Publication Brief

One-donor, two-recipient extracranial-intracranial bypass series for moyamoya and cerebral occlusive disease: rationale, clinical and angiographic outcomes, and intraoperative blood flow analysis[1]

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BACKGROUND

Cerebral extracranial-intracranial (EC-IC) direct bypass is a commonly used procedure for ischemic vasculopathy. A variation of this technique is to utilize one donor artery to supply two recipient arteries.[2] This approach is designated as1D2R.

OBJECTIVE

To present a single surgeon's series of 1D2R direct bypasses for moyamoya and ischemia using detailed clinical, angiographic, and intraoperative blood flow measurement data.

METHOD

Hospital, office, and radiographic imaging records that included demographic information, clinical presentation, associated medical conditions, intraoperative information, and postoperative course for all patients who underwent cerebral revascularization using a 1D2R bypass were reviewed.

RESULTS

- 21 1D2R bypasses were performed in 19 patients during the study period.
- Immediate bypass patency was 100%; 90% on delayed follow-up.
- Mean initial cut flow index (CFI(i)) was 0.64 ± 0.33 prior to the second anastomosis. The mean final value (CFI(f)) was 0.94 ± 0.38 after the second anastomosis ($p < 0.001$).
- With the addition of the second anastomosis, overall average bypass flow increased by 50% (mean 17.9 mL/min, range -10 to 40 mL/min).
- Whether an end-to-side anastomosis or side-to-side anastomosis was performed first caused no significant difference in overall flow values.
- There was a statistically significant difference in the proportion of patients with a modified Rankin Scale (mRS) score of 0 or 1 postoperatively compared to preoperatively ($p < 0.01$).
- Through application of Poiseuille's law, the authors analyzed flow dynamics, deduced the component vascular resistances based on an analogy to electrical circuits and Ohm's law, and introduced new concepts of "second anastomosis relative augmentation" and "second anastomosis sink index" in the evaluation of 1D2R bypasses.

CONCLUSIONS

- Application of the 1D2R technique in a series of 19 consecutive patients undergoing direct EC-IC bypass for flow augmentation demonstrated high patency rates, statistically significantly higher CFIs compared to 1D1R, and improved mRS scores at their last clinical follow-up.
- The 1D2R technique allows a shorter dissection time and preserves blood flow to the scalp.
- Routine use of intraoperative volumetric flow measurements in such surgeries provides a deeper understanding of the hemodynamic impact on individual patients.

TAKE HOME

Landmark flow paper that complements Arnone *et al* 2019 introduction to this approach.[2] See next page.

REFERENCES

[1]Khan NR, Lu VM, Elarjani T, Silva MA, Jamshidi AM, Cajigas I, Morcos JJ. One-donor, two-recipient extracranial-intracranial bypass series for moyamoya and cerebral occlusive disease: rationale, clinical and angiographic outcomes, and intraoperative blood flow analysis. J Neurosurg. 2021 Aug 20:1-10. doi: 10.3171/2021.2.JNS204333. Epub ahead of print. PMID: 34416732.(Transonic Reference # NS2021-30AH)

[2]Arnone GD, Hage ZA, Charbel FT. Single Vessel Double Anastomosis for Flow Augmentation - A Novel Technique for Direct Extracranial to Intracranial Bypass Surgery. Oper Neurosurg (Hagerstown). 2019 Oct 1;17(4):365-375. PMID: 30690506. (Transonic Reference # NS2019-30AH)

Direct Quotations from One-donor, Two-recipient EC-IC Bypass Series for Moyamoya & Cerebral Occlusive Disease...

INTRAOPERATIVE BLOOD FLOW ANALYSIS

"**The sequential steps in which intraoperative blood flows were measured are demonstrated in Fig. 1**. We are introducing two new concepts: 1) second anastomosis relative augmentation (SARA), and 2) second anastomosis sink index (SASI). As shown in Fig. 1, SARA measures the relative increase in flow afforded by adding a second anastomosis, compared to what the final flow would have been with only one anastomosis. A SARA of 2, for example, indicates that the final flow is 2 times the interim flow. This index is a reflection of how much blood flow was increased by adding a second arteriotomy in the donor STA, coupled with adding a second vascular territory to receive the added flow. SASI describes a related but distinct concept. Unlike SARA, SASI is independent from the interim flow and simply measures the proportion of the final flow that is due to the second anastomosis. In effect, it reflects the degree to which the addition of the second recipient territory to the bypass acts as a "sink" that redistributes flow away from the first territory. A SASI of 0.4 signifies that the second anastomosis is responsible for 40% of the total final bypass flow. SARA and SASI are undoubtedly affected by multiple factors, including STA donor factors (length, diameter, arteriotomy cross-sectional area and position, etc.), recipient vessel factors (such as diameter, angle of anastomosis), and recipient territory factors (presence of actual and potential collaterals, interconnectedness to other territories, and others). A semi-quantitative derivation of SARA and SASI is discussed in Supplemental Data 2."

FLOW DATA ANALYSIS

"Intraoperative quantitative blood flow measurements in bypass surgery and in cerebrovascular surgery are used by many neurosurgeons, although not universally. A lot of useful information can be extracted from the data on individual patients as well as patient cohorts. When CFI was calculated twice in the same patient (CFI(i) after the first anastomosis, and CFI(f) after both anastomoses), there was a statistically significant increase in the CFI ($p < 0.01$). Their ratio CFI(f)/CFI(i), which we have defined as SARA, was almost always > 1 (in 11/12 hemispheres; range 0.87–3.00, mean 1.79), confirming a robust demand for additional blood flow in our patients, and the appropriateness of selecting them for bypass surgery. This is consistent with prior reports from Arnone and indicates that there is potential for increased flow augmentation when utilizing this technique compared to the classic 1D1R technique. Furthermore, the flow was directed preferentially toward areas of angiographic hypoperfusion when such an area could be objectively identified on a preoperative angiogram. This is well corroborated by examining the ΔFM4 and ΔTM4 in Table 3. In the 5 cases in which there was clear evidence of preoperative angiographic hypoperfusion in the frontal territory, mean ΔFM4 was +40 ml/min, compared to a much smaller ΔTM4 of +8 ml/min. In the single case in which there was clear evidence of angiographic hypoperfusion preoperatively in the temporal territory, ΔFM4 was +18 ml/min, compared to a much larger ΔTM4 of +36 ml/min. These phenomena are simply a reflection of reducing the vascular resistance compounded by a steeper pressure gradient in hypoperfused areas. It is the interplay of pressure and resistance within individual vascular territories perfused by the bypass that determines the proportional immediate distribution of flow and its redistribution over time. The introduction and calculation of SARA and SASI in such patients allow a quantitative description of these phenomena. As seen in Table 3, mean SARA is 1.79, and mean SASI is 0.40, highlighting a dis- tinct perfusion advantage in adding a second anastomosis. These parameters can be easily utilized prospectively by other groups (as we intend to do) in similar series and may correlate with events such as postoperative hypoperfusion, postoperative hyperperfusion, clinical outcomes, angio- graphic outcomes, flow redistribution, and short- and long- term patency of the anastomoses."

STRENGTHS AND LIMITATIONS

"The strengths of this study are that it is currently the largest series of this novel technique with postoperative angiographic and clinical outcomes that **also provides very detailed analysis of intraoperative blood flow measurements, which are rarely performed or reported in the literature."...**

CONCLUSION

..."When intraoperative flow measurements are routinely incorporated in such surgeries, a deeper understanding of bypass physiology is achieved, which can only better guide clinical care, help properly interpret perioperative complications, and potentially predict long-term flow redistribution and patency rates."...