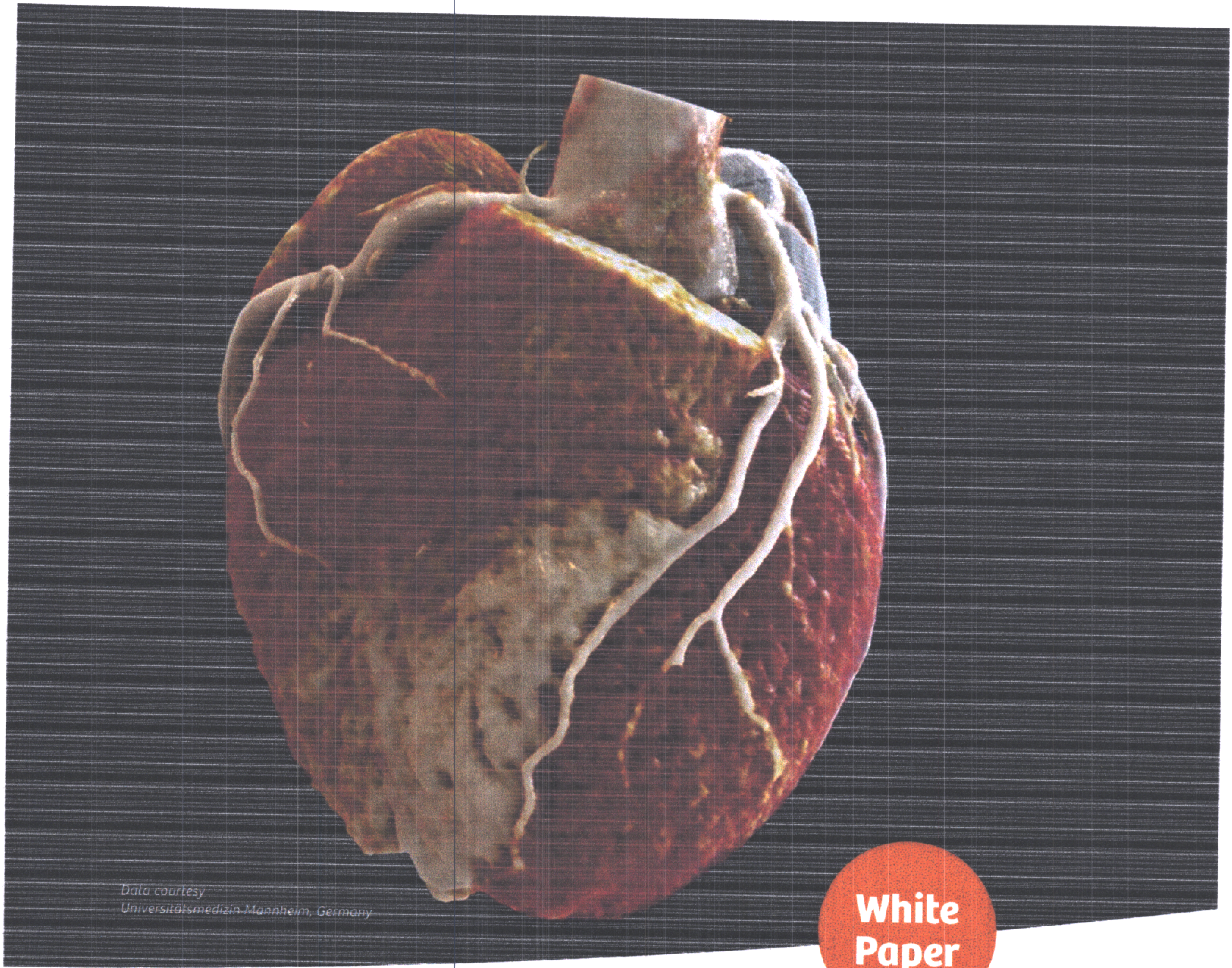

Cinematic Rendering
for Medical Imaging

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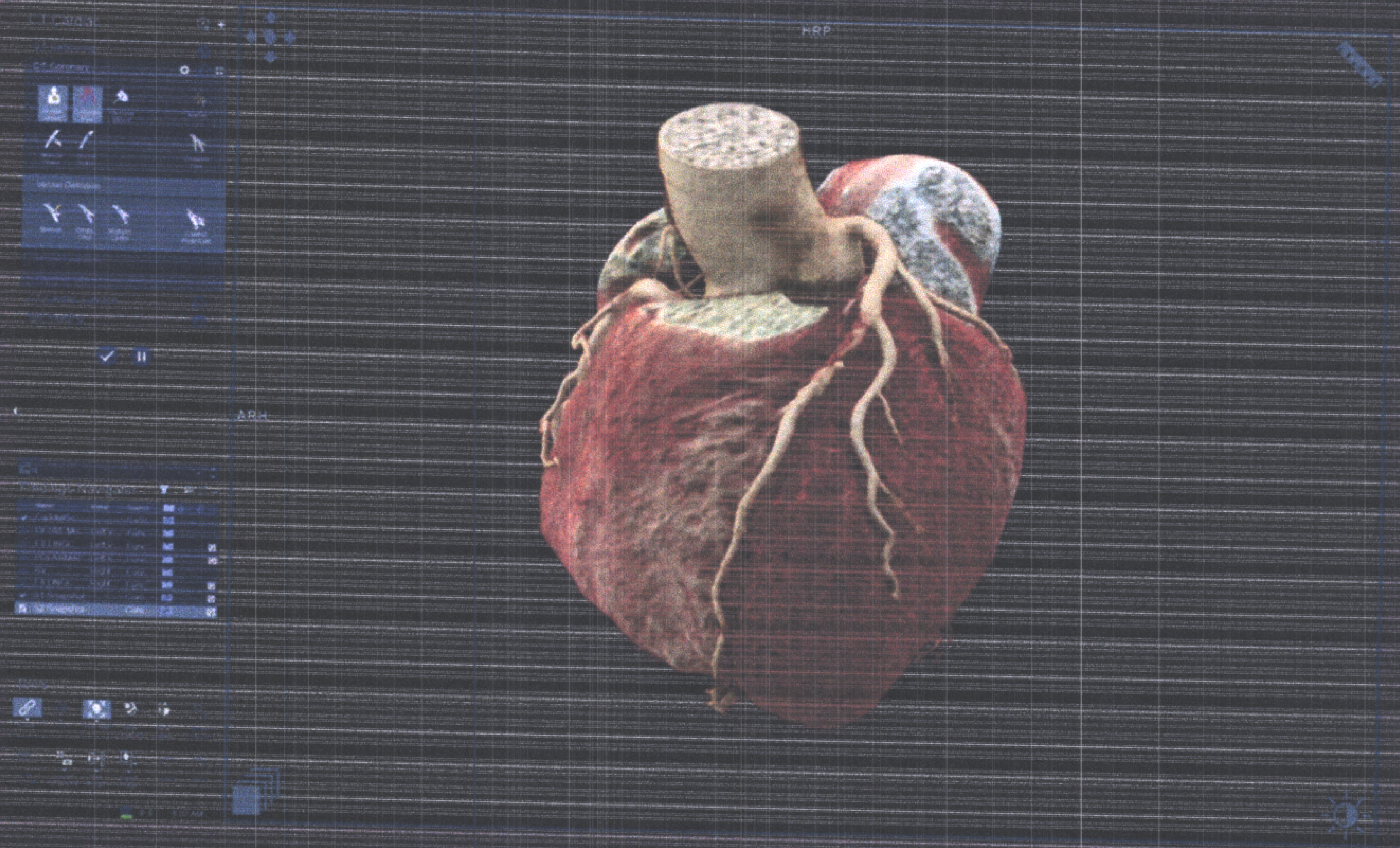

