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[1] *G.P. Colby at al. Historical perspective of treatments of cranial arteriovenous malformations and dural arteriovenous fistulas. Neurosurgery Clinics 23(1):15-25., Jan 2012*

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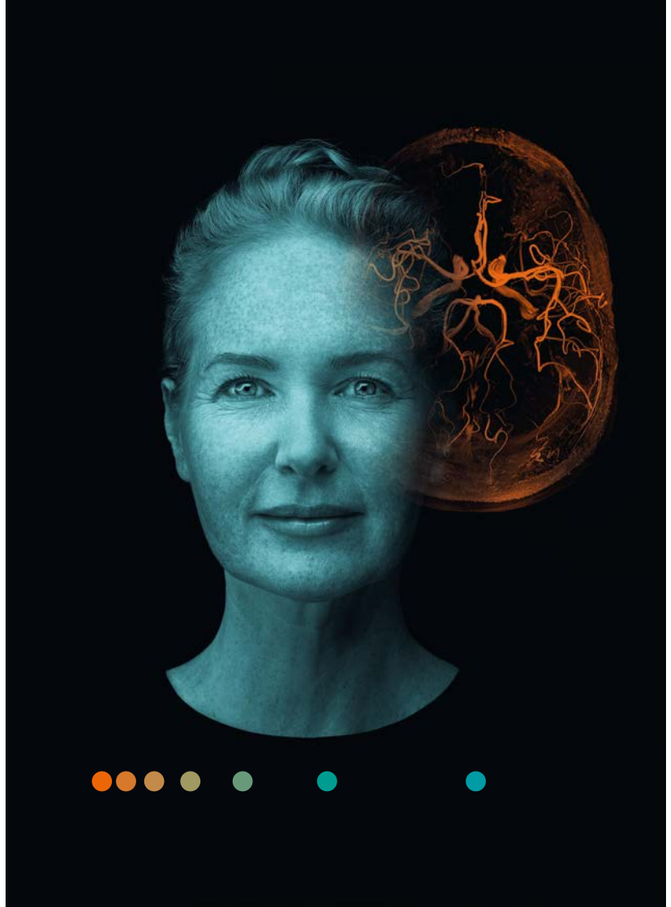

Robotic imaging after microsurgical excision of an arteriovenous malformation (AVM)

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Neurosurgery at Ulm University

Rainer Wirtz, MD and Ralph König, MD

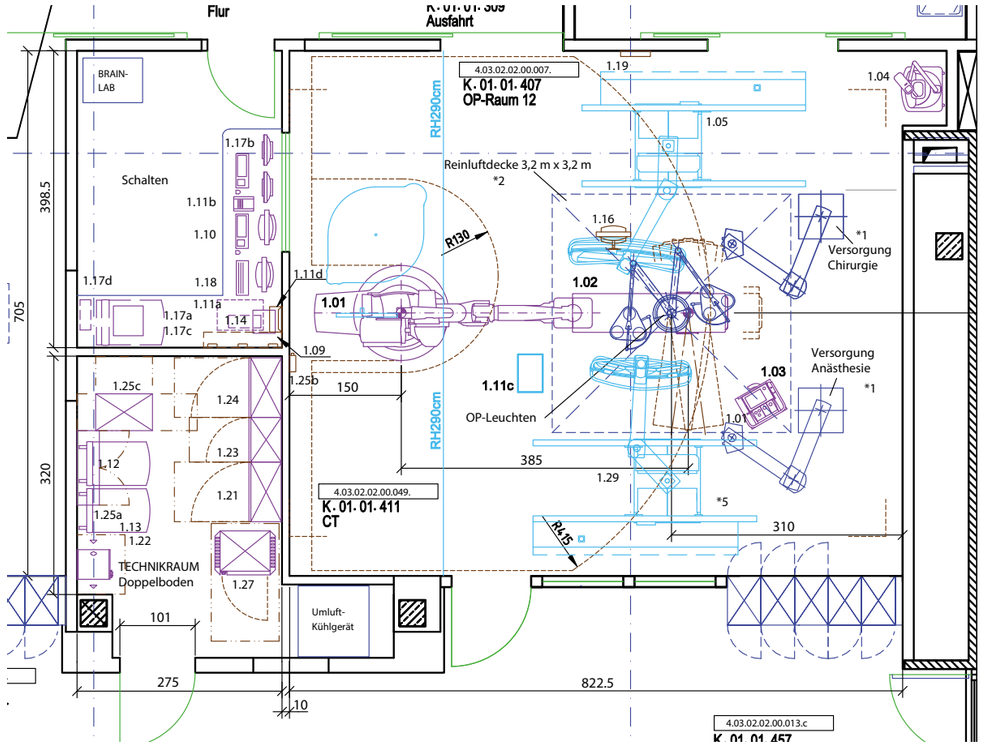
The university hospital of Ulm in Germany is a center of maximum care with over 1,100 beds and over 5,000 employees.
In 2012, the university hospital built a high-end hybrid operating room in their center for surgery. Trauma, neuro, vascular as well as cardiac surgeons share the new operating room, which combines a robotic 3D imaging angio system, the Siemens Artis zeego, with a modern OR table by Trumpf and the new Curve navigation system by BRAINLAB.
Since 2008, Prof. Wirtz MD (right) has been director of neurosurgery with two operating sites in Günzburg and Ulm.

