

OsiriX allows surgeons an accurate planning for aortic interventions.

By Germano Melissano, M.D. and
Roberto Chiesa, M.D. , Professor of Vascular Surgery

Division of Vascular Surgery - Scientific Institute H. San Raffaele
"Vita-Salute" San Raffaele University - Milano, ITALY

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Executive summary

Aortic disease is a frequent and potentially serious condition; when it involves the thoracic segment or the whole thoraco-abdominal aorta it can be particularly severe. In many cases thoracic aortic disease can be diagnosed and treated before it becomes dangerous. The most appropriate treatment may be an open surgical operation, or a less invasive endovascular procedure that involves the use of a stent-graft.

In order to plan the best possible treatment modality for each individual patient, accurate imaging must be obtained preoperatively. Most surgeons prefer a high quality CT scan for patients with aortic aneurysms or dissections. To obtain the most from the CT dataset one must be able to navigate through the images and manipulate them (reformatting techniques) in order to extract the most appropriate images. Until recently, reformatting the CT dataset in order to plan the procedure was possible only on dedicated (and expensive) imaging workstations with limited availability.

A new software solution has been recently created, it is called OsiriX. It has been specifically designed for navigation and visualization of multi-modality and multidimensional medical images (DICOM) including CT, and runs on regular Mac OS X computers. It is world widely available to be freely downloaded on the Internet. OsiriX allows Vascular Surgeons to accurately plan an aortic procedure employing sophisticated post-processing of their CT data-set in a very cost and time effective fashion.

A well-timed diagnosis and an accurate planning and sizing allows to offer an effective treatment to many patients; however, in spite of a flawlessly executed operation, several important complications may occur after thoracic or thoraco-abdominal aortic procedures. The most severe complication is spinal cord ischemia which can cause symptoms as dramatic as paraplegia. One of the elements that could help reducing the risk of postoperative paraplegia is an accurate preoperative knowledge of the blood supply to the spinal cord.

A very recent study that will be published in the April 2009 issue of the European Journal of Vascular and Endovascular Surgery was performed at the San Raffaele Scientific Institute in Milano. In this study the same CT datasets of patients with severe aortic disease were studied with the standard radiological workstations and with the OsiriX software running on a regular Mac Book Pro in order to detect the artery of Adamkiewicz, the principal supplier of blood of the thoraco-lumbar spinal cord. The results showed that the analysis performed with OsiriX was not only comparable with

those obtained with the standard methods but also consistent with the data obtained from a systematic review of the literature.

While further studies are certainly needed, these initial results are very encouraging because they confirm the value and the accuracy of OsiriX in the preoperative diagnostic workup of patients with aortic disease.

Background

Thoracic aortic disease

Aortic disease is a potentially serious condition and unfortunately it is not uncommon¹; when it involves the thoracic segment or the whole thoraco-abdominal aorta it can be particularly severe^{2,3}. Among the most common causes of disease there are arteriosclerotic aneurysms (dilatation of the vessel).