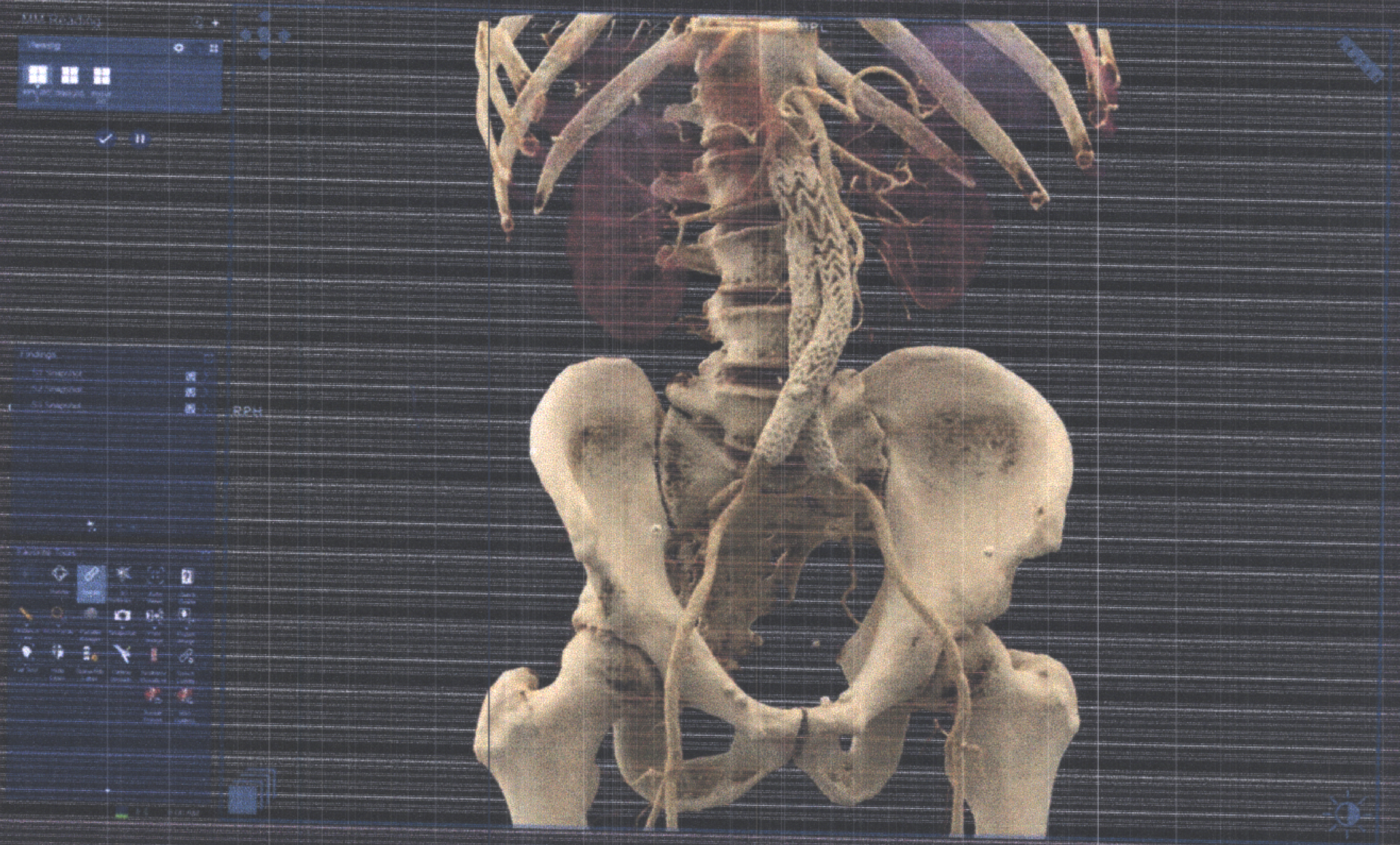

A journey into the human body

Data Courtesy Fakultní Nemocnice Pilzen, Czech Republic

This White Paper presents both the clinical and technical aspects of Cinematic Rendering. It will highlight the application in trauma, cardiac and vascular imaging. The content was created by Gudrun Feuchtner, MD (Department of Radiology, Innsbruck Medical University, Austria), Hatem Alkadhi, MD (Institute of Diagnostic and Interventional Radiology, University Hospital Zurich, Switzerland), and Stéphane Rusek, PhD (Cardiothoracic Center of Monaco, Monaco) in collaboration with Siemens Healthineers.

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Data courtesy CHI Health Lakeside Omaha, Nebraska, US

Introduction

Computational graphics and digital technologies have a significant impact on a wide spectrum of media and have revolutionized animations, movies, advertising, and video games, including medical imaging. While in the past, volume rendering required high computational resources and power, long data processing times and intensive user interaction, nowadays, the production of volume rendering (VR) of medical images is fast and has become a reality in medical practice. Thus, the three dimensional (3D) visualization of human organs and body regions using VR color capabilities is feasible for several medical imaging modalities such as Computed Tomography (CT) and Magnetic Resonance Imaging (MRI).

Current medical imaging scanners provide three-dimensional (3D) submillimeter resolution enabling the utilization of various 2D and 3D post-processing and visualization techniques with excellent image quality. Three-dimensional volume rendering capabilities are widely available and used mainly for visualization of complex anatomy. Furthermore, volume rendering (VR) techniques offers relevant information for pre-operative planning as well as post-operative follow-up. However, conventional VR techniques have significant limitations such as distortion and limited spatial resolution as compared to the original axial source images. Therefore, conventional VR may mask important information which, if used independently, could cause a misinterpretation of the medical image.

Siemens Healthineers has developed a novel physiologically-based volume rendering method called Cinematic Rendering [Engel, 2016 and Paladini et al. 2015] which computes in real-time photorealistic 3D renderings of medical data, such as CT or MRI acquisitions. This technique allows for the first time production of medical VR images with improved spatial resolution and image quality. It mimicks the real-world interaction of light and offers and easier way for visualization of different shading, shapes, and depth of medical VR images. Cinematic Rendering allows a visualization of medical imaging of human anatomy such as the heart or great vessels. This technique can be used in patient-centered therapy planning, wherein the physician can study the patient's anatomy and explain the specific details of the procedure, giving the patient a better understanding and involvement in the decision-making process.

