A Multiscale Model of Cerebral Perfusion During Acute Ischaemic Stroke With Collaterals

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1 Introduction

An acute ischaemic stroke is caused by the sudden blockage of a large cerebral vessel by a thrombus. The loss of blood flow to cerebral tissue leads to the formation of an infarct. The speed of infarct formation depends on the level of remaining tissue perfusion. Accurately predicting tissue perfusion during acute ischaemic stroke requires the two-way coupling between arterial blood flow and tissue perfusion models. In addition, the collaterals provide alternative pathways for blood flow in the event of an acute ischaemic stroke, thereby slowing infarct formation [1]. The collaterals are highly variable between patients, and capturing this variability is essential to accurately predicting tissue perfusion and subsequent infarct formation. Good collaterals increase the residual flow during an acute ischaemic stroke. Thereby leading to smaller infarct volumes, and resulting in better patient outcome.

2 Methods

Arterial blood flow is modelled using a one-dimensional steady state blood flow model. The vasculature is modelled as a network of pressure dependent resistances. Cerebral tissue is modelled using a three compartmental porous medium approach. The three compartments capture the arterial, capillary, and venule vessel scales of the brain [2]. These two models are coupled by linking the outlet pressure and flow rate of the arterial blood flow model to the surface boundary conditions of the tissue perfusion model [3, 4]. The pressure drop between the outlets of the arterial blood flow model and tissue perfusion model, caused by vessels not included in either model, is captured by a coupling resistance.

The collaterals are captured by allowing flow between the surface regions of the tissue model, this is functionally equivalent to allowing flow between the outlets of the arterial blood flow model. A single constant is used to capture the degree of collateral flow. Infarct volume can be determined by setting a threshold on the (relative) perfusion levels. An acute ischaemic stroke can be modelled by setting the conductance of a cerebral vessel to zero, i.e. infinite resistance. A blockage of the right middle cerebral artery is modelled in this abstract.

3 Results & Discussion

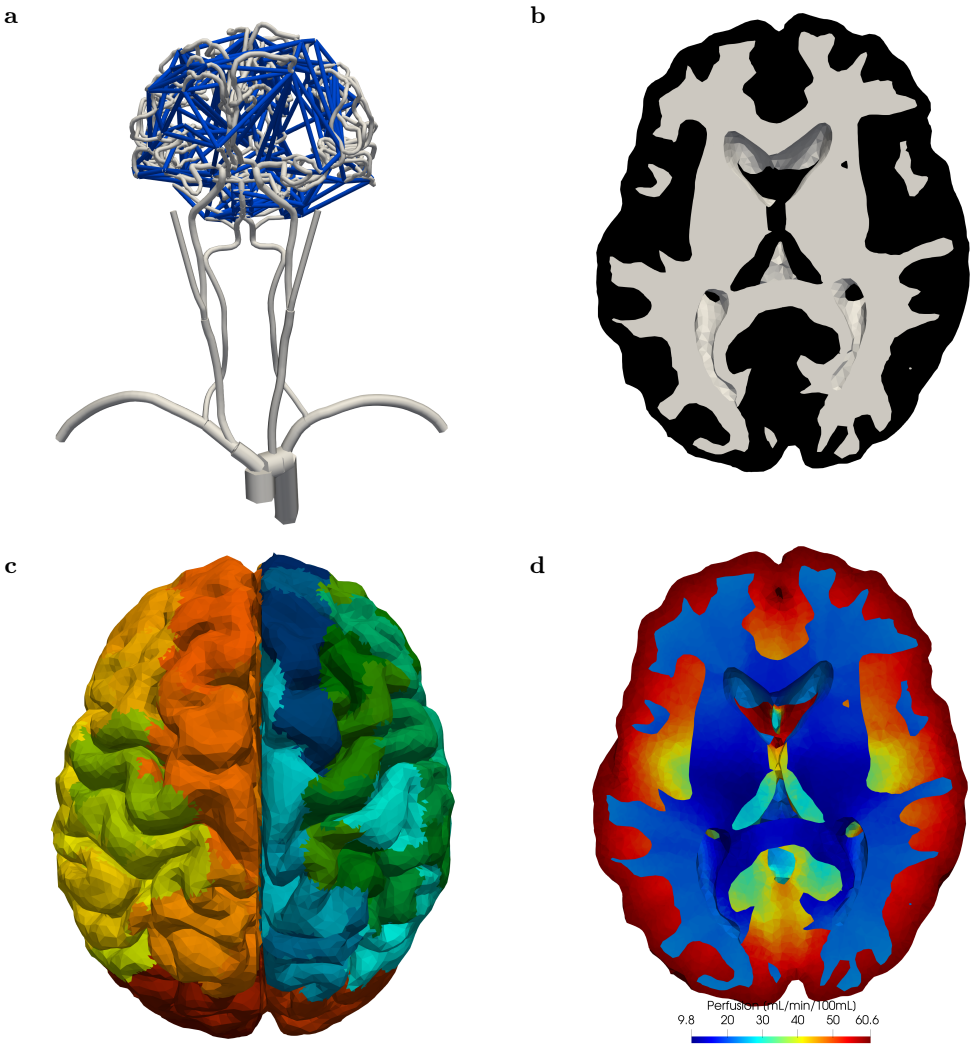

Figure 1: *(a) The arterial blood flow model. The vessels are shown in white, while the collaterals are shown in blue. (b) Slice through the tissue perfusion model showing the white and grey matter regions of the brain. (c) Surface boundary mapping. Each region is perfused by a single outlet of the arterial blood flow model. (d) Healthy tissue perfusion. The grey matter regions have higher overall perfusion than the white matter regions.*