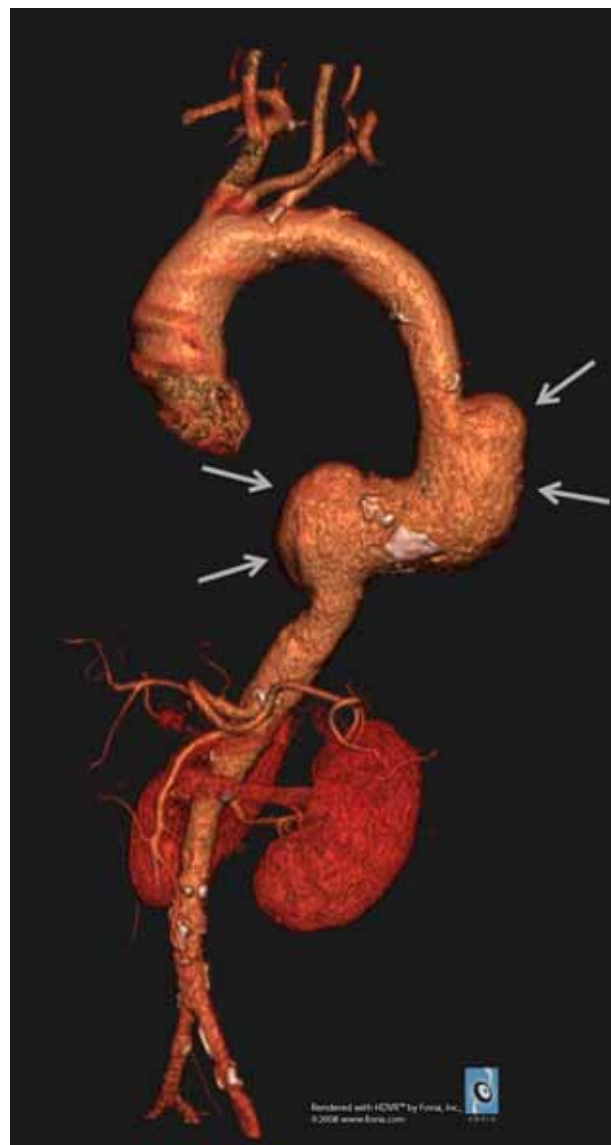


Figure 1: this image depicts a three-dimensional rendering of the entire aorta obtained with the OsiriX software and the Fovia high definition volume rendering software. The aorta is the principal artery that supplies blood to the whole body. We can observe an ascending portion, an arch and a descending portion. From the arch depart three important branches that supply the head and the upper limbs. In the descending

portion we can observe a large atherosclerotic aneurysm (arrows). Lower down we can observe branches to the abdominal organs; the kidneys are visualized in red. More distally the aorta bifurcates in two branches (the common iliac arteries) that supply the lower limbs. The white patches on the surface of the aorta denote areas of calcification of the aortic wall, an other consequence of arteriosclerosis.

An other important disease is aortic dissection (disruption of the vessel wall with secondary dilatation). If undiagnosed or left untreated, aneurysm and dissections may both grow larger and eventually rupture with possible catastrophic consequences (fatal internal haemorrhage).



Figure 2: this image is also a three-dimensional rendering of the aorta obtained with the OsiriX software and the Fovia high definition volume rendering software. In this case, we can observe the wall dissection (arrow head) that begins between the arch and the descending portion and proceeds spirally all the way

down to the artery that supplies the right lower limb. We can also observe a significant dilatation of the upper part of the descending aorta (arrows).

Luckily in many cases thoracic aortic disease can be diagnosed and treated before it becomes dangerous. The most appropriate treatment may be an open surgical operation⁴⁻⁸, or a less invasive endovascular procedure that involves the use of a stent-graft⁹⁻¹².

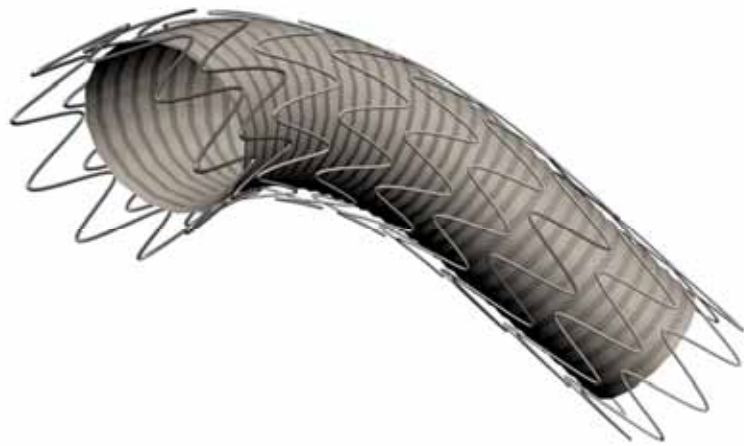


Figure 3: artist's concept of a stent graft for endovascular treatment of aortic aneurysms. The metal stents are self-expandable and allow the fabric to “seal” the aneurysm and exclude it from the blood flow.

In order to plan the best possible treatment modality for each individual patient, accurate imaging must be obtained preoperatively; most surgeons prefer a high quality CT scan for patients with aortic aneurysms or dissections.

Imaging modalities

Evolution of CT scanner: from slices to volumes

There are many different modalities that allow to image the thoracic aorta, each one have its own advantages and drawbacks:

- Chest XR (a valuable basic screening exam)
- Ultrasonography (in particular trans thoracic and trans-oesophageal echography)
- Digital Subtraction Angiography (implies arterial catheterization, contrast media injection and exposure to ionizing radiation)
- MR-Angiography (no radiations are involved but an intravenous contrast agent may still need to be injected)
- CT-Angiography (exposure to ionizing radiation, intravenous contrast agent injection)

There are several reasons why most surgeons that treat thoracic aortic disease choose CT-Angio as their preferred imaging modality, provided that there aren't specific contra-indications. State-of-the-art multi-detector CT scanners produce excellent imaging. Typically a complete exam to study the thoraco-abdominal aorta consists of at least 1000-2000 scans, possibly a few times as many. Old fashioned XR films or paper prints are obviously inadequate to visualize a stack of thousands of images and even standard computer based viewers are not adequate. To obtain the most from the CT dataset one must be able to navigate through the images and manipulate them (reformatting techniques) in order to extract the most appropriate images that are needed.