The benefit in the automatic presentation of interactive 3D images for the patient is to better understand pathology and disease without the need for the physician to recreate a verbal description of anatomy, specific organs and disease etiology. Thus, brain plasticity develops by viewing 3D imaging. For complex procedures such as cardiac surgery, minimal invasive, or transcatheter intervention where the surgeon does not have a direct view a high level of "brain elasticity" is required. The spectrum of minimal invasive surgical techniques has widened over the last decades and is still expanding, warranting the demand for advanced high resolution 3D visualization to allow for procedure success.

Technology

The Cinematic Rendering (CR) software produces photorealistic images of patient anatomy by simulating the interaction of visible photons with the volume data obtained using CT or MRI scanners.

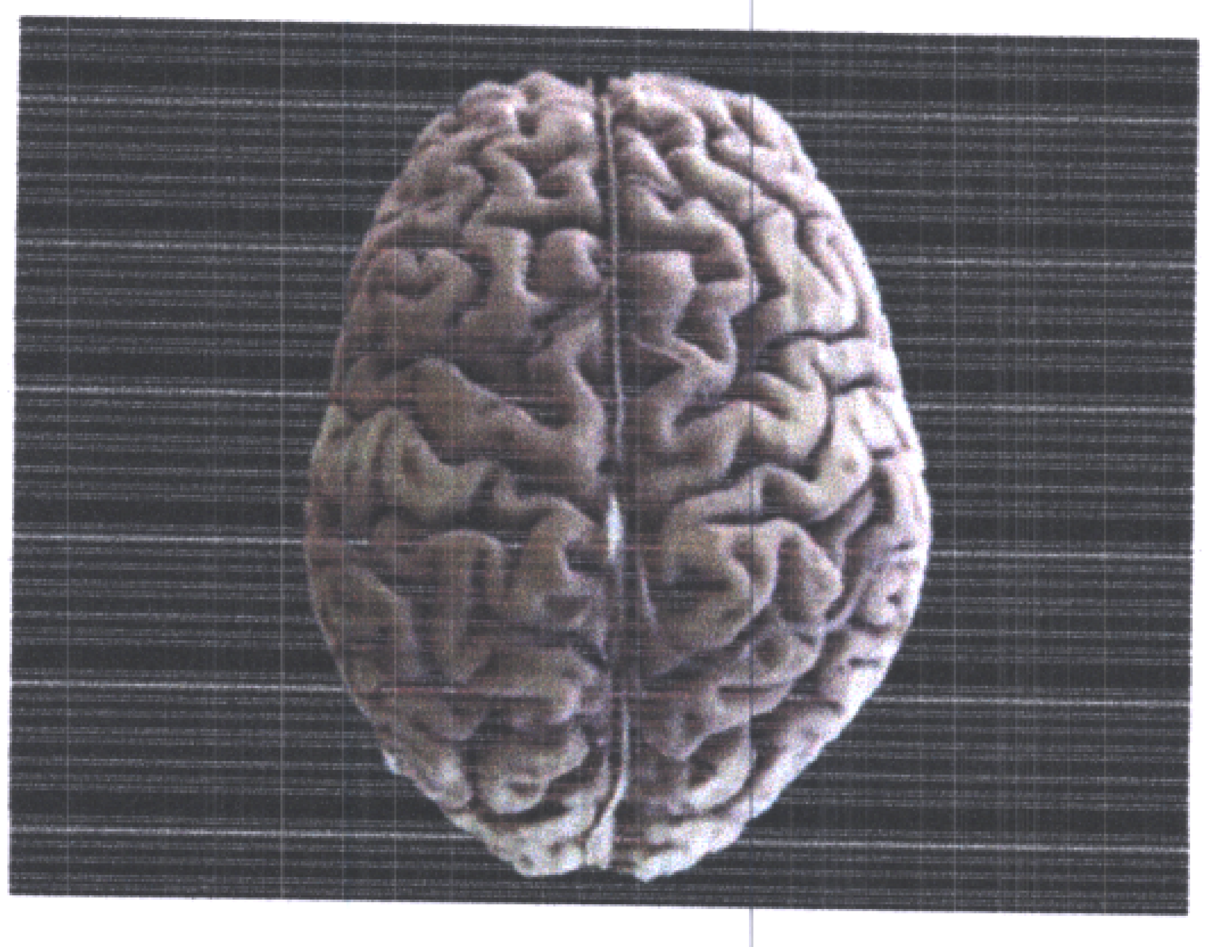


Figure 1a): Human brain visualization: Photorealistic Cinematic Rendering of Magnetic Resonance (MR) data of the brain acquired with a 7 Tesla scanner.

