Arterial flows as social networks: a novel approach to disentangle hemodynamic complexity

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1. Introduction

Current approaches for deciphering the richness of information in cardiovascular flows are mainly based on visual evaluation or integral quantities. To disentangle complex arterial hemodynamics identifying coherent blood flow patterns, an approach modelling arterial flows as "social networks" is proposed [1]. The final aim is distilling the information emergent from blood flow topology into physio-pathological significance. The Complex Networks (CNs) are exploited to quantify the degree of dynamical similarity of correlated blood flow patterns, and the association with vascular geometric attributes is explored *in silico* and *in vivo*.

2. Materials and Methods

Like a social network made up of a set of dynamical units and social interactions among them, here arterial flows are modelled as a set of hemodynamic time-dependent signals interconnected based on the correlation between their dynamic behaviours (Fig. 1A). The pattern of connections between correlated fluid structures in a CN is called *topology* and it contains useful information on the level of organization of the investigated 4D flows. To extract such information, a series of CNs metrics can be computed to quantify, for example, (1) the degree of dynamical similarity of arterial structures, and (2) the anatomical propagation distance over which a hemodynamic signal maintains its coherence (i.e., correlation) inside the vessel. The presented approach has been successfully applied in a series of *in silico* and *in vivo* studies [1,2].

3. Results

Explanatory results of the application of CNs to study axial velocity features in computational models of healthy carotid bifurcation [1], and 4D flow MRI models of dilated thoracic aorta [2] are reported in Fig. 1B: the volume maps of CNs metrics, measuring topological and anatomical hemodynamic similarity allow to visualize coherent hemodynamic patterns and quantify the extent of their dynamical similarity within the fluid domain. From the distribution of the anatomical length of persistence of the hemodynamic correlation, regions where flow coherence is disrupted (e.g., by vascular geometric attributes, as in the carotid bulb [1] or in the ascending aorta [2]) or is maintained for a longer distance in the vasculature can be identified.

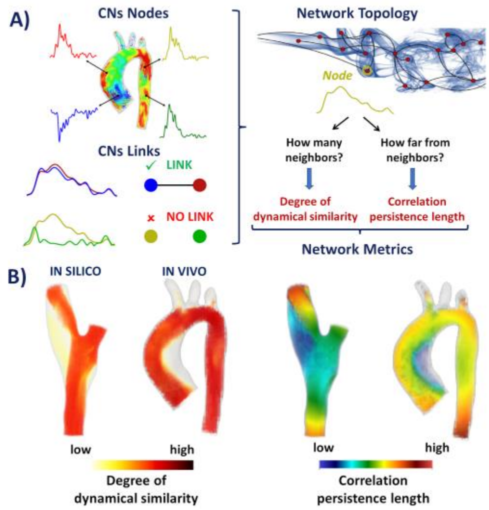

Figure 1: A) Schematic of the CNs approach. B) Explanatory results of coherent flow structures characterization using CNs.

4. Discussion and Conclusions

A new paradigm is introduced, which models arterial flows as social networks, providing a stronger quantitative definition of "coherent hemodynamic structures". CNs emerge as a powerful tool for identifying still poorly explored/hidden features of arterial hemodynamics.

5. References

1. Calò K et al., IEEE Trans Biomed Eng, 67(7) (2020).
2. Calò K et al., Ann Biomed Eng, 49(9) (2021).