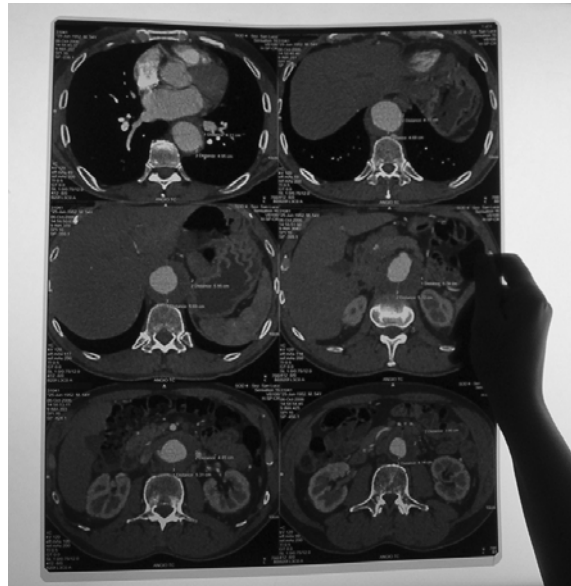


Figure 4: old CT scanners could only produce images of thick (1 cm) axial (transverse) sections of the body.

Unlike older CT scanners that could only produce axial sections ("slices"), the information that the newer scanners extract include the whole volume of the part of human body that is scanned. If the right tool is available, the digital information concerning this volume (the CT dataset) can be displayed in infinite ways.

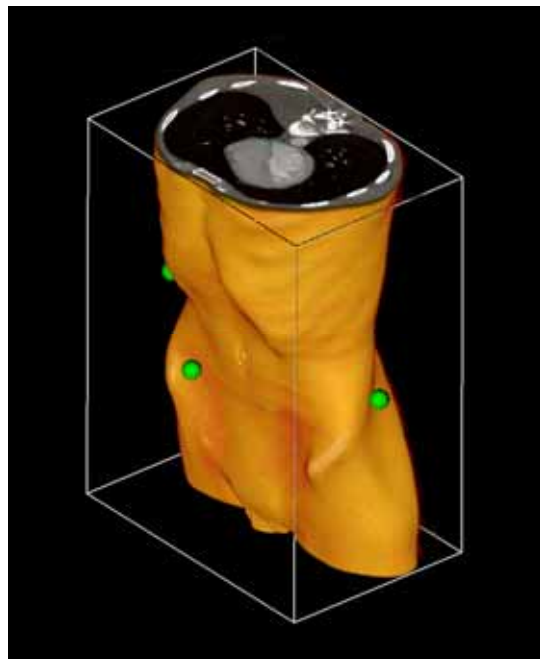


Figure 5: newer CT scanners can collect information on the whole volume that is studied. This data-set can be manipulated in many different ways to obtain images that highlight the part of the body that we need to study.

An imaging workstation for all

The birth of OsiriX

Until recently, reformatting the CT dataset in order to obtain the images that we really need in order to plan our procedure was possible only on dedicated imaging workstations that are really expensive and are usually located in the radiology department and have to be shared by many specialists, making practical access to them rather difficult and not convenient. Since 2004 and especially in the last couple of years the situation have changed considerably. We owe to the ingenuity of Dr. Ratib and his co-workers from the University of Genève (CH) for the creation of the OsiriX software¹³⁻¹⁶.

OsiriX is dedicated to “DICOM” images (Digital Imaging and Communications in Medicine) produced by current medical equipment, and runs on regular Mac OS X computers.

It has been specifically designed for navigation and visualization of multi-modality and multidimensional images, including CT. It is world widely available to be freely downloaded on the Internet, and is released under GNU free software license, which grants recipients rights to use, modify and redistribute copyrighted work. It is possible to create personalized plug-ins that performs desired actions. The active participation of the “open source” community assures a very rapid evolution and improvement of OsiriX. [Learn More](#).

As of the beginning of 2009 there are more than 32.000 users of OsiriX, and the number is rapidly growing¹⁷.

Displaying a CT dataset

How to render on a flat screen an object with 3 or more dimensions

With the help of the OsiriX software we can start working on our CT dataset to obtain the images of the aorta that we need. The classic way to show a CT dataset are axial (transverse) scans.