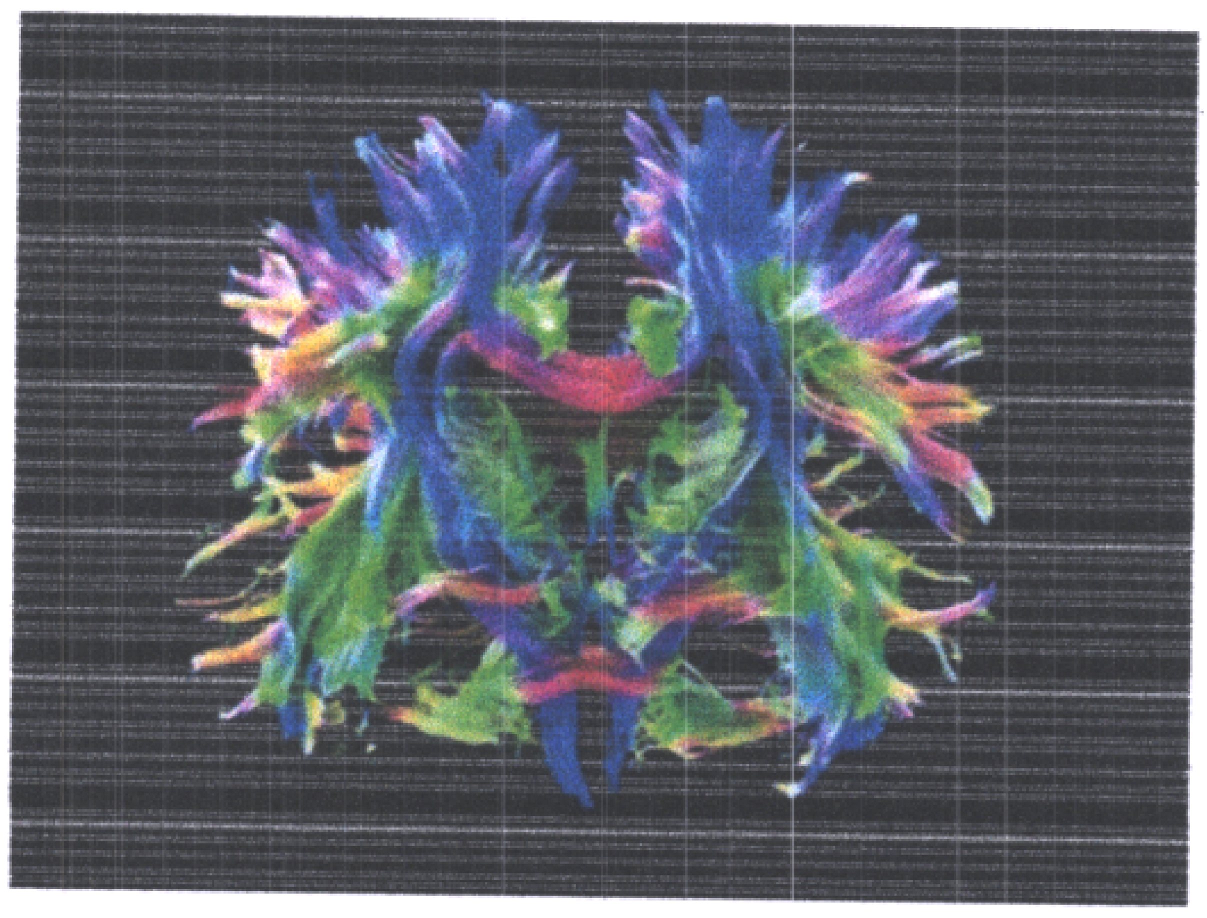


Figure 1b): Visualization of diffusion of water to map white matter tractography in the brain. Cinematic Rendering applied on MR diffusion tensor imaging (DTI).

Cinematic Rendering is motivated by the photo-realistic quality of visual effects in modern cinema and made possible by recent advances in computer graphics algorithms and multi core processor architectures. Beyond photorealism, CR is also able to produce hyper realistic images, i.e. images that look real but could never have been captured by a physical camera (Figure 1a/1b).

In contrast to traditional VR methods which trace a single straight ray through each pixel into the volume data ("ray casting"), CR traces hundreds or thousands of photon paths per pixel through the captured patient anatomy (Figure 2). These complex photon paths are due to the interaction of photons with matter, potentially changing the direction of photons multiple times before reaching a photoreceptor. Just like in nature, photons might also be emitted and absorbed along a light path. An infinite number of possible photon paths exist; CR computes a randomized subset of the most relevant paths using a "Monte Carlo" method. The final image is obtained iteratively by progressively averaging numerous Monte Carlo samples representing radiance coming from random directions with light scattered many times along each light path. To overcome the enormous computational load of such a Monte Carlo simulation, only light paths that reach the eye are computed, and among those, the most relevant photon paths are prioritized.

Data courtesy of Max Planck Institute, Leipzig, Germany (figure 1a) and Cardiff University, Wales, UK (figure 1b)

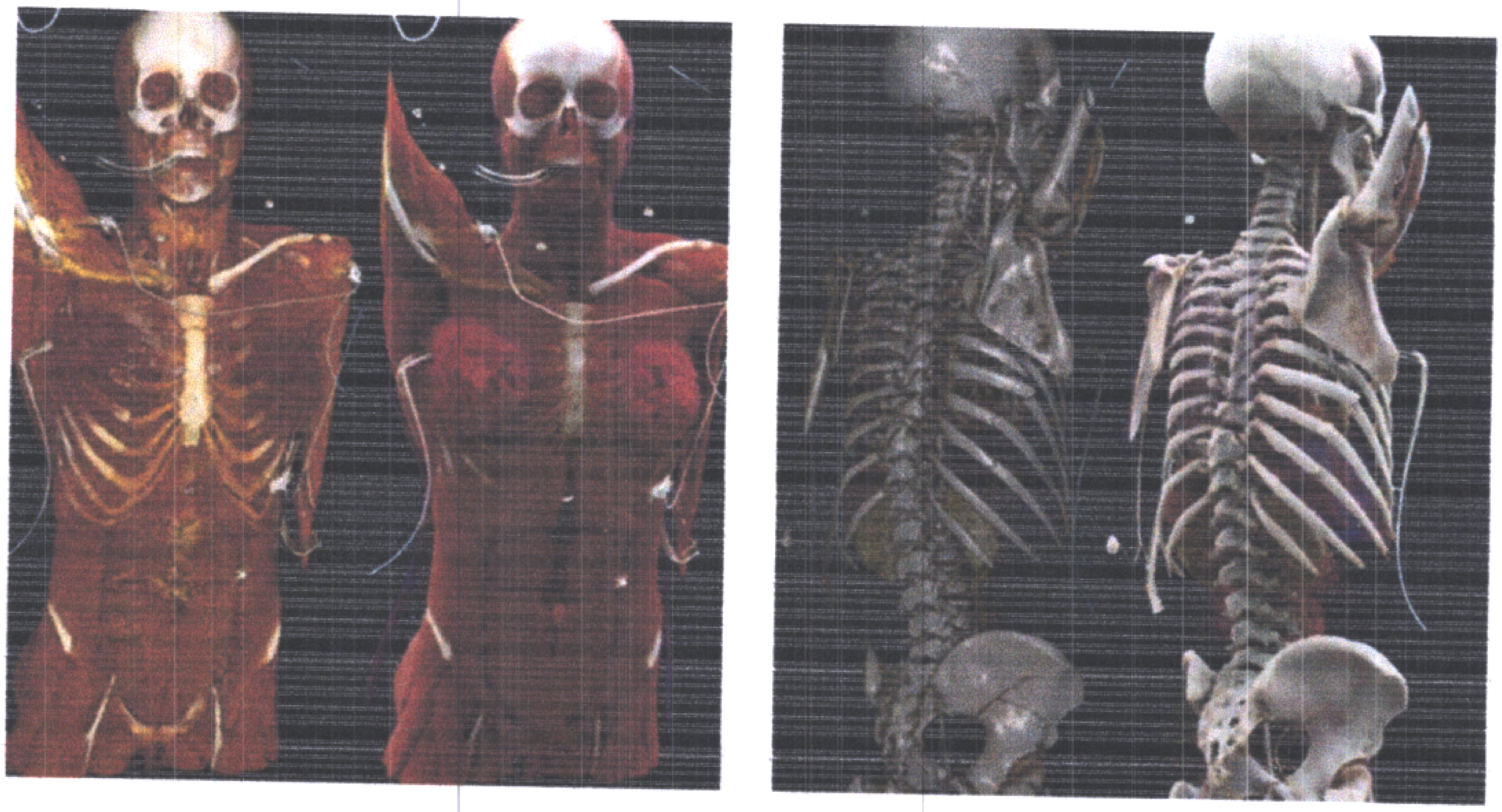


Figure 2: Comparison of traditional ray casting (left, respectively) and Cinematic Rendering (right, respectively) using a trauma CT scan.

