



# From cerebral blood flow modeling to vascular units map in primate cortex

Romain Guibert, Caroline Fonta, Franck Plouraboué

## ► To cite this version:

Romain Guibert, Caroline Fonta, Franck Plouraboué. From cerebral blood flow modeling to vascular units map in primate cortex. EUROMECH Colloquium 521 - Biomedical Flows at Low Reynolds Numbers, Aug 2011, Zurich, Switzerland. hal-00944750

**HAL Id: hal-00944750**

**<https://hal.science/hal-00944750>**

Submitted on 18 Mar 2014

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



## Open Archive TOULOUSE Archive Ouverte (OATAO)

OATAO is an open access repository that collects the work of Toulouse researchers and makes it freely available over the web where possible.

This is an author-deposited version published in : <http://oatao.univ-toulouse.fr/>  
Eprints ID : 10542

**To cite this version** : Guibert, Romain and Fonta, Caroline and Plouraboué, Franck From cerebral blood flow modeling to vascular units map in primate cortex. (2011) In: EUROMECH Colloquium 521 - Biomedical Flows at Low Reynolds Numbers, 29 August 2011 - 31 August 2011 (Zurich, Switzerland)

Any correspondence concerning this service should be sent to the repository administrator: [staff-oatao@listes-diff.inp-toulouse.fr](mailto:staff-oatao@listes-diff.inp-toulouse.fr)

# FROM CEREBRAL BLOOD FLOW MODELING TO VASCULAR UNITS MAP IN PRIMATE CORTEX

Romain Guibert<sup>1,2</sup>, Caroline Fonta<sup>2</sup> & Franck Plouraboué<sup>1</sup>

<sup>1</sup> *Université de Toulouse ; INPT, UPS ; IMFT (Institut de Mécanique des Fluides de Toulouse) ; Allée Camille Soula, F-31400 Toulouse, France*

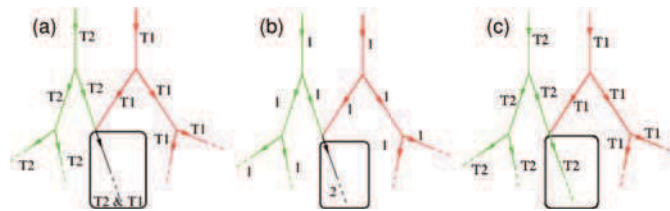
<sup>2</sup> *Université de Toulouse; UPS; Centre de Recherche Cerveau et Cognition; France*

## INTRODUCTION

The amazing topological and geometrical complexity of micro-vascular networks in the brain, and in other organs, has challenged many researchers for decades. Since the brain's vascular system is structured by a highly reticulated pial surface network which plunges down into a set of penetrating vessels, it is tempting to attribute a vascular unit to each penetrating arteriole. Recent experimental analysis have led to a breakthrough on the properties of the blood supply in the brain [1]. Penetrating arterioles have been identified as the bottleneck of brain perfusion [2]. Furthermore, it has also been realized that targeted clots of penetrating arterioles are not compensated by active changes in the diameter of their neighbor arteries [3]. This observation suggests passive compensatory mechanisms resulting from the couplings between arteriolar territories consistent with other recent observations of active blood flow reorganization via collateral vessels (inter-arterial connections) [4]. A systematic investigation of the three-dimensional extent of compensation is not possible with experimental measurements but *in silico* simulations permit a systematic investigation of the spatial distribution of the brain perfusion. The direct computation of blood flow considering a complete mechanical description of its components interactions (red blood cells, plasma, vessel shape, Endothelial Surface Layer – ESL –) over several cubic millimeters of tissue is a more than challenging task for any computer at present. Approximate methods are needed to provide a realistic picture of blood distribution inside tissues [5]. Such approximate network method have permitted to realize that vessel shape, realistic boundary conditions, and *in vivo* (ESL included) effective apparent viscosity are important ingredient for the pressure and blood flux distributions [5]. We analyze here the functional topological and spatial couplings of arteriolar and venous inputs/outputs.