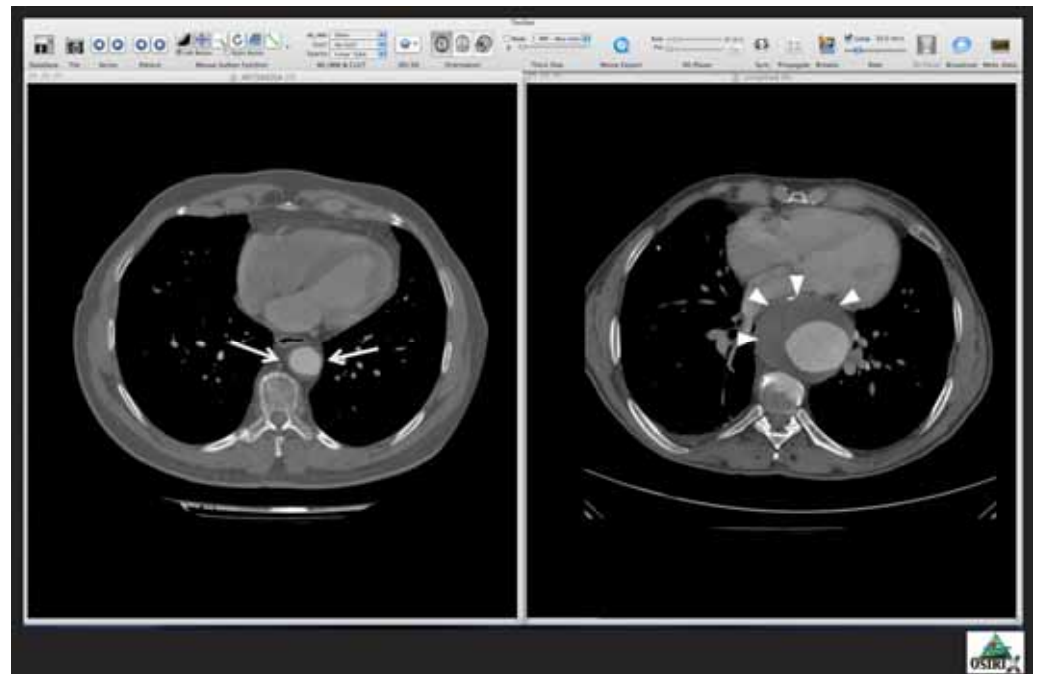


Figure 6 : this screen-capture obtained with OsiriX displays axial views of a normal (left, arrows) and an aneurysmatic (right, arrowheads) aorta.

However once we understand that the dataset contains the whole volume of the body, it is obvious that the slices can be cut not only in a transverse (Axial) plane but also in a frontal (Coronal) or in a lateral (Sagittal) plane. Scans in these 3 orthogonal planes (orthogonal multi-planar reformatting MPR) can be obtained easily and showed together in the same window.



Figure 7: the insert on the left depicts a schematic drawing of the human body with the 3 orthogonal planes: transverse (Axial - blue), frontal (Coronal - red) and lateral (Sagittal - green). The screen-capture on the right shows how OsiriX can display the three planes simultaneously. A grossly dilated aorta is evident however this orthogonal projections fail to show the entire course of the aorta.

Scrolling these 3 sets of scans, adjusting the window level and width, zooming and modifying the slice thickness will allow us to gain a lot of information, however unfortunately the important structures in our body don't always follow orthogonal planes; the aorta in particular (from the Greek word a-orthos = not straight) have a tortuous path that curves in all directions of space. An oblique MPR may therefore help us producing a scan whose angulation matches that of the aorta, or the vessel we need to study.