For illuminating the data, photographic high dynamic range (HDR) light maps are utilized. Such panoramic photos capture light arriving at the data from any direction and lead to a natural appearance of the data. The natural lighting in combination with the accurate simulation of photon scattering and absorption produces photorealistic images that resemble many shading effects that can be observed in nature, such as soft shadows, ambient occlusion, volumetric scattering and subsurface photon interaction. By modelling a virtual camera with variable aperture, focal length and exposure, additional effects such as depth-of-field and motion blur can be achieved. This increases the realism of the resulting images tremendously, and allows for artistic techniques to produce descriptive visualizations of the human anatomy.

As a result, the images are physically plausible and are instantaneously intuitive for the human brain. Just like in traditional volume rendering methods, colors and opacities are assigned using a transfer function, which assigns color and opacity where the photons interact with the anatomy. Since interaction paradigms such as window leveling, cutting and cropping are possible just like in existing volume rendering products, CR can easily be integrated into existing clinical workflows. It is compatible with any existing medical volume data of reasonable resolution and runs on a single modern desktop PC with of-the-shelf processor and graphics card.

Data courtesy of Vancouver General Hospital (VGH), Canada (figure 2).

Solution

Cinematic Rendering applications are available on *syngo*.via and *syngo*.via Frontier[1]. The spectrum of applications range from cardiovascular (CT Vascular, CT Coronary and CT Cardiac Planning) to the general multi-modality reading environment (MM Reading). While the focus of CR integration into *syngo*.via is based on the implementation of the essential Cinematic Rendering features, the *syngo*.via Frontier platform was created for researchers by offering the full spectrum of rendering parameters and additional image creation tools. In the following section, the features available in both environments will be outlined.

Application integration and invocation

The integration of Cinematic Rendering (CR) as a new visualization technique follows the same principles and patterns like other rendering techniques available in *syngo*.via. It is available as the new display type "Cinematic VRT" in addition to the classical VRT.

In order to keep the interactions fluent despite the computational demand, a progressive rendering technique has been implemented. The renderer is iteratively rendering the scene until it reaches cinematic image quality. The use of specific features like centerline editing in CT Vascular will allow real time editing in the foreground, while the rendering refines the image progressively in the background. All other image interactions like zoom, pan and rotate may be performed in the same way as in classical VRT.

Visualization parameters

Upon initialization of CR, an application specific default "preset" is automatically applied. The visualization may be further adapted according to the needs for the current case by modifying the window center and window width using well-known mouse interactions. For further refinement, the user is able to open the VRT gallery which provides dedicated additional Cinematic Rendering color presets, designed for different organs and use-case scenarios. Each rendering preset provides a transfer function which maps, in the case of CT studies, the Hounsfield units (HU) to color and opacity values.[2] These transfer functions may be edited interactively or even created from scratch and saved as a new rendering preset, which allows customized rendering presets for a wide range of clinical use-cases, including any individually preferred settings and colors.

[1] ***syngo***.*via can be used as a standalone device or together with a variety of* ***syngo***.*via-based software options, which are medical devices in their own right.* ***syngo***.*via and the* ***syngo***.*via based software options are not commercially available in all countries. Due to regulatory reasons its future availability cannot be guaranteed. Please contact your local Siemens organization for further details.* ***syngo***.*via Frontier is intended for research use only - not for clinical use.*

[2] *MR studies can also be used for the generation of Cinematic Renderings. E.g. "Similarly MR studies can be generated based on different presets."*

Editing and segmentation tool support

In most cases, the removal of obstructing structures from the target volume visualization is required in order to achieve an unrestricted and optimal 3D view of the clinically relevant target volume regions (by cropping and cutting obscuring structures, e.g. the lung vessels in case of the heart or the surrounding rib cage or other bony/ osseus structures. Hence, most applications already provide automatic and interactive segmentation tools which define and remove masking structures, and these tools may be activated or deactivated in order to hide or show the target volume region of interest. The Cinematic Rendering technique supports the same mechanism, leading to full compatibility with the features provided by the applications. Features like automatic table and bone removal can be used for the visualization of vessels in all regions of the body and are essential e.g. to visualize the great vessels such as the aorta and iliac arteries without being shadowed by the rib cage and spine. Further-more, the heart isolation and coronary tree views reveal the heart and its feeding vessels without being overshadowed by the lungs and other osseous structures. For special use-cases, the user may create segmentation masks manually using generic editing tools like 'region growing'. Any of these techniques may be combined with basic tools like clipping planes or the punch tool.

Creation and storage of images

The images created using Cinematic Rendering can be stored and added to the clinical report using snapshots. In typical scenarios, multiple snapshots are taken sequentially from different orientations and zooming levels. Due to the progressive nature of the rendering method, it would take substantial time if the user would have to wait for each snapshot until cinematic image quality has been reached. To avoid that, the snapshot images are rendered asynchronously in the background. This way, the user can efficiently rotate and take snap-shots sequentially without waiting, even if the on-screen visualization is still in an initial lower quality state. The availability of the off-screen rendered image is then visualized by the "findings navigator". Any snapshot may be stored as secondary capture image and can be distributed to other DICOM nodes, or also added to the clinical report.

syngo.via Frontier

syngo.via Frontier, the open platform for translational research, offers a dedicated Cinematic Rendering prototype.[3] In addition to software features comparable to *syngo*.via Frontier provides full control over all relevant camera, material and lighting parameters. This enables the user to create illustrative visualizations by increasing the aperture size of the underlying camera model and moving the focal plane to the clinically relevant area. Other possibilities include adaptation of the lighting conditions such as changing the light probe or adapting the appearance of surfaces by altering the diffusion and specularity material parameters.

[3]Research prototypes are not intended for clinical use.

Cinematic Rendering – Synopsis

Cinematic Rendering was used in the following clinical cases to highlight the usefulness of the new technology. These cases were used to support the development and launch of Cinematic Rendering. The technology was applied for research purposes and not for diagnosis or treatment planning.