He focuses on computer assisted surgery including augmented reality, treatment of neurovascular disease, and neurooncological pathologies by means of intraoperative imaging using interventional MRI and intraoperative ultrasound.
PD König MD (left) was appointed co-medical director and head of the department of neurosurgery at the site in Ulm and in this role oversees the neurosurgical program in the new hybrid operating room in Ulm. Among other things, he focuses on neurovascular surgery and is also trained in endovascular approaches.

The Hybrid Operating Room

A hybrid operating room combines a traditional OR with high-end imaging equipment. The department of neurosurgery at the University of Ulm is equipped with a well-tried robot-supported angiographic imaging system. The robot is utilized by the neurosurgeons for spine surgery, aneurysm clipping, and AVM treatment. It enables hybrid procedures where an open approach is interlinked with endovascular interventions.

The room size is about 58 m2 (625 sq ft), excluding the control room. Two Display Ceiling Suspensions (DCS) are installed on both sides of the OR table, equipped with one large display and two standard monitors, respectively. Two anesthesia booms by Dräger are mounted to the ceiling and the OPMI PENTERO 900 microscope by Carl Zeiss is available in the room.
The TruSystem OR table by Trumpf and the CURVE navigation system by BrainLab are integrated and exchange data with the robot-supported angiographic imaging system.



Clinical Case

A 26-year old female patient presented with an arteriovenous malformation (AVM) located left precentrally, close to the pyramid tract, Spetzler-Martin Grade III. She had a history of previous bleeding at the age of 12 and 22 with consecutive spastic hemiparesis in her right arm.

The patient decided for a microsurgical excision of the arteriovenous malformation to exclude the risk of further hemorrhages in the future. Because of the vicinity to the motor cortex, neurophysiological monitoring with cortical strip electrodes was applied during the surgery.