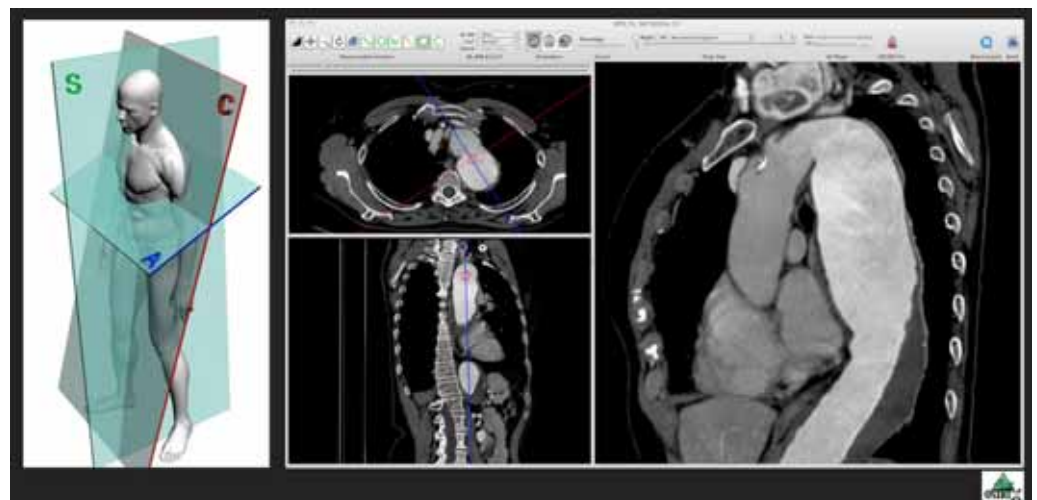


Figure 8: the insert on the left shows how the human body can be crossed by 3 oblique (non-orthogonal) planes: para-Axial - blue, para-Coronal - red, para-Sagittal - green. The screen-capture on the right

obtained with OsiriX displays the three oblique planes simultaneously, and how the curved path of the dilated aorta is now evident in the larger image.

Nevertheless if the vessel (or any other structure) we are studying is too tortuous to be followed even in an appropriate oblique MPR we can use an even more sophisticated tool: a curved MPR where the plane we are going to extract from the dataset is hand-drawn on the scan and have precisely the course of the anatomical structure we need to follow.

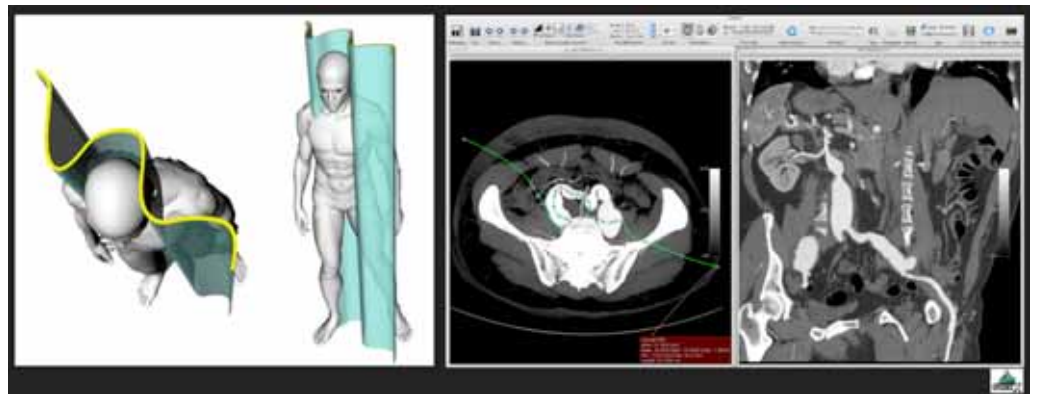


Figure 9: the insert on the left shows how the human body can “sliced” in a curved fashion. The curved plane is hand-drawn on the axial scan (OsiriX screen-capture left). This allows to show on the resulting image (OsiriX screen-capture right) the course of a very tortuous vessel.

To help us even more to view the structure we are studying in a very realistic three-dimensional way, 3D rendering tools are available such as MIP, volume rendering, surface rendering etc. (See also Figures 1 and 2). Working with colours to differentiate structures that have different but similar radio-opacity is a further way to enhance our diagnostic capability.

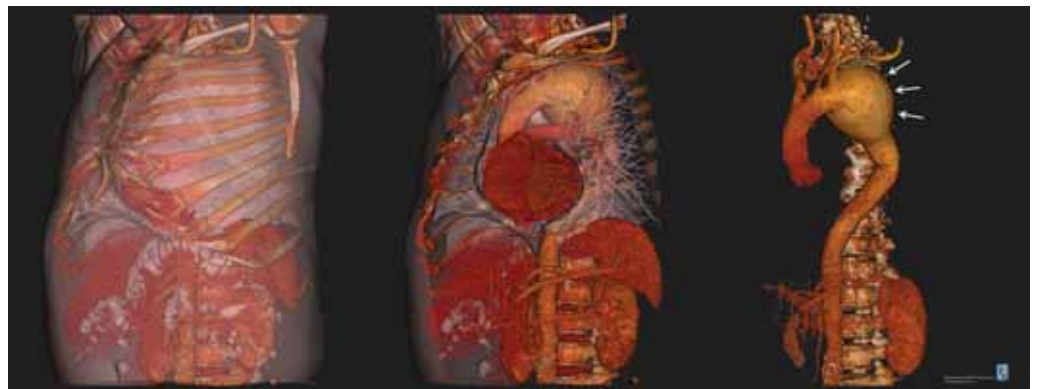


Figure 10: this image obtained with the OsiriX software and the Fovia high definition volume rendering software allows a pseudo-realistic three-dimensional depiction of the human body highlighting different