Figure 1 shows the arterial blood flow model, the tissue perfusion model, the boundary

surface mapping, and healthy perfusion. The collaterals are modelled as connections between the different outlet regions on the surface of the brain. Blood can therefore only flow between neighbouring surface regions, similar to pial surface vessel network.

Figure 2 shows tissue perfusion and the percentage change during an acute ischaemic stroke for absent and good collaterals. The strength of the collaterals, i.e. amount of flow, is set by a single constant. This value has to be calibrated to obtain tissue perfusion levels that match the clinical collateral scores. This is achieved by matching clinically measurable quantities, such as perfusion distributions or infarct volume, for different collateral scores [5]. The model captures the effect of the collaterals, resulting in lower infarct volume for patients with good collaterals.

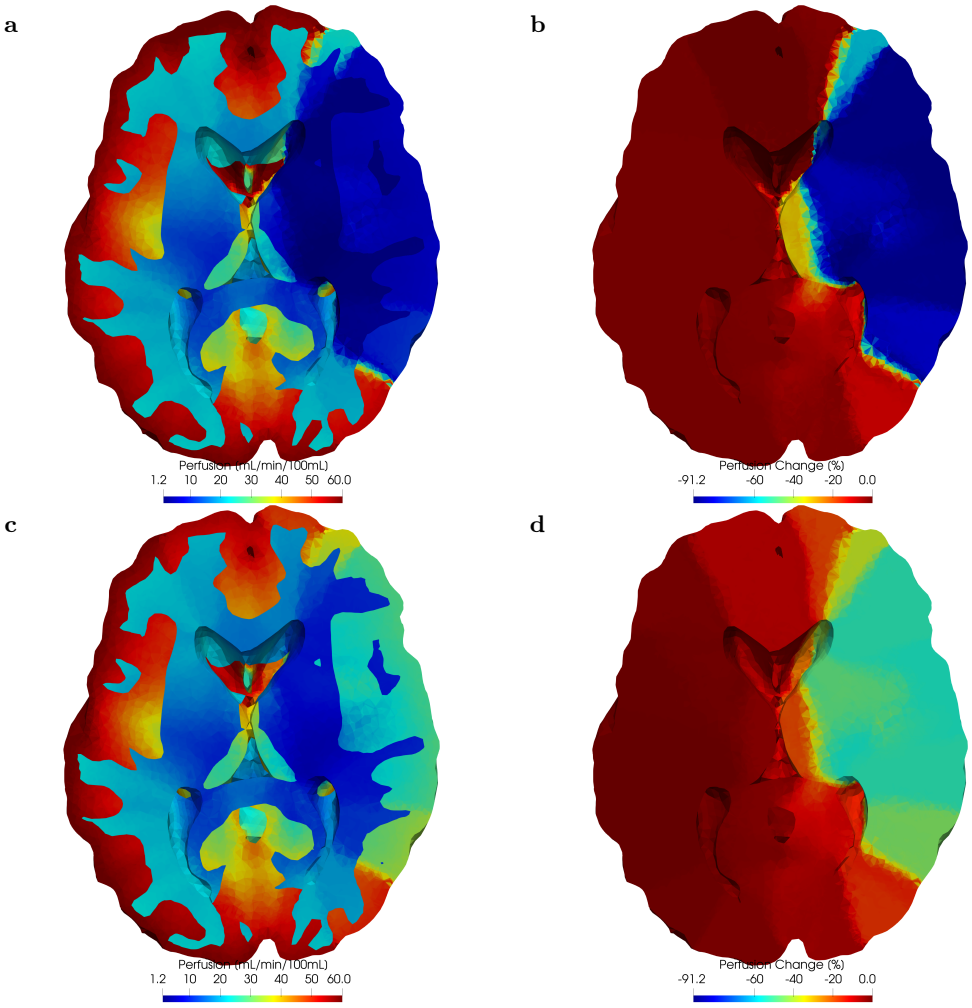

Figure 2: *Perfusion comparison between absent and good collaterals. (a, c) Absolute perfusion during an acute ischaemic stroke for absent and good collaterals respectively. (b, d) Perfusion change in percentages for absent and good collaterals respectively.*

4 Conclusion

Accurately predicting tissue perfusion and infarct volume requires a two-way coupled model that captures arterial blood flow, tissue perfusion, and collateral flow. In this work, a multiscale model of cerebral blood flow including the collaterals is presented. The model is able to capture the residual blood flow due to the collaterals. Capturing collateral flow, including the variation between patients, during an acute ischaemic stroke leads to better estimates of infarct volume.

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6 Conflicts of Interest

The authors declare that there is no conflict of interest

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