# Bernoulli effect exacerbates malperfusion of the femoral-arterial cannulated leg during ECLS - an in silico study

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## Introduction

During extracorporeal life support (ECLS) using femoral arterial cannulation, limb ischemia is often observed, even in patients with normal vessel diameters and without peripheral arterial occlusive disease. The underlying pathomechanisms have been investigated using a simulation of the hemodynamics of the human circulation.

## Methods

Based on the CT scan of the silicone model of an original cardio-vascular system, a digital model has been created by segmentation (Mimics). The CAD model of a straight cannula (16 Fr) has been inserted via the left common femoral artery. The hemodynamics at different cardiac outputs (0%-100%) has been simulated stationary using Computational Fluid Dynamics (CFX). For this purpose the ECLS flow varied between 1 and 5 l/min. The pressure boundary conditions at the arterial outlets were selected in such a way that the downstream vascular system is represented. The flow velocity and especially its direction in the model was visualized.

## Results

In the individual reduced cardiac output with appropriately adapted ECLS support, retrograde blood flow from the cannulation site to the aortic bifurcation has been observed. The ECLS flow never reached the ascending aorta. Although the vessel diameter around the cannulation site was sufficient, no antegrade flow into the distal femoral artery was observed. Instead, a retrograde flow from the distal extremity towards the aortic bifurcation was detected. This effect can be explained by the Bernoulli principle, in which the ECLS jetstream with its high velocity induces areas of low pressure around the cannula with retrograde flow.

## Conclusion

In ECLS patients with a femoral arterial cannulation, blood flow into the cannulated leg is impaired even if the vessel diameter is sufficient. Retrograde ECLS flow causes this phenomenon by drawing blood from the limb. Therefore, separate leg perfusion is mandatory regardless of vessel diameter or any peripheral arterial occlusive disease.

# Developing an Intuitive and Feasible Setup for In-room Control During MRI-guided Interventions

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## Introduction

High soft-tissue contrast and the absence of ionizing radiation are indisputable advantages of Magnetic Resonance Imaging (MRI)-guided interventions. Yet, the gold standard for observing minimally-invasive procedures stays X-Ray based fluoroscopy. The approach of this work is using everyday technology to establish an interventional MRI suite that can be operated by minimally trained experts. The main goal is availability to a broader community by trying to adapt an exemplary interventional suite to the MRI environment.

## Methods

With optical fibre cables and adapters, several signals (video, USB, Ethernet) were routed into the imaging systems room through waveguides. By trial-and-error, a broad range of devices was examined to explore their behaviour in the MRI environment enabling imaging-system control, communication, and console screen replication. Multiple options were elaborated and systematically developed to a sophisticated solution.

## Results

To offer clinicians technical support during MRI-guided interventions, an advanced setup was established. As input devices, a wireless mouse and a wired programmable foot pedal were used. The video signal of the console was replicated and displayed on a roll screen with a projector. Communication between imaging room and control room was realized with Voice over IP in a shared local network and in-ear Bluetooth headsets. The functionality of the setup was successfully tested by performing a needle-guided biopsy in a phantom.

## Conclusion

The presented technical setup for in-room MRI system control is suitable to conduct interventional MRI studies in a research setting. For our setup, we could prove feasibility, affordability, and flexibility. Extended safety investigations will be conducted next. Concurrently, implementing additional devices may enable a broader range of application to conduct research studies, for example, vascular interventional use cases. Moreover, provisions for installing such equipment could be made in the planning phase of hybrid PET/MRI imaging suites, should our approach further prove it's utility in our research setting.

# Fully Data-Driven Pseudohealthy Synthesis for Planning Valve-Sparing Aortic Root Reconstruction using Conditional Variational Autoencoders

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## Introduction

In valve-sparing aortic root reconstruction surgery, the dilated root is replaced by a prosthesis which should mimic the native, individual root morphology. The challenge in estimating the optimal prosthesis shape rises from the highly patient-specific geometry as well as the absence of the original information on the healthy root. Therefore, a surgical planning tool should incorporate the prediction of the individual healthy shape based on pathological images.

## Methods

In this work, we present a novel end-to-end approach for pseudohealthy synthesis from ultrasound images of the dilated roots using representation learning. We utilize Conditional Variational Autoencoders (CVAE) to learn two latent space distributions of images, conditioned by the labels 'healthy' and 'pathological'. By encoding a pathological image and changing the condition from 'pathological' to 'healthy' for decoding, the synthesized image is an estimation of the individual healthy shape. In contrast to previously published methods, there is no handcrafted modeling necessary.
We evaluated our approach on a data set of ultrasound images (2D, commissure plane) of 24 porcine aortic roots ex-vivo. As the pathology was simulated manually, the healthy ground truth is known. We compared different CVAE architectures and benchmarked our method against previously published ones.

## Results

We found that an architecture with five convolutional layers (kernel size 3x3) in the encoder combined with a latent space dimension of 16 and a mirrored decoder architecture delivered the highest mean structural similarity (0.79) between the predicted images and the ground truth. Compared to previously published methods, the proposed approach delivered comparable results while explicitly avoiding any manual interaction steps.

