Development of a Computational Model to Determine the Risk of Aneurysm Rupture

Umang Patel1, Alberto Marzo2, Alan Waterworth1, Rod Hose3, Alejandro Frangi3, Pat Lawford2, Keith McCormack2, Stuart Coley1

1Royal Hallamshire Hospital, Sheffield, UK,
2University of Sheffield, Sheffield, UK
3Universitat Pompeu Fabra, Barcelona, Spain

1. Introduction
@neurIST is a major multidisciplinary European initiative. The project brings together neurosurgeons, neuroradiologists, epidemiologists, engineers, biologists and computer scientists from 32 European institutions, both public and private, in 12 countries (see Fig. 1) to develop a usable interface for personalised risk assessment and treatment of patients with cerebral aneurysm and subarachnoid haemorrhage. The University of Sheffield and the Sheffield Teaching Hospitals NHS Trust have a major role in the development of image processing and computational tools to provide new, non-observational measures for the characterisation of the disease. Epidemiologists in @neurIST will explore how these measures might be linked to aneurysmal evolution and risk of rupture with the ultimate aim of assisting clinicians in their decision-making process.

2. Rationale and Objectives
It is the primary thesis of the project that the process of disease diagnosis, treatment and planning is compromised by the fragmentation of the data that should underpin it. These data are increasingly heterogeneous in form (textual information, image information, numerical information, etc.), multi-scale (from genomics through cellular to organ, patient and population length scales), and cross-disciplinary in nature (bioinformatics, medical informatics, etc.) [1, 2]. @neurIST is developing an IT infrastructure and computational tools that will assist the collection, processing and integration of data from all data sources on cerebral aneurysm.

The team in Sheffield will use advanced computational models to extract haemodynamic and structural measures that have been associated in the literature with the evolution or risk of rupture of the aneurysm. Examples of these measures include blood velocity patterns, wall shear stress (i.e. viscous shear stress exerted by blood and experienced by endothelial cells), wall strain and pressure on the aneurysmal wall. The @neurIST computational tools will extract these measures from a database of 800 aneurysms provided by the participating clinical centres*.

3. Methods and Results
Using input parameters such as neuroradiological studies (e.g. 3DRA, CTA), blood density, haematocrit, heart rate, and cardiac contractility, the @neurIST computational toolchain uses advanced numerical methods such as Computational Fluid Dynamics and Finite Element Analysis to solve the equations that represent the physical system. Haemodynamic data and structural stress and strain of the arterial wall are computed in the region represented by the aneurysm and its surrounding vessels. Fig. 2 and 3 illustrate some of the variables computed by these tools for a saccular aneurysm located at the branching point between the right internal carotid artery and the right posterior communicating artery. These data will then be returned to the @neurIST database, integrated with data coming from other processing tools within the project (genetic, morphological, biological data etc.) and statistically linked to the categorisation (ruptured or unruptured) of the processed aneurysms.

Another important part of the project will support the design of novel implantable devices (stents) and intervention planning by simulation of the structural, haemodynamic and biological response to intervention, see Fig. 4.

4. Discussion and Conclusions
The goal of @neurIST is for all data, computed and data-mined, to be integrated and made available to medical practitioners through an intuitive interface in the clinic, permitting individual, personalised risk assessments. The impact, in both health and economic terms, is likely to be profound.

The computational tools being developed within @neurIST will permit additional measures of haemodynamic and structural data of patients-specific cerebral aneurysms to be obtained without additional intervention. These tools will be deployed on mathematical approximations of the real systems and confidence in their reliability rests upon their validation with in-vivo measurements; unfortunately making such measurements is extremely difficult. To overcome this difficulty @neurIST will obtain measured, experimental data from a number of specially-constructed artificial phantoms resembling the complex anatomical shapes encountered in cerebral aneurysms. The @neurIST tools will then be applied to several hundred real aneurysms, computing in each case a comprehensive set of haemodynamic and structural variables that, in the literature, have been associated with aneurysmal growth and rupture. The extent to which these associations are matched by @neurIST findings will represent an additional measure of the tools’ validity, and the process may also deliver fresh insights into the disease process.

Clinical acceptance of the @neurIST approach to diagnosis will fundamentally alter the treatment pathway, and success in this arena could lead to the application of these techniques in many other disease areas.

REFERENCES

ACKNOWLEDGEMENTS
Project Identifier: IST-2004-517763

* Clinical centres: The University Hospital of Geneva, The Royal Hallamshire Hospital (Sheffield Teaching Hospital NHS FoundationTrust), Erasmus Universiteit Medisch Centrum Rotterdam, The Chancellor Masters and Scholars of the University of Oxford, Neurangiograf ia Terapèutica S.L (Hospital General de Catalunya), Hospital Còrset.Lesclavoreu y de Barcelona, Fèix Tumorsvascular (The University Medical Center of Pecs)