Imaging of Intracranial Stenosis

Objectives & Next Steps
- Collaterals offset ischemia
- Systematic evaluation of collaterals
- Hemodynamic impact, not % stenosis
- Develop fractional flow measures
- Collateral perfusion patterns distinct
- Establish noninvasive risk markers

Collaterals Offset Ischemia

WASID Collaterals & Hypoperfusion
- Collateral grade (ASYN/SIR) variable, yet more robust with greater % stenoses and diminished antegrade (TICI) perfusion (p<0.001)

SAMMPRIS Collaterals
- 424/451 cases with DSA available, collaterals in 376
  - Complete collaterals in 117 (31%)
  - Hemodynamic effects (partial TICI scores) in only 188 (50%), all in excess of 70% luminal stenosis
  - More robust collaterals (complete versus none/partial) associated with patients who at baseline were:
    - Younger (mean age 58.0 vs 61.5 years, p=0.009)
    - Had higher serum HDL (40.0 vs 37.7 mg/dL, p=0.035)
    - Participated in moderate exercise (43.1 vs 27.9%, p=0.004)
    - Did not smoke (79.5 vs 69.4%, p=0.042)

WASID Collaterals & Outcome

"Severe" - 70-99%

"Moderate" - 50-69%
SAMMPRIS collaterals

- Impaired perfusion – partial TICI and none/partial collaterals
- Normal perfusion – complete TICI and no collaterals
- Robust collaterals – partial TICI and complete collaterals
- 364/451 subjects (186 medical, 190 stenting)
- early territorial stroke (SIT) in 6/186 (3.2%) medical, 20/190 (10.5%) stenting
- 0/66 (0%) SIT in medical, 0/51 (0%) SIT in stented when collaterals were complete

Medical
- partial TICI/partial collaterals (5/25 (20.0%) p<0.001)
- complete TICI/partial collaterals (1/95 (1.1%))
- partial TICI/complete collaterals (0/66 (0%))
- ICH within 30 days in 0/186 (0%) subjects

Stenting
- partial TICI/partial collaterals (11/46 (23.9%))
- complete TICI/partial collaterals (9/93 (9.7%))
- partial TICI/complete collaterals (0/51 (0%))
- p<0.001

ICH within 30 days in 7/46 (15.2%) partial TICI/partial collaterals

perfusion – antegrade & collateral

36 cases, mean age 63 ± 14.5 years, 28% female, and time from last symptomatic event to stenting was median 15.5 (IQR 27) days

baseline degree of luminal stenosis ranged from 63 to 99% (median 85%)

collateral grade varied across cases (0-4)

more robust collaterals linked with reduced rate of peri-procedural stroke (p=0.04)

good collateral flow associated with in-stent restenosis on follow-up DSA

Collaterals avert complications

perfusion angiography

Next step

Collaterals offset ischemia

Systematic evaluation of collaterals

Hemodynamic impact, not % stenosis
percent stenosis?

- historical translation
- unique features
- 1D, not 2D or 3D
- 71-100% reliability
- no subsequent validation
- correlation with other features or clinical...

used in WASID and SAMMPRIS
more than 12 years

percent stenosis and outcomes?

- WASID – 50-99%
- SAMMPRIS – 70-99%
- no association with ischemia

atherosclerosis, not just stenosis

- physical properties, length, architecture, surface irregularity, diffuse disease, tandem disease
- % stenosis is a poor descriptor of intracranial atherosclerosis, not accounting for complexity of lesions and diffuse disease

\[ Q = \frac{\pi \Delta P r^4}{8L\eta} \]

fractional flow

- large, randomized trials established FFR for lesion-specific ischemia
- fractional flow measures proven:
  - enhance clinical decision-making
  - improve event-free survival
  - reduce unnecessary revascularization
  - lowers costs
- FAME, FAME II, DeFACTO
- anatomical luminal stenosis replaced by hemodynamics

fractional flow measures proven:

- enhance clinical decision-making
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TOF-MRA – SONIA to SINOA

- SONIA – % stenosis irrelevant
SONIA-WASID analyses included clinical variables, SIR, and invasive angiography measures. TOF-MRA was available in 189 patients with 50-99% symptomatic IAD. Univariate analysis showed a hazard ratio (HR) of 5.2 (1.8, 15.3; p=0.001) for SIR <0.9 (SIR below median) compared to SIR ≥0.9. Multivariate analysis, correcting for baseline blood pressure, LDL, percent stenosis, recency of symptoms, TICI, and downstream collaterals, showed an HR of 10.9 (2.0, 58.9; p=0.001) for SIR <0.9. Only collaterals were associated with independent stroke risk, HR 13.8 (3.4, 55.5; p<0.001). In patients with <70% stenosis, SIR <0.9 maintained a significant association with recurrent SIT (p=0.006), with a 2-year event rate of 17.3%, showing that even moderate stenoses can pose substantial ischemic risk.

CFD simulations were performed under normal inflow conditions (120/80 mm Hg) for 407 patients with 70-99% symptomatic stenosis. SIA bifurcation views were available for 3D reconstruction in 249 cases, and CFD simulations were performed in 188 (25 VA, 45 BA, 32 ICA, 86 MCA). During simulated hypertension, FF improved to normal in 5 (12.6%) cases, and during simulated hypotension, FF worsened from normal in 12 (6.4%) cases. Other hemodynamic parameters including shear stress were calculated and visually depicted.
periprocedural CFD

next step

- hemodynamic impact, not % stenosis
- develop fractional flow measures

collateral perfusion patterns distinct

subtle signatures of stenosis

ASL signatures of stenosis

signatures of stenosis
collateral perfusion & sources

myriad mechanisms
- recurrent stroke risk predicated on mechanisms
  - decreased flow due to arterial narrowing
  - impaired tissue perfusion
  - plaque instability with perforator occlusion and/or distal embolism

risk of collateral perfusion

next step
- collateral perfusion patterns distinct
  - establish noninvasive risk markers

conclusions
- systematic evaluation of collaterals
- develop fractional flow measures
- establish noninvasive risk markers