structures: the ribcage in the left image, the internal organs in the center image and the aorta (with a large thoracic aneurysm - arrows) with vertebral column in the background in the right image.

OsiriX also allow us to show on our screen the 4th dimension: time. Provided that the CT scan is obtained gating the acquisition with the different phases of a heartbeat, the exam will be shown dynamically in motion. Finally a 5th dimension, that of function may be shown simultaneously, metabolism for instance may be captured with PET exams and the resulting images can be fused to those of a dynamic CT producing for instance the stunning images of a beating heart with its metabolic activity.

Preoperative planning & sizing

(“Failure to plan is a plan for failure”)

OsiriX allows Vascular Surgeons all over the world to accurately plan an aortic procedure employing sophisticated post-processing of their CT dataset in a very convenient and cost / time effective fashion. Accurate planning is even more important when a stent-graft procedure is considered, because precise quantitative measurements are needed besides the usual qualitative diagnosis. Diameters, lengths and angles need to be measured very accurately together with the presence of thrombus, calcifications, anomalies, etc.

The importance of precise measurements in the preoperative planning cannot be overemphasized. So as the Russian proverb appropriately says “Measure seven times and cut only once...”.

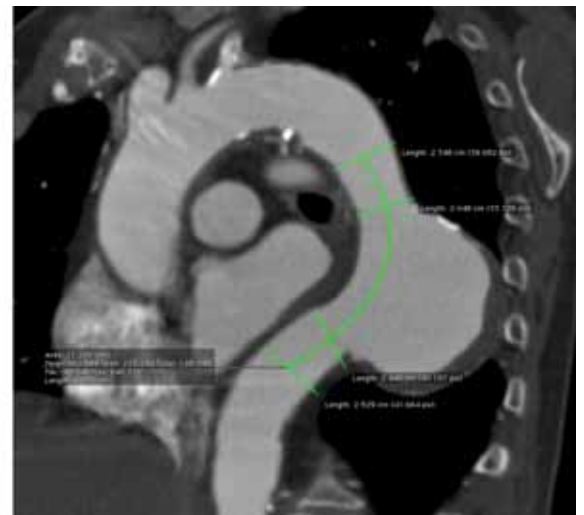
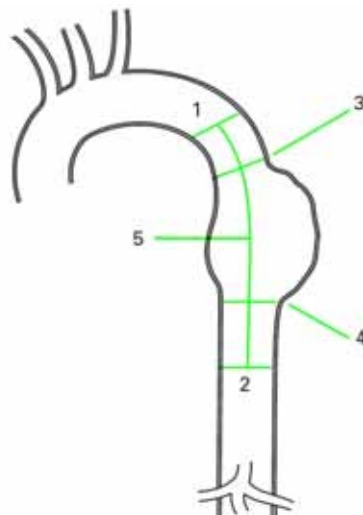


Figure 11: an example of sizing required to plan an endovascular procedure for a thoracic aortic aneurysm. A schematic drawing of the measurements needed (Left) and the actual measurements taken on an appropriately reformatted CT scan .

From diagnosis to treatment

And the struggle to avoid complications

A timely diagnosis and an accurate planning and sizing allows to offer an effective treatment to many patients, however, in spite of a flawlessly executed operation, several important complications may occur after thoracic or thoraco-abdominal aortic procedures. The most severe complication after these procedures is certainly spinal cord ischemia which can cause symptoms as dramatic as paraplegia.

This terrible event has many potential causes (multifactorial) but regrettably in spite of all the efforts it is still often unpredictable. One of the elements that could help reducing the risk of postoperative paraplegia is an accurate preoperative knowledge of the blood supply to the spinal cord¹⁸⁻³⁸. This is difficult to obtain because arteries that supply the spinal cord are small (< 1 mm), surrounded by osseous structures (vertebrae) and have an extreme inter-individual variability.