## VASCULAR TERRITORIES ANALYSIS

### Definition

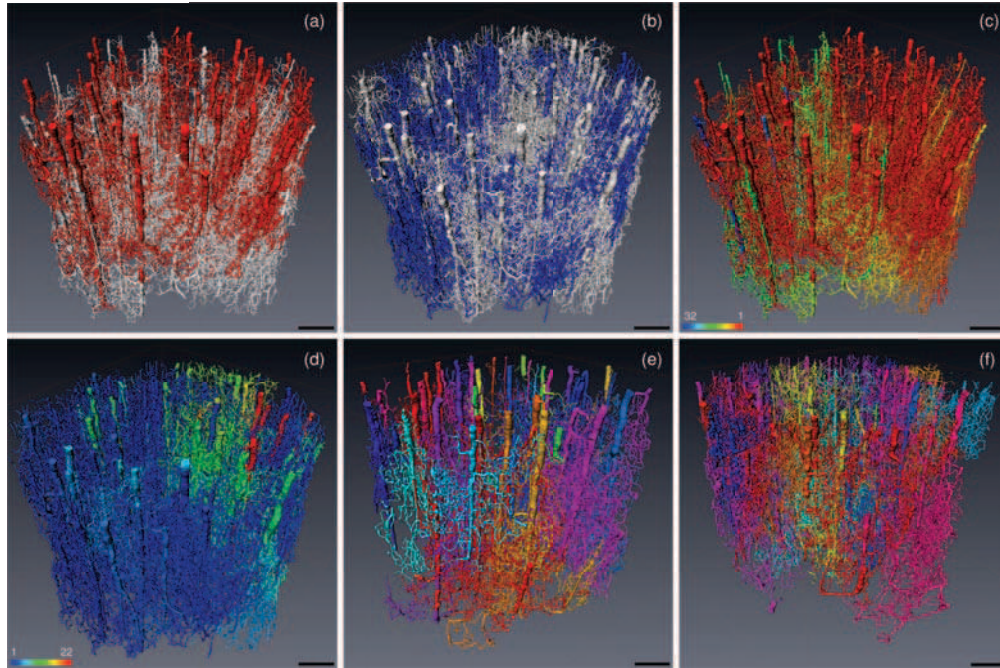


**Figure 1.** (a) Illustration of Perfusion/Drainage Territory and (b) Robustness Index (RI).

- *Perfusion-Drainage Territory* (PDT) is defined as the entire region either spanned through perfusion (Arterial PDT), or drained by perfusion (Venular PDT) (see Figure 1a) which are possibly overlapping.
- *Arterial/Venular Robustness Map* (ARM, VRM) quantifies the redundancy of the perfusion at one point (see Figure 1b). Arterial Robustness Map (ARM) provides, for each segment, the number of input penetrating arteries which contribute to its perfusion, a number called Arterial Robustness Index (ARI).

### Vascular territories evaluation

We analyze the territories of 37 penetrating arterioles and 24 draining venules resulting from the analysis of 18 cubic millimeters of monkey cerebral cortex where the blood perfusion has been previously evaluated [5]. Figures 2a,c and Figures 2b,d illustrate the arterial and venous Perfusion/Drainage Territories (PDT) respectively.



**Figure 2.** (a) Non overlapping Arterial Preferential Drainage Territory regions are displayed in red whilst overlapping one are represented in white, (b) same convention as (a) for Venous Preferential Drainage Territory with blue instead of red, (c) Arteriolar Robustness Map (ARM) and (d) Venular Robustness Map (VRM). (e) Arteriolar PT (APT), (f) Venular PT (VPT).

### CONCLUDING REMARKS

These estimations support the classical picture of preferential neighbors hemodynamics interactions of vascular territories, either inside the network, or between pial input/output penetrating vessels. Although we found very localized functional couplings between preferential arterio-venular partners, we also brought to the fore important potential collateral supplies which can be distributed over a surprisingly large spatial extent.

### References

- [1] Schaffer CB, et al. (2006) Two-photon imaging of cortical surface microvessels reveals a robust redistribution in blood flow after vascular occlusion. *PLoS Biol.* 4:258–270.
- [2] Nishimura N, Schaffer CB, Friedman B, Lyden PD, Kleinfeld D (2006) Penetrating arterioles are a bottleneck in the perfusion of neocortex. *P. Natl. Acad. Sci. USA* 104:365–370.
- [3] Nishimura N, Rosidi NL, Iadecola C, Schaffer CB (2010) Limitations of collateral flow after occlusion of a single cortical penetrating arteriole. *J. Cerebr. Blood F. Met.* p doi:10.1038/jcbfm.2010.157.
- [4] C. C. Lay, M. F. Davis CHCB, Frostig RD (1981) Mild sensory stimulation completely protects the adult rodent cortex from ischemic stroke. *Plos one* 7:519–579.
- [5] Guibert R, Fonta C, Plouraboué F (2010) Cerebral blood flow modeling in primate cortex. *J. Cerebr. Blood F. Met.* 30:1860–1873.