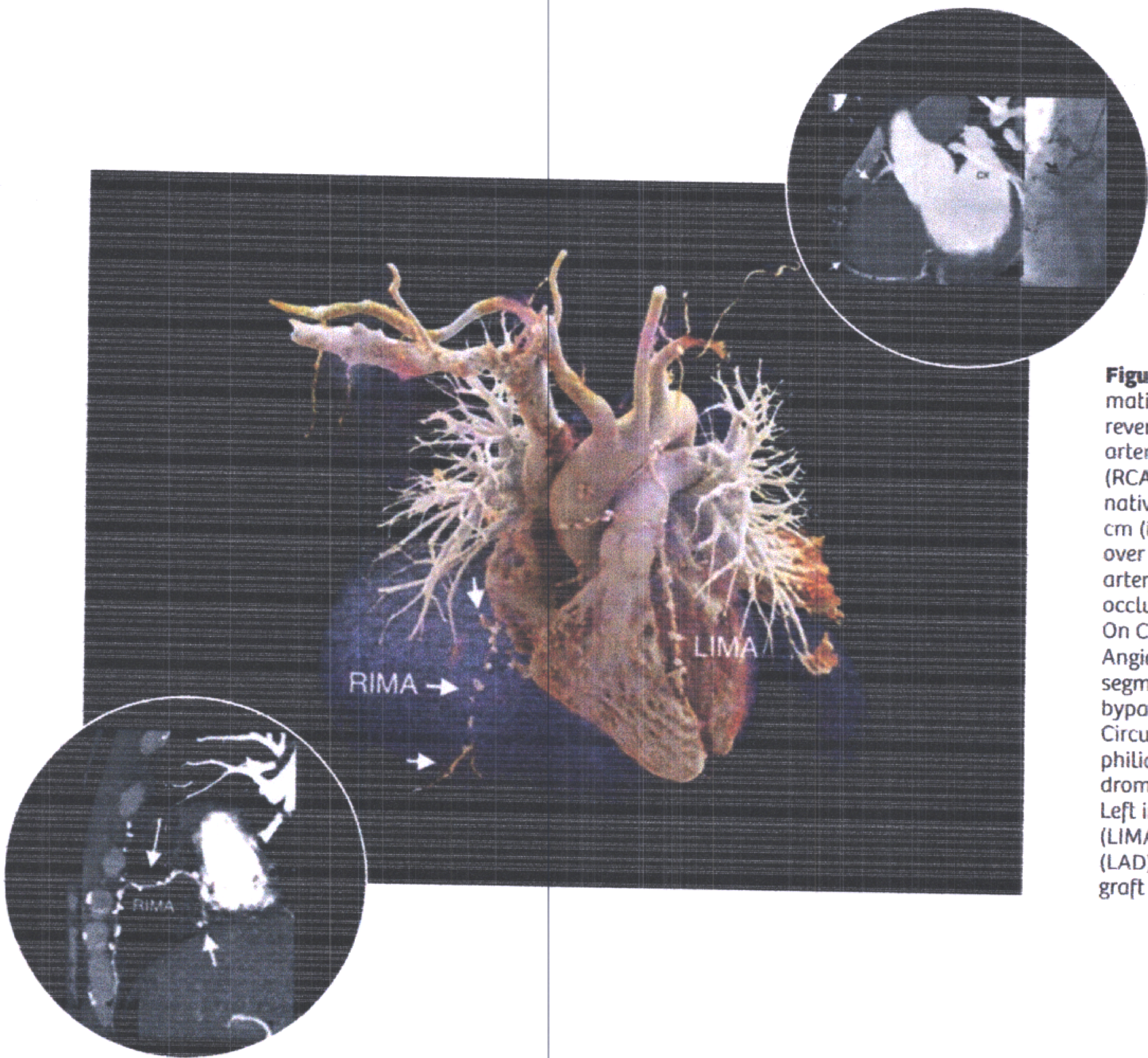


Figure 3: Three-dimensional cinematic rendering shows patent reverse right internal mammary artery (RIMA)/Right Coronary Artery (RCA) graft (see above arrows). The native RCA occlusion length was 5 cm (inlay upper right, white arrows) over the entire mid-section of the artery, and invasive chronic total occlusion (CTO) intervention failed. On Computed Tomography Angiography (CTA), the distal RCA segment was found appropriate for bypass grafting. Note: ectatic Circumflex (CX) due to hypereosinophilia-induced vasculitis (HES syndrome).
Left internal mammary artery (LIMA)/Left Anterior Descending (LAD) and vein to Diagonal (DG) graft were patent.

Data courtesy of of University of Innsbruck (figure 3).

Cinematic Rendering for Cardiac Imaging

Gudrun Feuchtner, MD

A 36-year-old male smoker (20 pack/years) presented with Non-ST Elevation Myocardial Infarction (NSTEMI) after some weeks of recurrent chest pain to the emergency department. Severe multi-vessel disease was diagnosed by invasive coronary angiography with multiple thrombotic occlusions (100% RCA, 100% LAD, and 90% DG 1). Interventional re-opening of both right coronary artery (RCA) and left anterior descending (LAD) failed, due to high occlusion length. Therefore, the patient underwent triple coronary artery bypass surgery. Left internal mammary artery (IMA) was anastomosed to the LAD and a vein graft was sutured to DG. The right IMA (RIMA) was harvested to the distal RCA because the patient's current occupation (steel worker) which requires heavy iron bar lifting by arms led to the decision to spare the radial artery from being removed in order to avoid potential arm movement restrictions due to malperfusion by a lacking radial artery. Finally, the RIMA was harvested and sutured to the distal RCA with an end-to-side anastomosis. Intraoperative RIMA retrograde flow was found to be very high.

Post-operative CTA showed patent RIMA to RCA graft with high transluminal attenuation gradients of 270–255 HU from RCA to RIMA and the phrenic arteries. The patient recovered fast and was discharged on day 8. The novel Cinematic Rendering technique visualization improved the three-dimensional-plasticity aspect of small vessels and bypass grafts, which was helpful for both surgical procedure planning and post-operative control and visualization of graft patency.

Cinematic Rendering for Trauma and Vascular Imaging

Hatem Alkadhi, MD

Figure 4: Non-enhanced 3D CT image of the skull and face showing a fracture of the mandible (left).