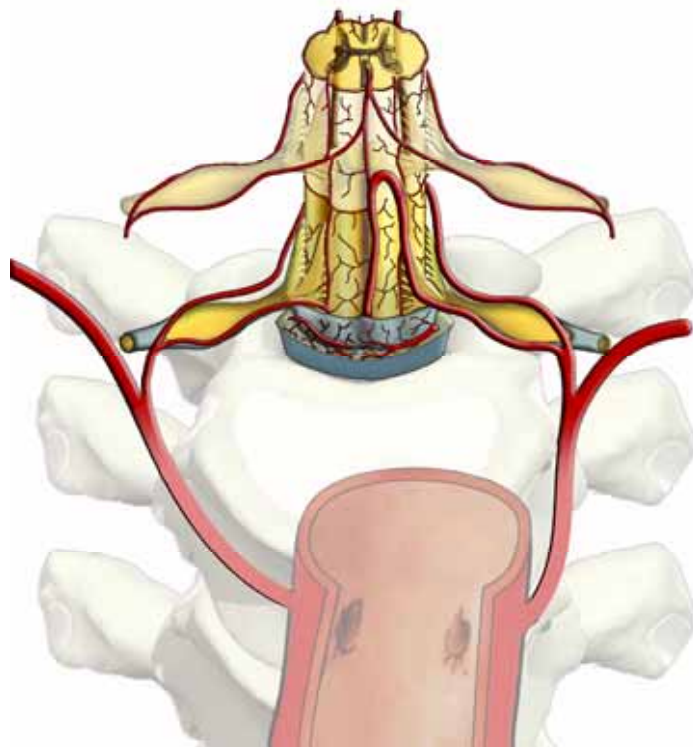


Figure 12: an artist's depiction of the spinal cord blood supply: the aorta is in the foreground and the spinal cord with its arteries is depicted in the background after removal of the vertebrae.

The identification of the spinal cord vasculature, in patients with aortic disease, has been shown to be possible with non-invasive imaging modalities such as MR-Angiography or CT-Angiography since 200²⁶⁻³⁸. All studies however have been performed in highly specialized radiology research institutions (mainly in Japan) and the potential clinical benefit for patients seemed to be still far away.

A very recent study that will be published in the April 2009 issue of the distinguished European Journal of Vascular and Endovascular Surgery³⁹ was performed at the San Raffaele Scientific Institute in Milano. Our Institution is especially active in aortic surgery, teaching and education. [Learn more.](#)



Figure 13: some of the clinical and research facilities at the San Raffaele Scientific Institute in Milano

In this study the same CT datasets of patients with severe aortic disease were studied with the standard (and expensive) radiological workstations and with the OsiriX software running on a regular Mac Book Pro in order to detect the artery of Adamkiewicz, the principal supplier of blood of the thoraco-lumbar spinal cord ([See how the artery of Adamkiewicz is detected with OsiriX in less than a minute.](#)). The results showed that the analysis performed with OsiriX was not only comparable with those obtained with the standard methods but also consistent with the data obtained from a systematic review of the literature.