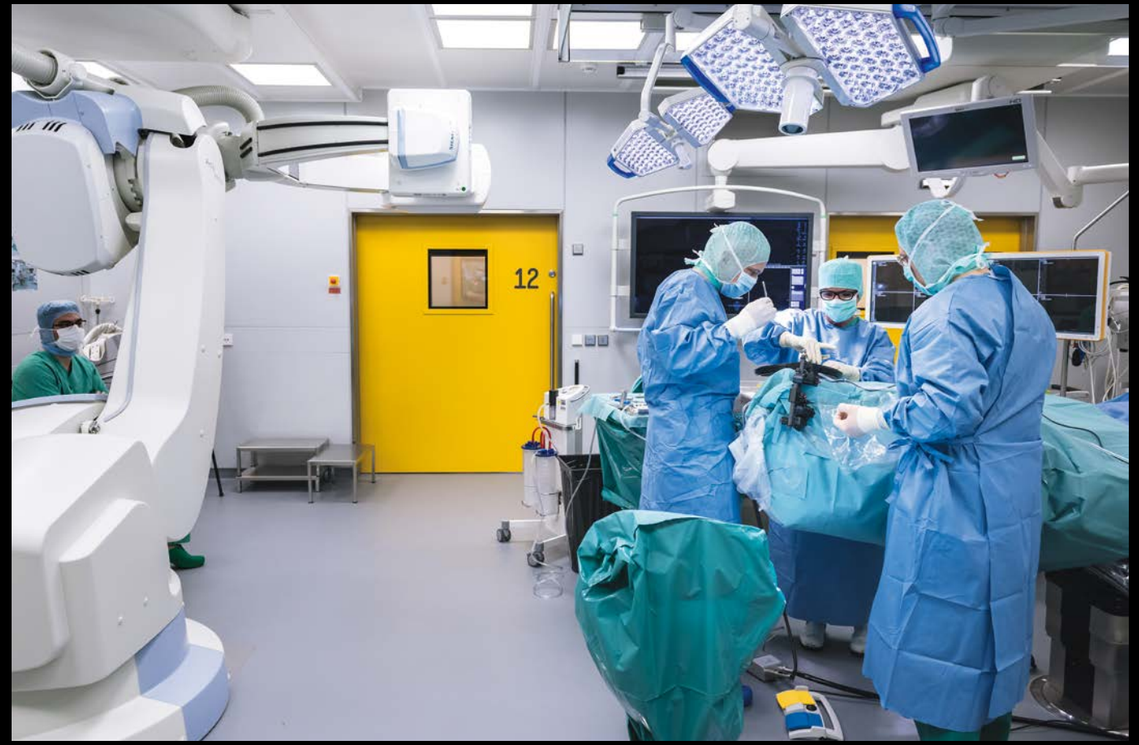
Step 1

Patient preparation

The patient is carefully positioned with the head towards the robotic imaging system and stabilized with the DORO Radiolucent Headrest System by pro med instruments (PMI). The headrest system is configured so that no element extends below the tabletop. This guarantees collision-free 3D imaging at a later stage of surgery.

Sterile sheets are wrapped around the patient, so the sheets do not touch the C-arm during imaging. The DORO Radiolucent Halo Brain Retractor System is mounted to the headrest and stays attached during the entire surgery (see picture on the right).

At the beginning of surgery, the robotic imaging system is parked in a corner of the ceiling to provide unrestricted access to the patient and free space for other surgical equipment, like microscopes and navigation systems. The space beneath the parked robot can be used by staff or for accessories, e.g., tables.



Step 2

Microsurgical excision

A craniotomy is performed and the AVM is isolated from the tissue around the brain using the surgical microscope.

Intraoperative neurophysiological monitoring is applied by placing strip electrodes at the cortical surface and by recording motor-evoked potentials (MEP).

The pre-operative 3D angiography as basis for vessel segmentation is fused to the preoperative MRI and loaded in the surgical navigation system prior to surgery. The microscope is interlinked with the surgical navigation system, i.e., the MRI is reformatted according to the perspective and the focal point of the microscope.
The direction of the view is displayed as a line in the orthogonal slices (see picture on the right).
The segmented structures are overlaid on top of the live microscopic view.

Step 3

Intraoperative 2D angiography

After completing the microsurgical excision, intraoperative imaging is applied to verify the successful completion of the AVM excision.

To secure sterility, one big sterile bag is slipped over the patient, the table, and the halo ring. The angiography system moves its robotic C-arm from the park position into the surgical field. Since the OR table is integrated with the robotic imaging system, the robot calculates the exact position and angulation of the tabletop and adapts its movement to prevent any collision with the table. The patient does not need to be moved.

A 2D angiography is performed in order to detect any residual AVM. Intraoperative angiography can evaluate for complete extirpation, localize small AVMs, find missing or hidden feeding vessels, detect AVM in a patient undergoing evacuation of a hematoma, and evaluate the real-time hemodynamics of the lesion. Unexpected residual AVM is shown in 3.7 % to 27.3 % of intraoperative angiograms during AVM resection cases[1].