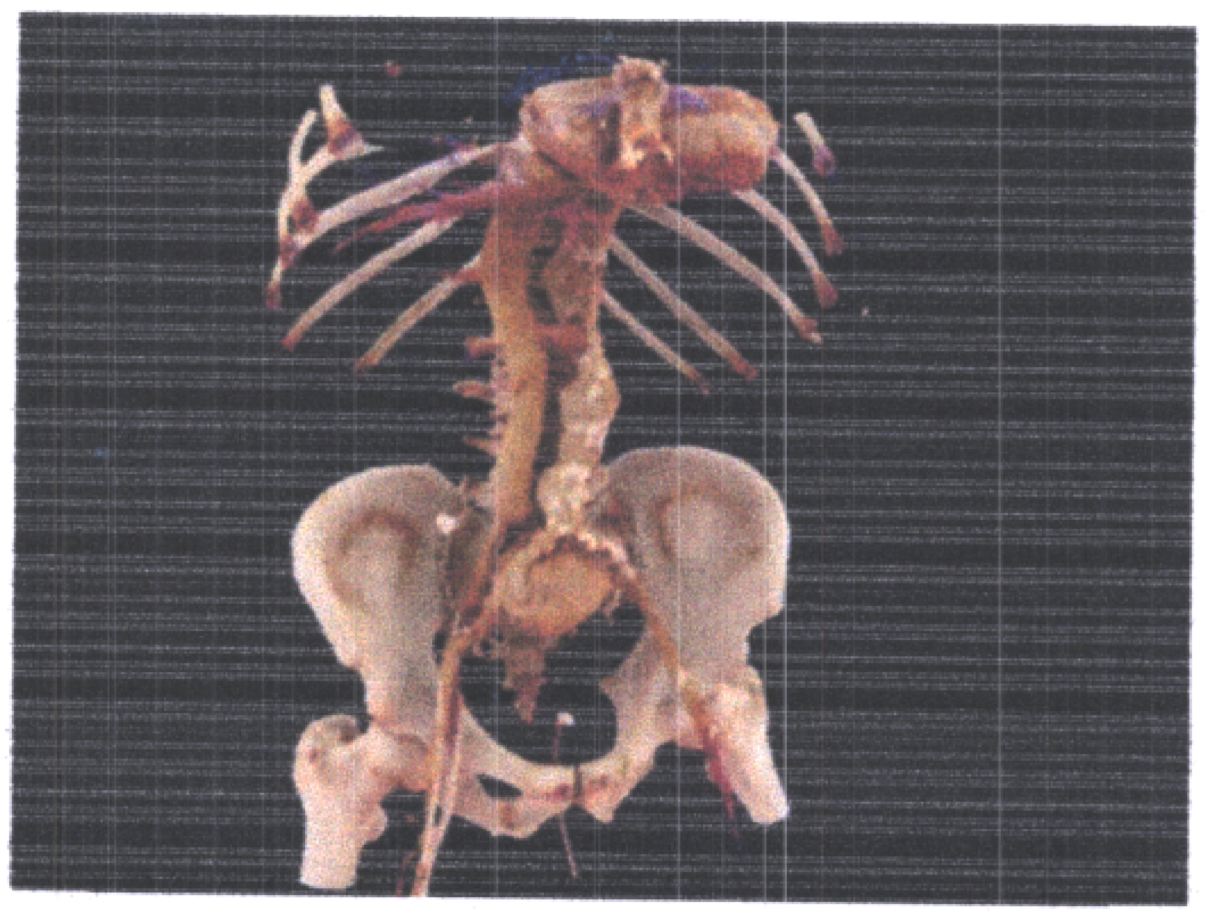


Figure 5: Contrast-enhanced 3D CT imag e of the abdomen showing an arteriovenous (AV) fistula from the infra-renal abdominal aorta to the inferior vena cava and an infra-renal aortic aneurysm (right).

Comparable to VR, in trauma patients Cinematic Rendering yields information about fragment size and position in relation to adjacent structures and thus it is a tool that can be used for preoperative or pre-radiotherapy planning. 3D imaging can also help in determining the location and extent of the tumor involvement in difficult anatomical settings and complex cases.

Similar to the VR technique, high-contrast structures such as contrast-enhanced vessels and bones are depicted with high quality with Cinematic Rendering. As opposed to conventional VR, CR improves the perception of depth and soft tissue structures providing a more photo-realistic depiction of human anatomy and disease.

Data Courtesy Institute of Diagnostic and Interventional Radiology, University Hospital Zurich, Switzerland (figure 4 and 5).

Cinematic Rendering for Vascular Imaging

Stéphane Rusek, PhD

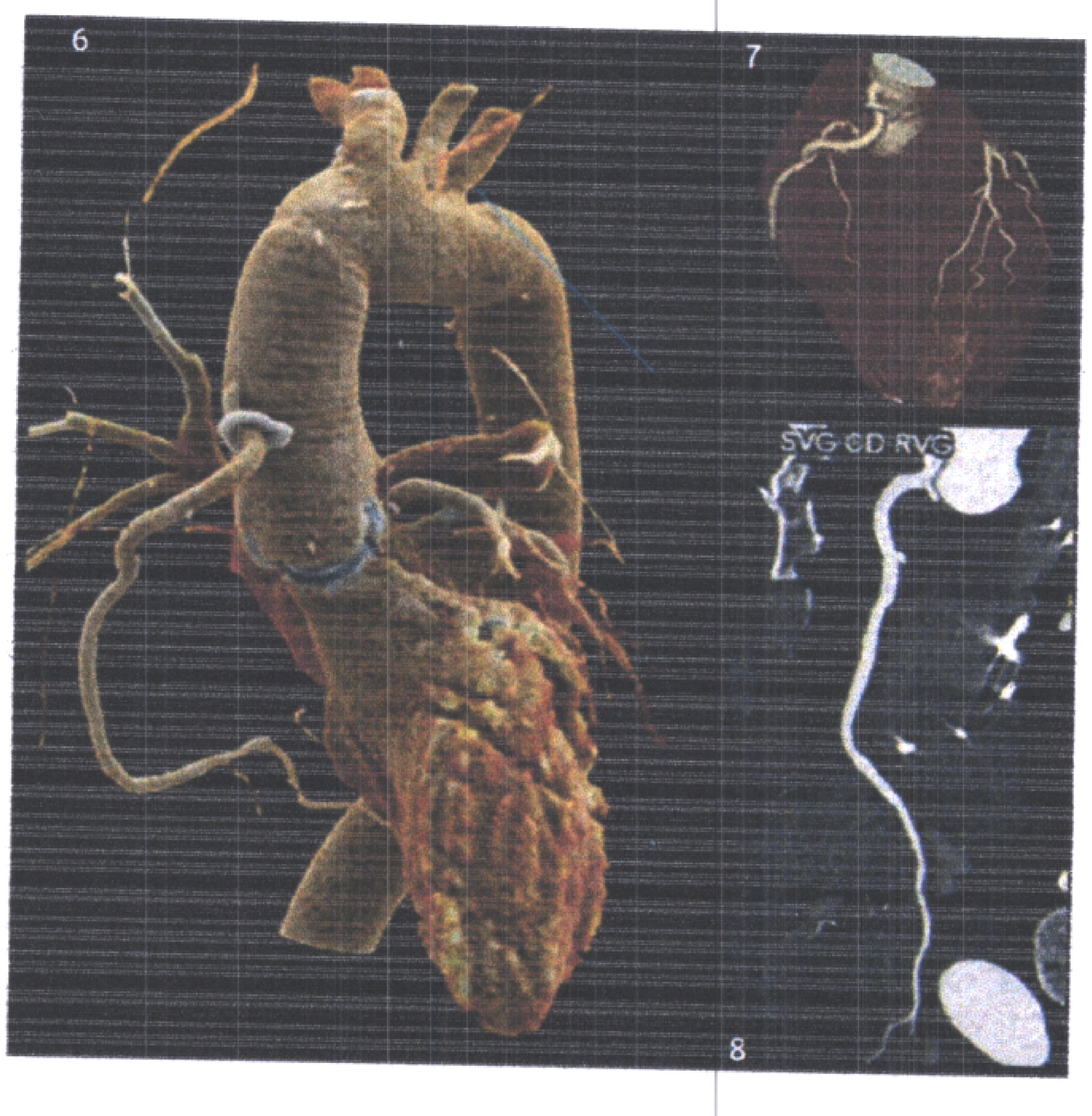


Figure 6: Cinematic Rendering
Figure 7: Standard VRT reconstruction
Figure 8: Curved MPR venous graft to RCA