## Conclusion

To the best of our knowledge, we presented the first fully data-driven approach to achieve pseudohealthy image synthesis for aortic root surgery planning. Even though our method does not contain any manual modelling, the results are comparable to approaches that rely on handcrafted deformation modelling.

# A minimally invasive approach for cochlear implantation: On site manufacturing of patient individual drilling jigs

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## Introduction

To continue the success story of cochlear implantation, further developments for surgical approaches aim to reduce patient risks, increase hearing preservation, reduce operation time, and reduce the overall costs of the surgery. To achieve those demanding aims, a minimally-invasive surgical approach is developed where an individual drilling jig is computed and manufactured in the operating room (OR).

## Methods

A system is developed assisting the surgeon by performing high precision drilling of one straight trajectory through the temporal bone. The system consists of a complete set of stereotactic hardware and software, including an automated manufacturing machine for individualization of the drilling jig. Using this set, a drilling jig can be mounted onto the patient's skull and the drill tunnel can be realized by drilling through the temporal bone with a spiral bone driller that is guided by the jig. To estimate the accuracy and repeatability of the manufacturing system, 12 minimally invasive tunnels were drilled in 6 full body donors. The drill accuracy of the system covering a CT-based planning and the automated fabrication of the drilling jig was evaluated using a coordinate-measuring machine.

## Results

The system was successfully used in 12 cases to plan the drill paths and to manufacture individualized drilling jigs. An average accuracy of 0.08 mm (±0.04 mm) in the jig and 0.14 mm (±0.07 mm) projected at the target (facial recess level) were determined with a coordinate-measuring machine. This high accuracy of the system allows for keeping a sufficient distance to vulnerable nerves and other critical anatomical structures in the patient's temporal bone.

## Conclusion

Automated manufacturing with a high precision and a good agreement between the planned drill path and the manufactured drilling jigs was achieved, indicating the potential feasibility of the presented system for minimally invasive CI surgeries.

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# 3D imaging technique for high-resolution slit lamp microscopy in ophthalmology

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## Introduction

Corneal confocal microscopy (CCM) using the Heidelberg Retina Tomograph (HRT) and the Rostock Cornea Module (RCM) is a well-established and promising high-resolution imaging modality (field of view: 400 x 400 µm²), which allows non-invasive in vivo imaging of corneal cell structures. The recent development of an RCM 2.0 prototype, equipped with a piezo drive for precise computerized focus control within a depth range of $\Delta z$ = 500 µm, enables extended depth scans. The acquired CCM data can be recorded as an image series by modified HRT software.

## Methods

To facilitate wide-field imaging of the sub-basel nerve plexus with mosaicking, we developed the system EYEGUIDANCE to control the eye movements during the imaging process. Combining the RCM 2.0 and the EYEGUIDANCE-system, oscillating depth scans of an extended area can be recorded. Special-purpose software for the registration of CCM data can transform the image series to a point cloud representation of the recorded volume. The success of the image registration process critically depends on the amount of overlap in the image data, and therefore on the careful adjustment of the speed of the eye movements controlled by EYEGUIDANCE and the piezo parameters (speed and oscillation amplitude) of the RCM 2.0. The aim of an ongoing project is realtime-visualization of the recorded 3D-CCM data. In this setting, gridded voxel data has performance advantages over point cloud data for the generation of arbitrarily oriented cross-sectional views. The registration software has been extended with algorithms to generate a voxel representation with an isotropic grid resolution of 1 µm from the image registration results.

## Results

The presented developments allow the direct generation of cross sectional views orthogonal to the three coordinate axes. Arbitrarily oriented cross sectional views in any spatial direction can be computed through interpolation of each pixel based on surrounding voxels.

## Conclusion

The presented 3D imaging technique lays the foundation for high-resolution slit lamp microscopy.

# Concept of a flexible endoscope with swiveling camera tip

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## Introduction

Endoscopy is an important modality in medical imaging. Thin flexible endoscopes are for example used to examine the upper airways, for gastroscopy procedures or lung inspection. With standard flexible endoscopes one can change the direction of view by bending the tip with the disadvantage of large space required due to the bending radius. In an earlier work we proposed a concept of a moveable camera head on the tip of rigid endoscopes. Based on these experiences we now propose a novel design employing a swiveling camera for flexible endoscopes.

## Methods

The prototype was realized in a first low cost setup using an adapted 5,5 mm HD chip on the tip camera with LED light. The steering concept is based on the use of a shape memory wire used to control the movement of the camera, a flexible plastic flap joint for tight rotation and flexible printed circuits for the electronic connection. A 3D printed handle with a rotatable lever allows nearly linear motion transfer over the NITINOL wire and a guiding tube.

## Results

The motion and imaging performance of the prototype allowed swiveling of the camera on the endoscope tip from straight view to 100° side view. The space needed in fully rotation was limited to 9mm with an overall diameter of the endoscope in straight view of only 5,6mm, but could even be further reduced in a more professional setup. The image quality is good, but close-up views appear blurry due to the fixed focus point of the low-cost camera.

## Conclusion

The presented steering concept of the camera is promising, as it could potentially improve imaging of narrow cavities using flexible endoscopes. Especially for “in office” examinations this principle could add value to diagnosis and patient comfort.