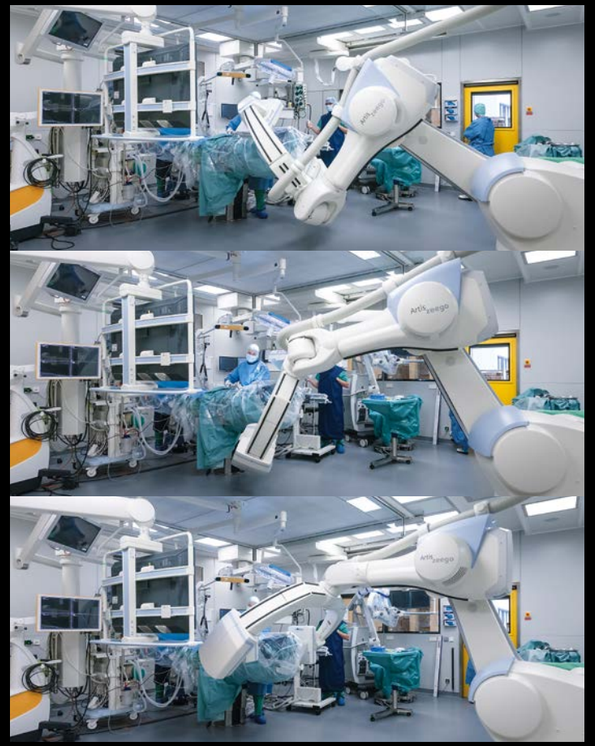
Step 4

Intraoperative 3D imaging

Three-dimensional angiography with *syngo* InSpace 3D provides detailed insight into the spatial relationship of the vessels and may detect even the smallest feeding vessels.

The intraoperative acquisition involves a 220 degree rotation around the patient in five seconds. For three-dimensional digital subtraction angiography (3D-DSA), the robotic C-arm rotates around the patient two times while the contrast agent is injected.

Sterility is ensured by the sterile bag around the surgical field during the acquisition. During the surgical excision, a free laminar air flow field is guarantied because the imaging robot does not need any ceiling mounted components.



The screenshots above show intraoperative 3D images acquired with Artis zeego. The skull can be interactively blended in and out at the 3D workstation as required. For example, the craniotomy is depicted in the upper screenshot while the position of the electrodes is clearly visible in the lower screenshot. The rendering can be interactively rotated and zoomed at the 3D workstation to investigate the vessel structure in detail.

Configuration of the Hybrid Operating Room

Department of Neurosurgery, Ulm

- Artis zeego with Automap functionality
- Trumpf TruSystem 7500 operating table, segmented carbon tabletop
- Large Display with 24 video inputs and AXIOM Sensis XP interface; two Display Ceiling Suspensions (DCS)
- 2k acquisition with 30x40 detector and laser cross light
- *syngo* X workplace
- *syngo* iGuide software with 3D/3D Fusion
- *syngo* iPilot software
- *syngo* DynaCT package
- Laminar airflow field
- Brainlab CURVE System
- DORO Radiolucent Headrest System
- OPMI PENTERO 900 Microscope by Carl Zeiss
- Two anesthesia booms by Dräger

Benefits

- Intraoperative angiography helps to detect residual AVMs after microsurgical excision.
- Potential costs savings because of reduced need of reoperation.
- Artis zeego can be parked far away from the OR table providing free space for staff and equipment.
- High-end 3D imaging in the OR without moving the patient and with a head frame and halo ring in place.
- Multi-disciplinary utilization by neuro, spine, trauma, orthopedic, vascular, and cardiac surgeons makes high-end 3D imaging equipment affordable.

System information

Artis zeego used in this workflow is no longer available and has been replaced by ARTIS pheno. For further information, please see siemens-healthineers.com/artis-pheno or contact your local sales representative.

Benefit of the Robotic C-arm in the Hybrid OR

1. Precise targeting and automatic image fusion using pre-operative MRI and *syngo* DynaCT with *syngo* Fusion Package
2. Intraoperative image control with *syngo* DynaCT without patient transfer, saving a significant amount of time
3. Increased procedural success by using intraoperative 3D imaging for quality control
4. Less radiation dose compared to workflows that include perioperative CT
5. Increased patient safety by reducing patient transfer and anesthesia times
6. Financial benefits for the hospital through optimized resources and higher utilization of the Hybrid OR

Want to know more?

For more information on our workflows, products, and solutions, please scan the adjacent QR code or open siemens-healthineers.com/neurosurgery