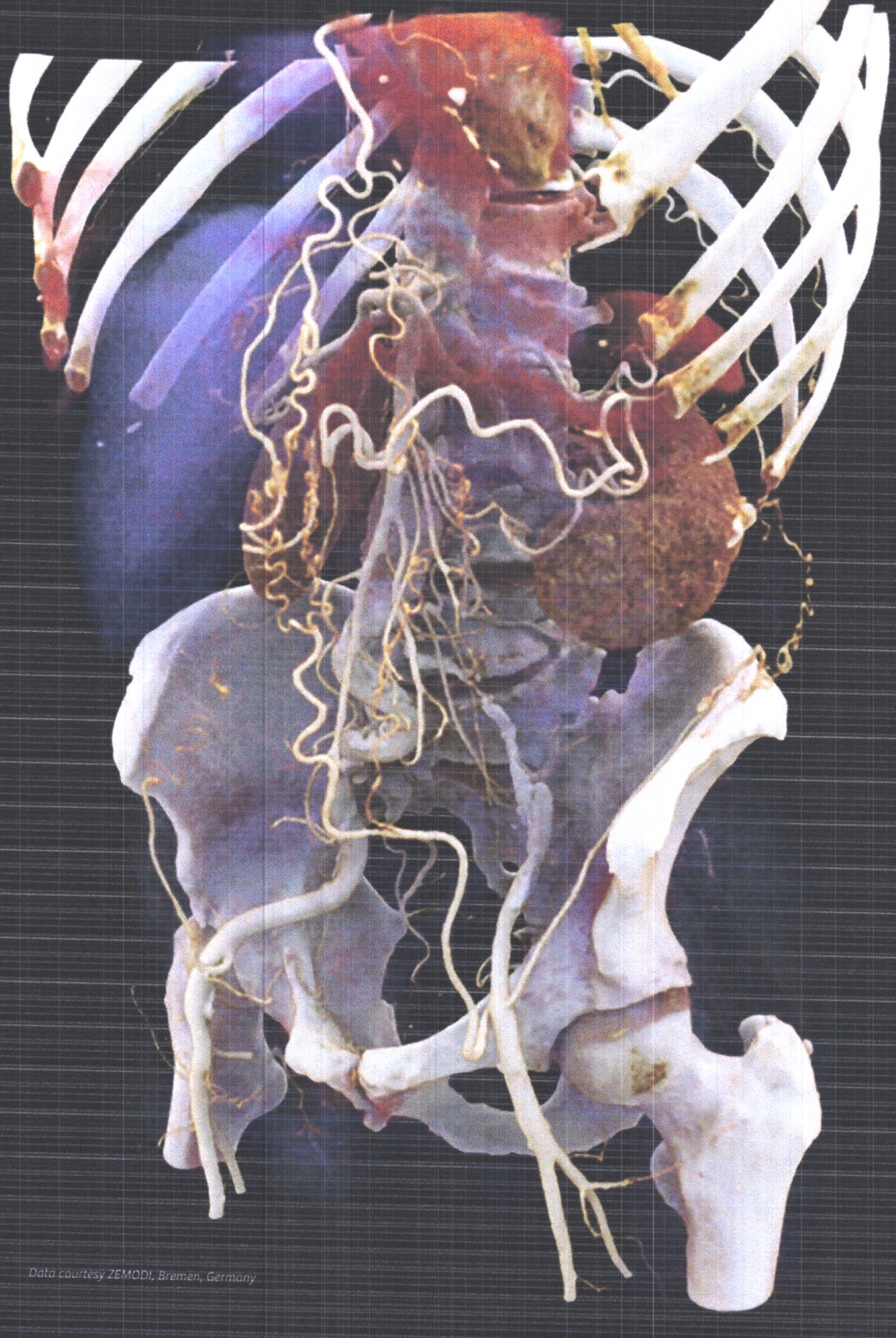
Data courtesy of Cardiothoracic Center of Monaco, Monaco (figures 6 to 8).

A 54-year-old male patient experienced a sudden onset of paroxysmal nocturnal dyspnea and was hospitalized. In his past medical history, there was an aortic insufficiency due to an aneurysm of the ascending aorta for which the patient underwent a complete replacement of the aortic root and of the ascending aorta by a Prima prosthesis 29, in 2003.

The transthoracic echocardiography shows a grade 4 aortic insufficiency due to a cusp rupture with a moderately dilated left ventricle and an ejection fraction of 50%.

The patient underwent surgery that consisted of an iterative replacement of the aortic root with re-implantation of the coronary ostia and an aortic valvular replacement by a bioprosthesis Carpentiers Edwards Magna Ease 25. Given the extensive calcifications of the aortic ring and of the aortomitral continuity it was necessary to first implant an endoventricular Dacron tube 2 cm long, which was implanted on the interventricular septum and the aortomitral continuity, which we have anastomosed the Dacron tube replacing the aortic root and the ascending aorta.

Cinematic Rendering visualization improved the natural three-dimensional aspect of the anatomy. E.g. by visualizing the aorta or other vessels with the shades that other surrounding structures cast, thus giving a better understanding of the depth and relation between these vessels and the surrounding tissue. Vascular images are depicted more photorealistically with Cinematic Rendering than was previously possible with Volume Rendering.



Data courtesy ZEMODI, Bremen, Germany

Conclusion

Cinematic Rendering is a valuable method that significantly improves the 3D renderings of advanced medical images, such as CT and MRI. Cinematic Rendering appears to be especially impressive when used to visualize high density and high contrast structures such as contrast-enhanced vessels or bones. The cases presented in this paper show that Cinematic Rendering can be useful for planning cardiac, vascular, and trauma surgery procedures or follow-ups. Cinematic Rendering can be used to provide referrers better insights into the topography of more complex fractures from 3D images. This is supported by the ability to either remove soft tissue, muscles, and blood vessels from images, or alternatively focus on individual organs and tissue structure.

The main innovation in comparison with conventional rendering techniques is observed in the enhanced depth and shape perception as well as in the photorealistic and natural representation of medical images.

Cinematic Rendering visualization improved the three-dimensional plasticity aspect of the anatomy. E.g. by visualizing the aorta without being shadowed by the rib cage and spine. Vascular images are depicted more photo-realistically with Cinematic Rendering than was previously possible with Volume Rendering.

However, more evaluation is required to confirm the use cases presented in this paper and evaluate further application potential.

Cinematic Rendering for Medical Imaging.

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