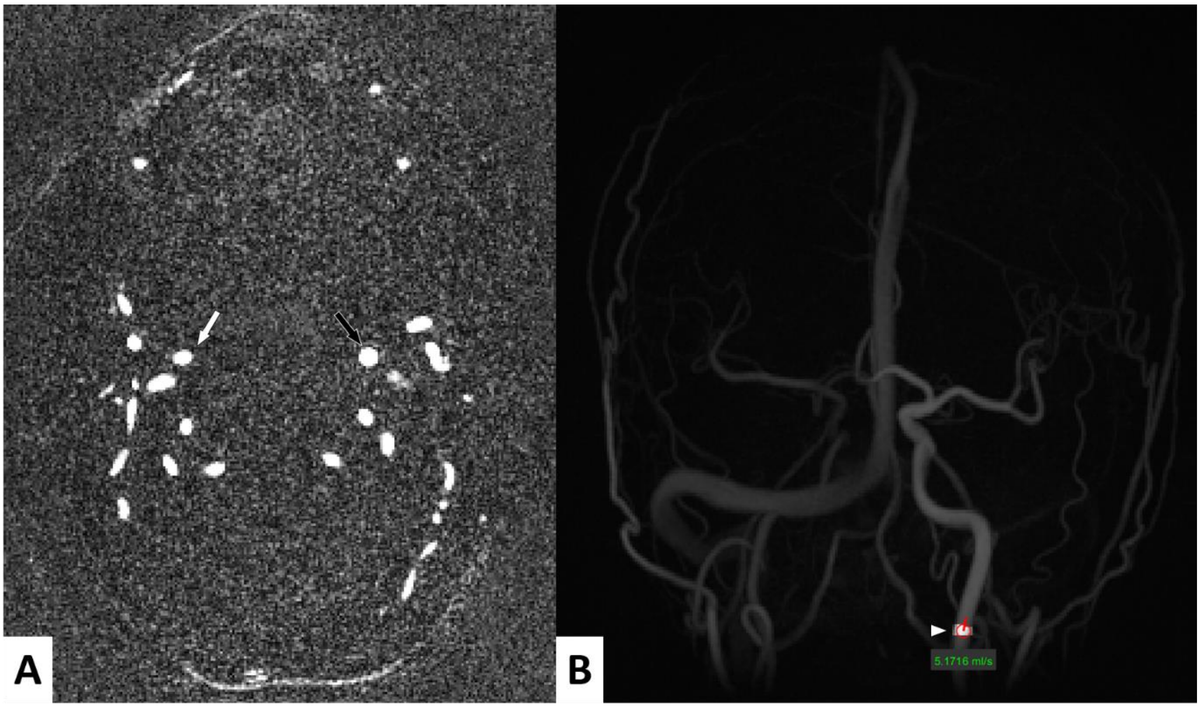
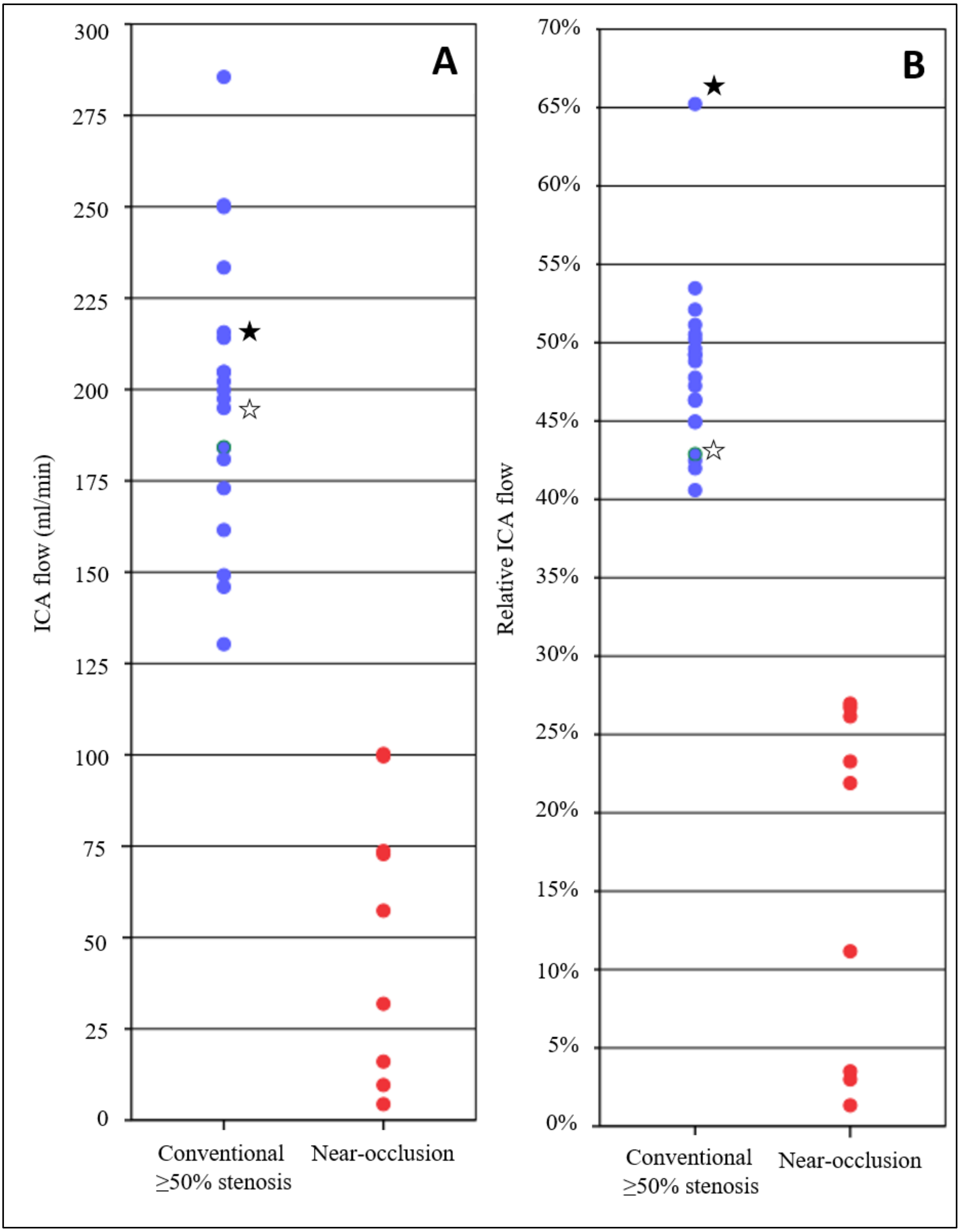
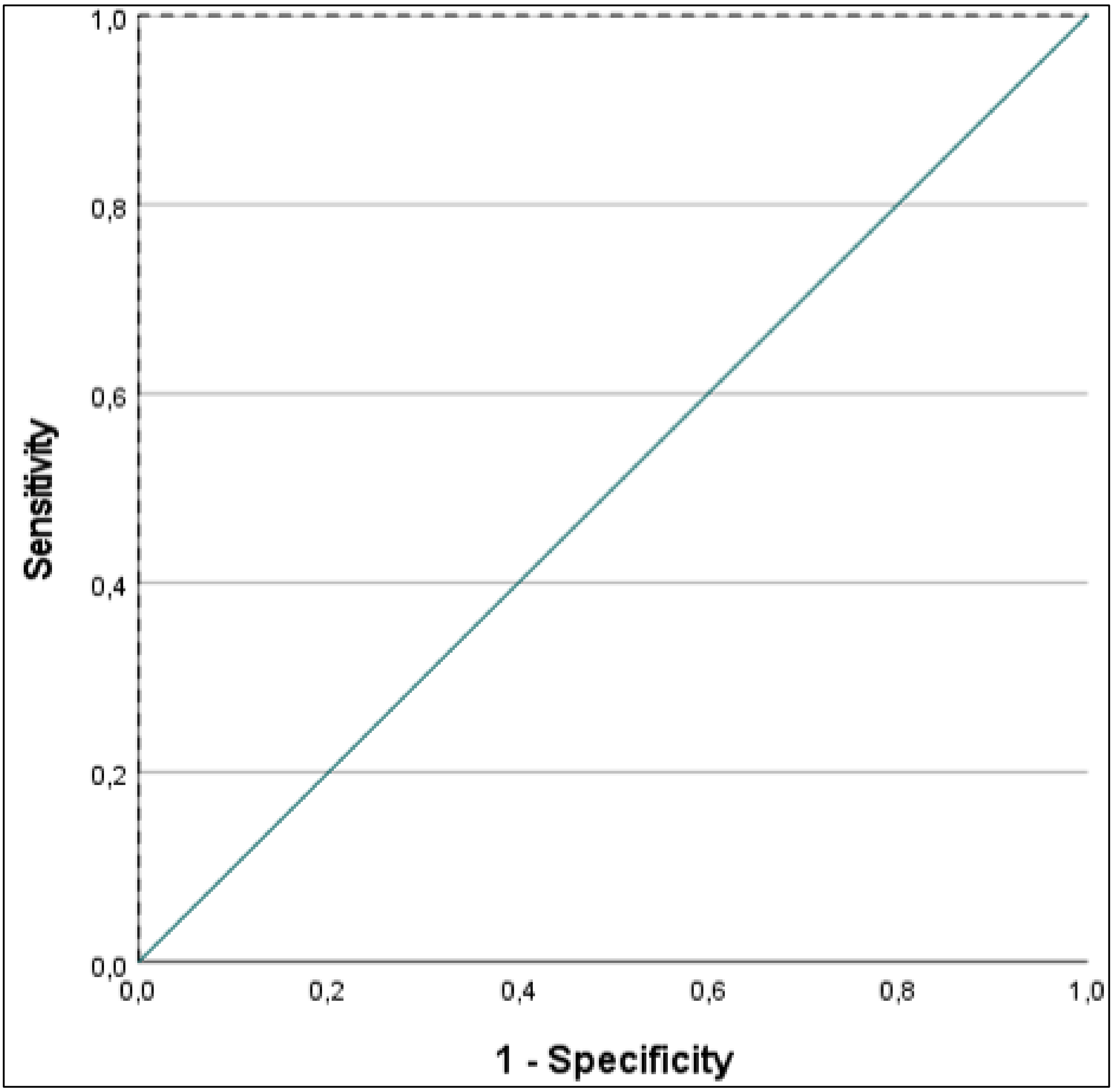


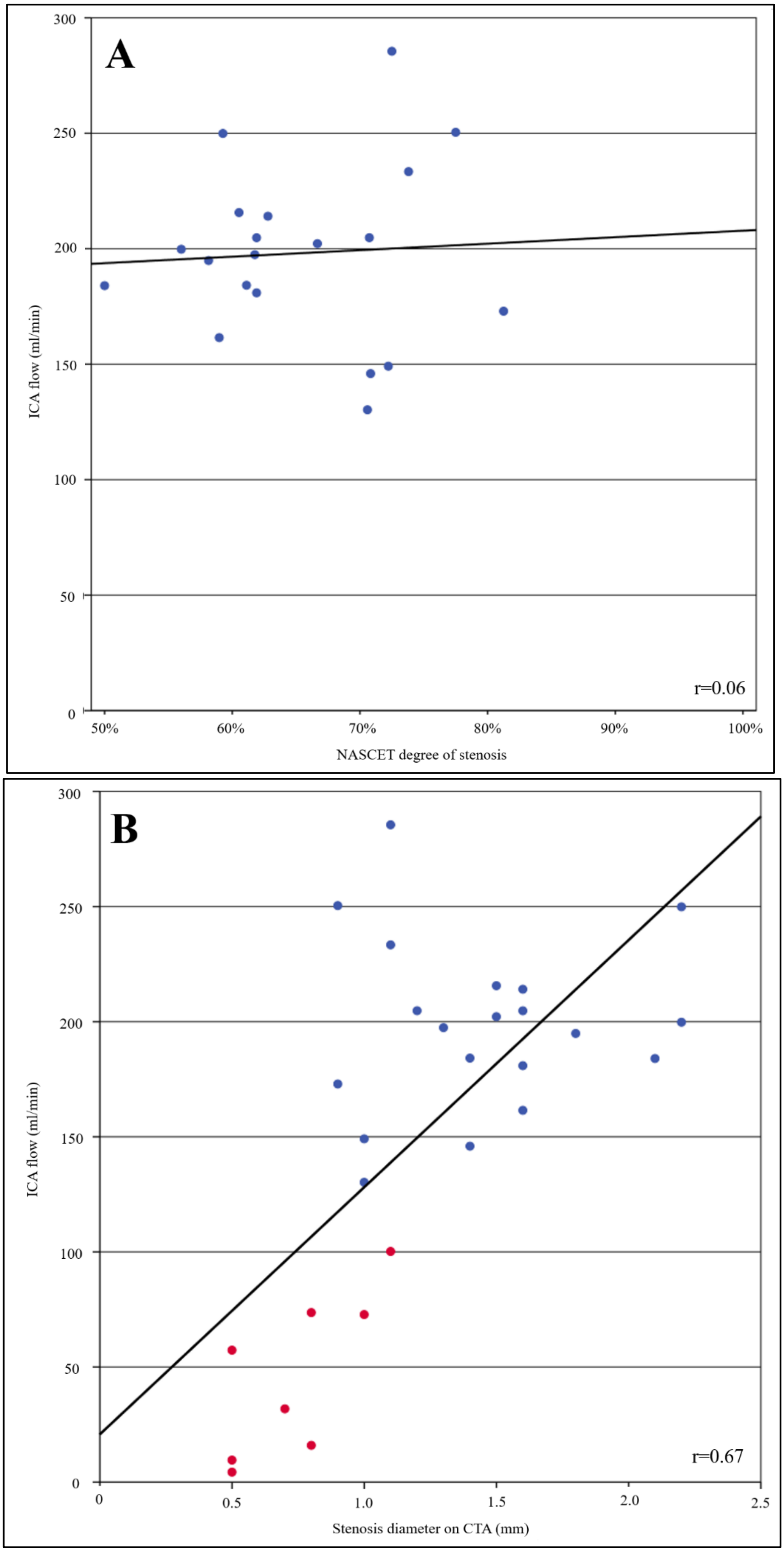
Online figure 1: Example of the in-house software display. A) Axial phase-contrast