# Evaluation of a computer-based simulation for the endovascular treatment of intracranial aneurysms

René Anxionnat, Federico Rocca, Serge Bracard, Jérémie Dequidt, Erwan Kerrien, Christian Duriez, Marie-Odile Berger, Stéphane Cotin

# Evaluation of a Computer-based Simulation for the Endovascular Treatment of Intracranial Aneurysms

R. Anxionnat, MD, PhD[a], F. Rocca, MD[a], S. Bracard, MD[a], J. Dequidt, PhD[b], E. Kerrien PhD[c], C. Duriez, PhD[b], M.-O. Berger, PhD[c], S. Cotin, PhD[b].

a Interventional Neuroradiology dept, CHU, Univ. Hospital, Nancy, France
b Alcove project-team, Univ. Lille & INRIA Lille-Nord Europe, Lille, France
c Magrit project-team , LORIA & INRIA Nancy-Grand Est, Nancy, France

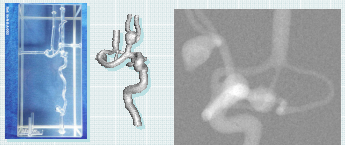
## Introduction - Purpose

Endovascular treatment (EVT) of intracranial aneurysms requires highly trained physicians and careful pre-therapeutic evaluation of the aneurysm morphology. A realistic interventional simulator would provide procedural and skill training for either educational purpose or pre-therapeutic simulation in complex cases. This work aims at evaluating the clinical realism of a computer-based simulator for the EVT of aneurysms.

## Real-time Simulation Prototype: main technical aspects

A prototype computer-based EVT simulation system was developed and implemented [1] in the Sofa framework. It relies on two modeling modules. In the first module, vessel walls are segmented from a 3D X-ray rotational angiography acquisition as a triangulated surface. In the second module, beam theory grounds the finite elements model of the coil. Real-time coil deployment simulation is based on a physical model of the contact (Signorini's law), including self-collisions.

## Evaluation: data

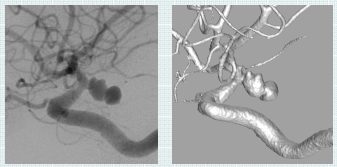


Elastrat phantom — Vessel walls segmented from 3DXA

Rigid silicon phantom from Elastrat (Geneva)

Patient #1: Middle cerebral artery aneurysm on AP view.

First coil deployed: Coil 3D 6/15.

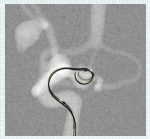


Patient #2: bilobated carotid siphon aneurysm on lateral view.

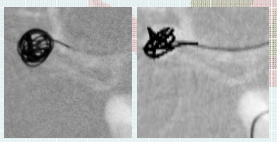
First coil deployed: Coil 3D 6/15.

## Qualitative Evaluation

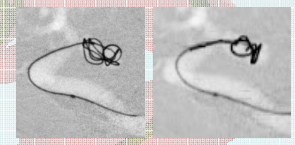
### Comparison with roadmap images



Phantom data: the simulated coil is superimposed onto the real coil.



Patient #1: (left) real coil; (right) simulated coil.



Patient #2: (left) real coil; (right) simulated coil.

The simulated coil was blended into a coil-free roadmap image. Comparison was carried out with real roadmap images.

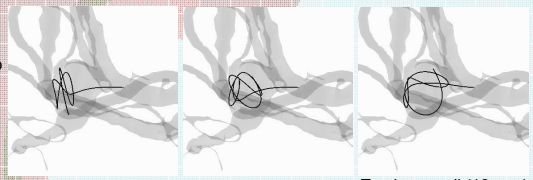
Results:
- very similar coil shape at the beginning and at the end of the deployment
- very realistic dynamic behavior of the coil, with rapid configuration changes successfully simulated during deployment
- some unknown parameters in practice (e.g. coil roll angle): point-to-point comparison is senseless => global comparison

### Testing various coil diameters

Various coil sizes were tested for helical coils.

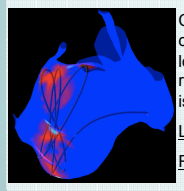
If the coil is too small: it floats and does not lead to a correct basket.

If the coil is too large:
- loops occasionally deploy outside the aneurysm,
- the coil jitters, due to the pressure becoming too high (the aneurysm should rupture).



Too small coil (4 mm) — Correct coil (7 mm) — Too large coil (10 mm)

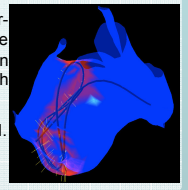
### Pressure assessment



Contact forces can be translated into pressure. This pressure was color-coded (blue=low to red=high) to enable a better comprehension of the locations of highest pressure on the aneurysm wall during coil deployment in real-time. Contact forces were also depicted as yellow arrows whose length is proportional to the intensity of the forces.

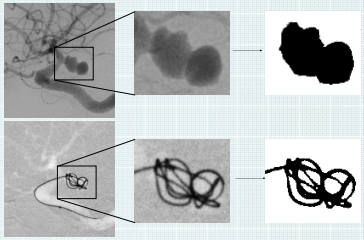
Left: the pressure is reasonable when a coil with the correct diameter is used.

Right: the pressure dramatically increases with too large a coil.



## Quantitative evaluation

### Coil Embolization Surface Ratio (CESR)




Experimental setup:
- 2 patients treated with 3D coils
- CESR from real roadmap image (REF)
- CESR from simulation with the right 3D coil (OK)
- CESR from simulation with a wrong helical coil (same diameter) (NOK)

Results: *the relative errors to the REF are provided in parentheses*

| | REF | OK | NOK |
|---|---|---|---|
| Patient #1 | 81 % (0 %) | 68 % (16 %) | 55 % (32 %) |
| Patient #2 | 24 % (0 %) | 17 % (30 %) | 11 % (54 %) |

Discussion

CESR is able to distinguish between a right (3D) coil and a wrong (helical) coil. This difference appears clearly in the case of the bilobated aneurysm (patient #2). For patient #1, the rounded shape of the aneurysm justifies a lower relative error for the helical coil. Interesting first results but the still quite large relative errors for the right coil require a refinement of CESR as a quantitative score.

## Discussion

Simulation tools are gaining more and more interest for various surgical procedures. Evaluating such simulation systems is both task dependent and has been but little investigated. We have proposed and applied various tests for a preliminary and promising qualitative and quantitative evaluation of our computer-based prototype for EVT's. Besides widening our patient database, designing refined performance scores is a challenging issue that requires multidisciplinary research efforts.

## Conclusion

A preliminary evaluation of a computer-based EVT simulation system was made on both phantom and patient data. Our report emphasizes the clinical realism of the simulated deployment of coils, in particular with regard to potential complications related to an inadequate choice of coil.

## References

[1] J. Dequidt, C. Duriez, S. Cotin and E. Kerrien. *Towards Interactive Planning of Coil Embolization in Brain Aneurysms.* To appear in the proc. of MICCAI'09.
[2] H.J. Cloft, G.J Joseph, F.C. Tong, J.H. Goldstein, J.H. Dion. *Use of 3D Guglielmi detachable coils in treatment of wide-neck cerebral aneurysms.* AJNR 21:1312-14, 2000.
[3] SIMPLE project web site: **http://simple.loria.fr**
[4]SOFA framework web site: **http://www.sofa-framework.org**