Stereotactic targeting of arteriovenous malformations using vessel tree segmentation

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Stereotactic radiosurgery: history

Invention of SRS with stereotactic frame
1951, Lars Leksell

GammaKnife SRS for AVM
1970, Steiner

Frame-based SRS with linear accelerators
1980’s, Betti & Colombo

Frameless SRS
1990’s, Adler

Towards non-invasive SRS approach for AVM

Benign and malignant lesions except AVM
State of the art: frame-based SRS

Localization of AVM on CT

Localize and target AVM on 2D DSA

Localizer box necessary for image registration between 2D DSA and 3D CT
Frameless approach: image registration software to register 2D DSA and 3D CT datasets without localizer box

Bony anatomy of skull
XNav
Burdenko Neurosurgery Institute, Moscow, Russia

Vessel tree registration
SmartBrush Angio element
Brainlab AG, Feldkirchen, Germany
Towards frameless SRS for AVM localization on 3D imaging, vessel tree registration, and localization AVM on 2D DSA. 2D-3D image registration is also shown.
Workflow SmartBrush Angio element

3D imaging
- CT
- MR
- CTA
- MRA

2D DSA imaging
- AP DSA
- LAT DSA

Vessel tree segmentation
Workflow SmartBrush Angio element

Cerebral vessel tree

AP DSA
LAT DSA

7DOF registration

Submillimetric targeting accuracy
3D vector = 0.8 ± 0.4 mm

E-Poster
Can we change the current practice?

Repeated angiography with invasive head frame and localizer box at the day of treatment
Can we change the current practice?

2D DSA  SMARTBRUSH ANGIO  3D CT(A) / MR(A)

Vessel tree segmentation out of CTA and/or MRA enabling the use of diagnostic frameless DSA images
Can we change the current practice?

Does the frameless registration using vessel tree segmentation require DSA imaging at the day of treatment?
Does the frameless registration using vessel tree segmentation require DSA imaging at the day of treatment?

Diagram:
- Diagnostic imaging
- Decision SRS treatment
- Analysis of stability vessel tree between diagnosis and treatment in order to cancel invasive DSA imaging at day of SRS

Frame-based approach:
- Imaging for treatment: DSA/CTA/MRA
- SRS treatment
Materials and methods

Retrospective study including patients:
- treated with Gamma Knife SRS @ CHUV Lausanne
- dedicated MRA at time of diagnosis and SRS treatment available
- without clinical changes (bleeding, edema) between both time points
- without intervention (irradiation, surgery, embolization) between both time points

Inclusion of 20 patients:
Average target volume of 2.96 ± 3.92 cc
Average time between both MRA of 174 ± 135 days
Materials and methods

VMTK = Vascular Modelling ToolKit

“Collection of libraries and tools for 3D reconstruction, geometric analysis and mesh generation for image-based modeling of blood vessels”

1) Segmentation of vascular segments of MRA
Materials and methods

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2) Compute centerline

- powerful descriptors of the shape of vessels
Materials and methods

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3) Compute bifurcation

- Comparison of corresponding bifurcations (AP, LAT, CC) using 3D-vector

- Hausdorff distance
# Results

Preliminary results of 19 patients with no clinical changes between diagnostic MRA and treatment MRA

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<th>3D vector (mm)</th>
<th>( \sqrt{\Delta AP^2 + \Delta LAT^2 + \Delta CC^2} )</th>
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<td>Mean ± SD</td>
<td>0.48 ± 0.05</td>
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Haussdorf distance (mm)

| Mean ± SD     | 0.65 ± 0.12                                          |
| Range         | 0.51 - 0.81                                          |

Submillimetric differences between corresponding vessel tree bifurcations
Results

Preliminary results of 19 patients with no clinical changes between diagnostic MRA and treatment MRA

The longest distance to travel from bifurcation X on diagnostic MRA to bifurcation X on treatment MRA

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Submillimetric differences between corresponding vessel tree bifurcations
Take home messages

1) **Cerebral vessel tree** remains **stable** within an average time span of **6 months**

2) DSA imaging before day of treatment can be used to delineate the AVM without affecting the targeting accuracy leading to a **non-invasive SRS procedure at the day of treatment**

3) **Reducing the number of invasive angiographic procedures** for the patient
General conclusions

- This element allows:
  - Fully multimodality image integration (DSA, MRA, CTA)
  - The use of DSA images performed at the time of diagnosis

- Complete non-invasive "frameless or framebased" radiosurgery solution for the patient with submillimeter targeting accuracy
  - Improvement in patient comfort
Aknowledgement