image from below skull base. Various artery and venous branches are visible, coded in white. The observer goes through the slices similar to any routine scan, identifies an artery segment of interest and clicks on it. B) Flow readout window. In addition to flow, the artery section that was sampled (white arrowhead) is indicated in white flow direction is indicated by a red circle and line. In the example, left ICA (black arrow) was chosen with a flow of 5.1716 ml/s (310 ml/min) and has antegrade flow direction. White arrow indicates right ICA.

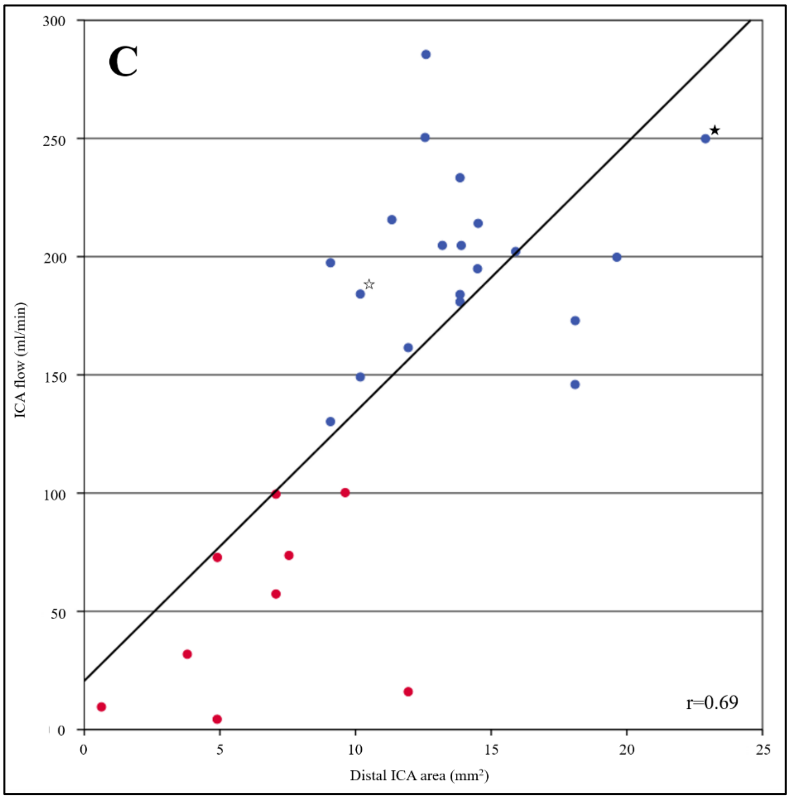


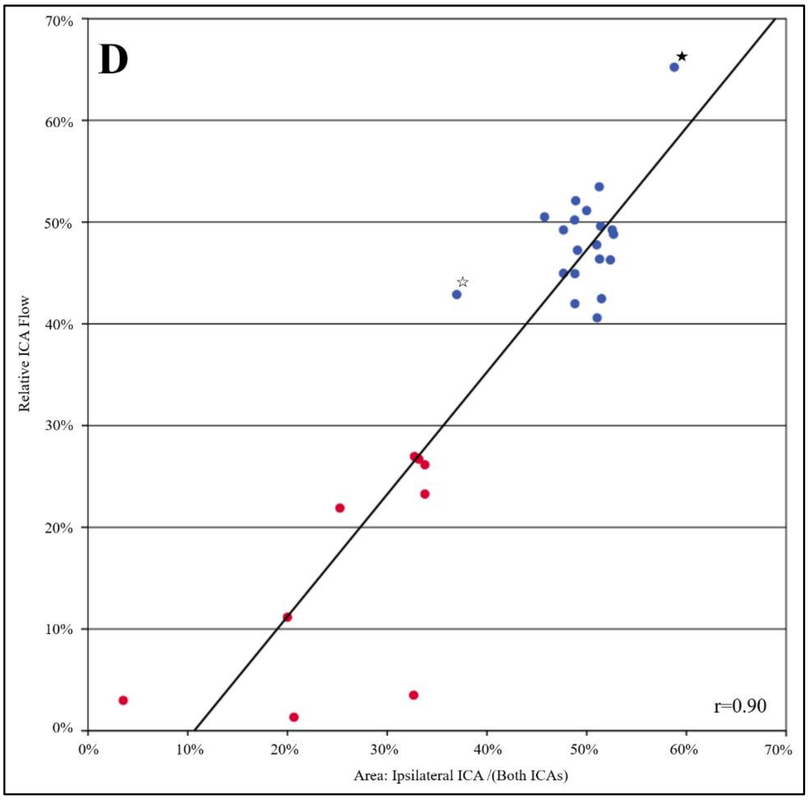
Online Figure 2: Flow in the ipsilateral ICA by stenosis category. A) Flow in ipsilateral ICA. B) Relative ICA flow. Cases with ICA asymmetry associated with Circle of Willis anatomy highlighted, mimicking near-occlusion by smaller ICA ipsilateral to stenosis (white star) and with smaller ICA on the opposite side of the stenosis (black star).



