2021 43rd Annual International Conference of the
IEEE Engineering in Medicine & Biology Society (EMBC)
Oct 31 - Nov 4, 2021. Virtual Conference

Contrast Reflux Length is Correlated to Baseline Blood Flow Rate and Injection Conditions: Preliminary In Vivo Results

Chander Sadasivan, Neil Sathi, Nakisa Dashti, and David Fiorella

***Abstract*— The hemodynamics of contrast reflux during 2D angiography has not been properly investigated in the literature. We conducted an *in vivo* study to evaluate the effect of injection conditions and baseline hemodynamics on reflux. Several parameters (catheter size, injection rate, Reynolds number of flow) were significantly correlated to contrast reflux length, while injection time had no effect. These correlations have never been noted before and may have clinical utility.**

***Clinical Relevance*— A simple measurement of contrast reflux length during standard angiography can provide an estimate of baseline (pre-injection) mean blood flow rate.**

I. INTRODUCTION

Contrast reflux, which is the retrograde movement of contrast proximal to the catheter-tip, is a commonly observed phenomenon during standard 2D angiography. However, other than some misconceptions, such as the so-called spillover flowmeter [1], the hemodynamics of contrast reflux has been rarely studied [2]. The Reynolds number is a dimensionless parameter relating inertial and viscous forces of fluid flow. In a previous benchtop experiment, we observed an exponential relationship between contrast reflux length and the ratio of Reynolds numbers of 'blood' to contrast flow [3]. Here, our goal was to investigate, *in vivo*, the relationship of contrast reflux to the underlying hemodynamics.

II. METHODS

With IACUC approval, we injected contrast into the right common carotid arteries of two domestic swine with different catheters (4Fr and 5Fr), injection rates (1-9 cc/s), and injection times (2 -10 secs) for a total of 76 injections. High-speed (15 frames/sec) angiographic runs were acquired and, in each run, the distance from the catheter-tip to the most proximal edge of the contrast bolus was recorded as the reflux length. In one animal, the ipsilateral internal carotid was embolized (Onyx, Medtronic Irvine CA USA) to assess the effect of the *rete mirabile* on injection hemodynamics and reflux. The reflux length was statistically compared to catheter size, injection rate, and injection time (Graphpad Instat, San Diego CA USA). The ratio of mean Reynolds number of blood flow to the Reynolds number of contrast injection was plotted against the normalized reflux length (ratio of reflux length to vessel diameter at catheter-tip). A simple exponential equation was fit to this plot using Matlab (Mathworks, Natick MA USA).

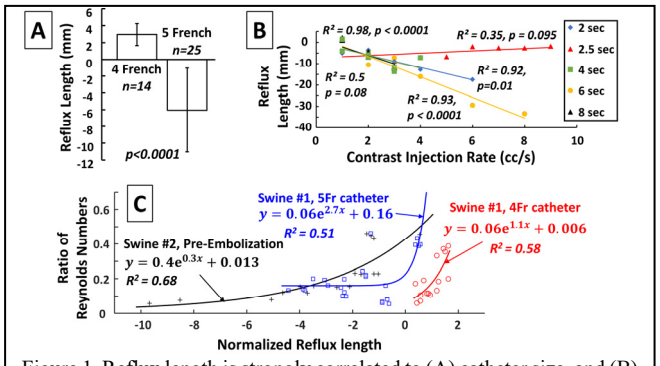

Figure 1. Reflux length is strongly correlated to (A) catheter size, and (B) injection rate. (C) exponential fits to the ratio of Reynolds numbers to normalized reflux lengths show moderate correlations

III. RESULTS

The reflux length was significantly correlated to catheter size (Fig. 1A) and injection rate (Fig. 1B). However, varying injection times had little to no effect on the reflux length (all R^2 values < 0.5). Contrast reflux lengths showed moderate exponential correlations to the Reynolds number ratios (Fig. 1C). Embolization of the ipsilateral internal carotid (Fig. 2) nearly tripled the reflux length (pre-embolization: -9.1±8.5 mm, n=26; post-embolization: -24.2±7.6 mm, n=20; p<0.0001) but resulted in poor correlation between the Reynolds number ratio and normalized reflux length (R^2=0.1).

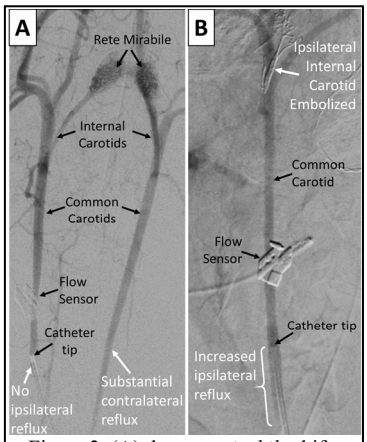

Figure 2. (A) the *rete mirabile* shifts reflux to the contralateral carotid (B) Embolization of the internal carotid significantly increases ipsilateral reflux.

IV. DISCUSSION & CONCLUSION

These preliminary results confirm that contrast reflux is dependent on specific injection parameters. The *rete mirabile* acts as a 'short-circuit,' and introduces variability into flow studies in the swine carotid. As the baseline blood flow rate is the only unknown in the ratio of Reynolds numbers, if such an exponential relationship is validated clinically, simply measuring the contrast reflux length can provide an estimate of the blood flow rate in the artery of interest. Additional data need to be collected to verify and validate these findings.

*In-kind services support by Siemens Healthineers (C00232062)

C. Sadasivan is with Stony Brook University, Stony Brook, NY 11794 USA, phone: 631-444-2658, email: csadasivan@sbumed.org

REFERENCES

[1] C. Gianturco et.al., *Invest. Radiol.*, vol. 5, pp. 361-3, 1970.
[2] G.D. Aviram, et.al., Am. J. Cardiol., vol. 109, pp. 432–7, 2012.
[3] B. Kovarovic et.al., *Cardiovasc. Eng. Technol.*, vol.9, pp.226-39, 2018.