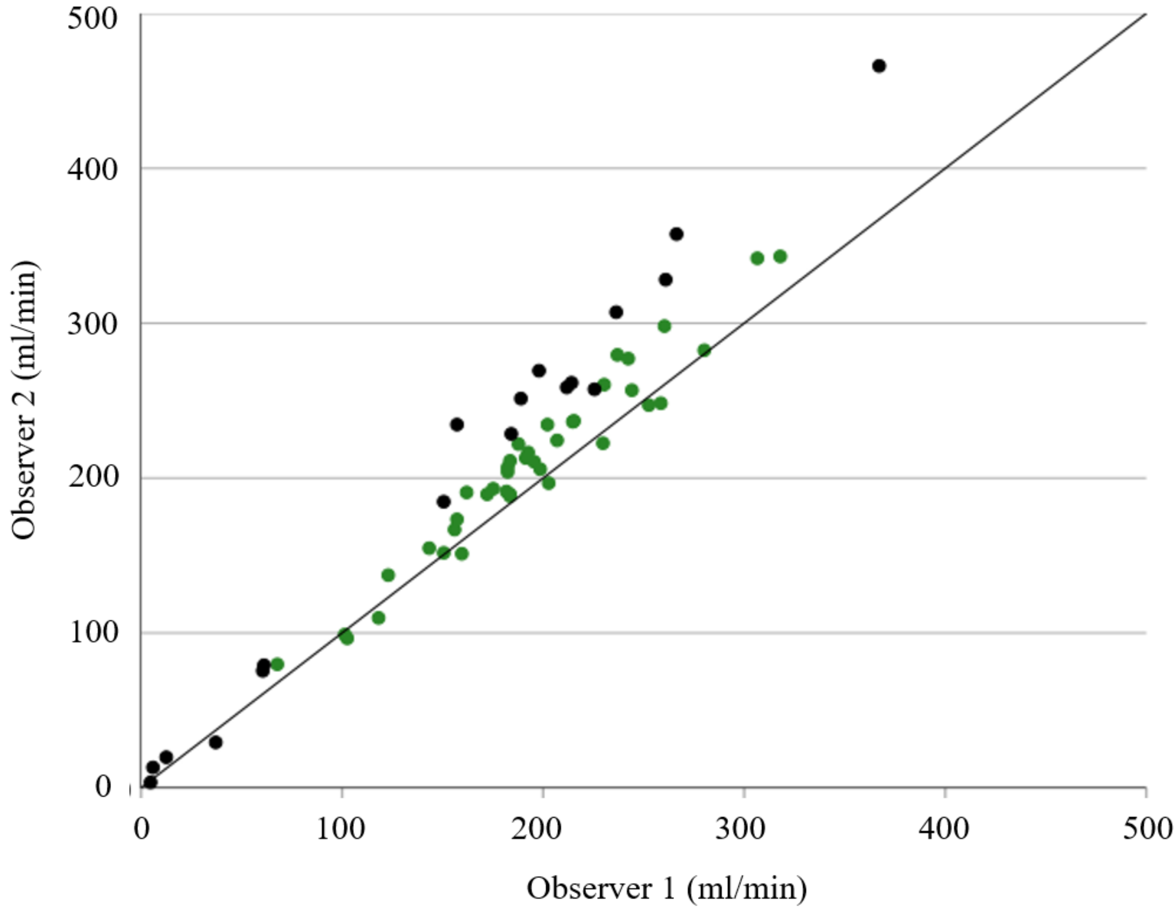
Online Figure 3: Receiver operating characteristic curve (dashed line) for ICA flow


A
ICA flow (ml/min)
300
250
200
150
100
50
0
50%
60%
70%
80%
90%
100%
NASCET degree of stenosis
r=0.06
B
ICA flow (ml/min)
300
250
200
150
100
50
0
0
0.5
1.0
1.5
2.0
2.5
Stenosis diameter on CTA (mm)
r=0.67





Online Figure 4: Blue: Conventional stenosis. Red: Near-occlusion.
A) Flow in ipsilateral ICA compared with percent degree of stenosis among all 20 cases with conventional stenosis by NASCET-grading.
B) Flow in ipsilateral ICA compared with stenosis severity in mm measured with CTA in all 28 assessable cases (one near-occlusion excluded due to extensive calcification in stenosis).
C) Flow in ipsilateral ICA compared with ICA area using absolute measurements. Black and white stars same as online figure 2
D) Relative ICA flow compared with relative ICA area. Black and white stars same as online figure 2



Online Figure 5: Difference in ICA flow findings between observers. Both ipsilateral and contralateral side assessed. Line is perfect agreement. Green: Observers within 20% of each other. Black: Observers >20% apart, requiring consensus discussion.

Online table 1. ICA flow in conventional ≥50% stenosis and near-occlusions.

	Conventional ≥50% stenosis (n=20)	Near-occlusion (n=9)	t-test
ICA flow ml/min mean (SD; Range)	198 (38; 130-286)	52 (38; 4-100)	p<0.001
Relative* ICA flow mean (SD; Range)	48% (5%; 41-65%)	16% (11%; 1-27%)	p<0.001
* Ipsilateral / (ipsilateral + contralateral)			