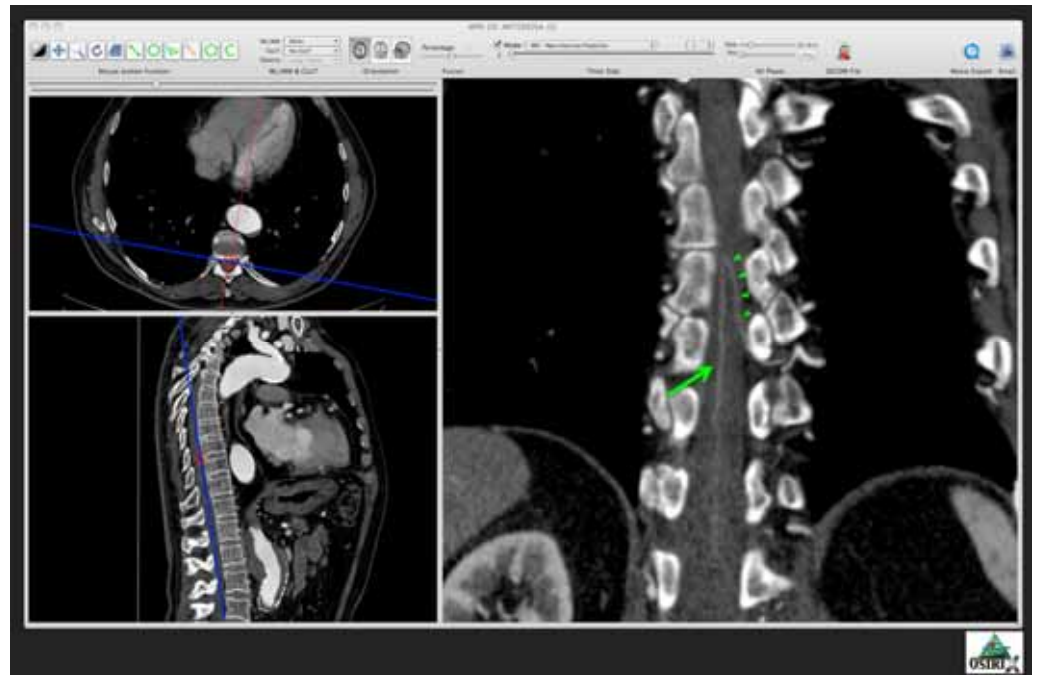


Figure 14: this screen-capture obtained with OsiriX displays a 2D oblique multi-planar reformatting performed in order to visualize the spinal cord and its principal blood supply: the anterior spinal artery (arrows) runs longitudinally and is fed by the great radicular artery or artery of Adamkiewicz (arrowheads) with its characteristic “hairpin” shape.

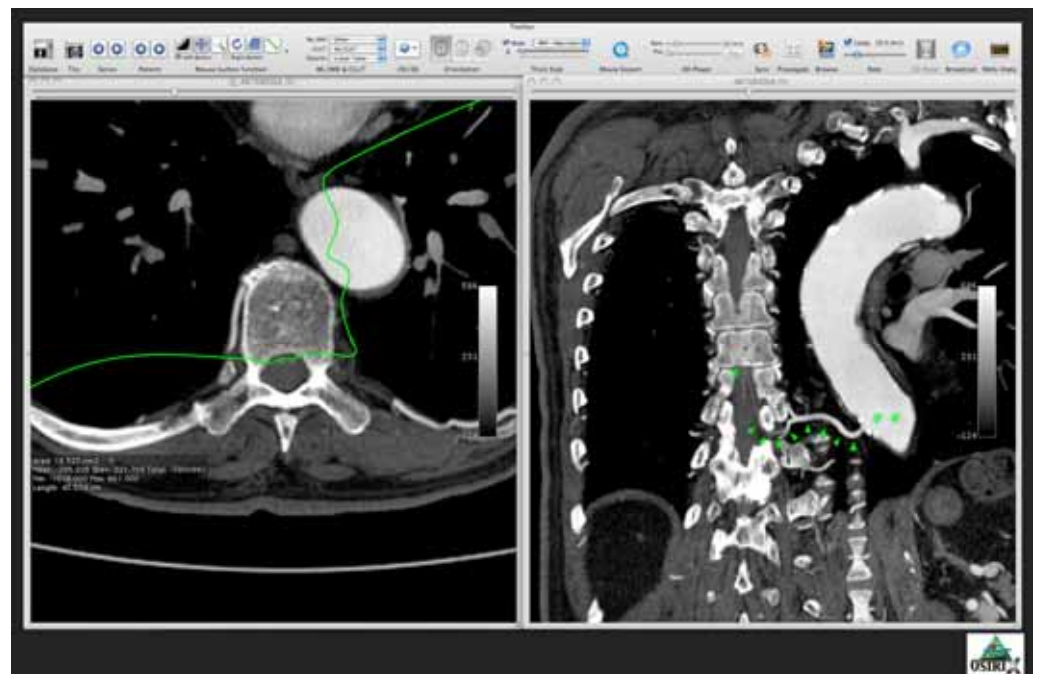


Figure 15: this screen-capture obtained with OsiriX displays a 2D curved multi-planar reformatting that allows to follow the continuity of the artery of Adamkiewicz (*) with the aorta (**) through the radiculo-medullary artery and the intercostal artery (arrowheads). Please note that the image on the right is a totally virtual curved plane “carved” from the CT dataset, its path is hand-drawn on the axial images (left image, green line).

While further studies are certainly needed, these initial results are very encouraging because they confirm the value and the accuracy of OsiriX in the preoperative diagnostic workup of patients with aortic disease.

Follow-up

Imaging medical devices at work

Once a stent-graft have been successfully implanted the patients need to undergo follow up imaging to confirm that everything is working properly, and if something is wrong, to allow for a well-timed and safe procedure to fix the problem.

The presence of metal parts (that are very radio-opaque) in the endovascular prostheses makes the postoperative scans not only important for the patient's safety but also fascinating to look at. Once again appropriate post-processing of the images is mission- critical for an accurate diagnosis.

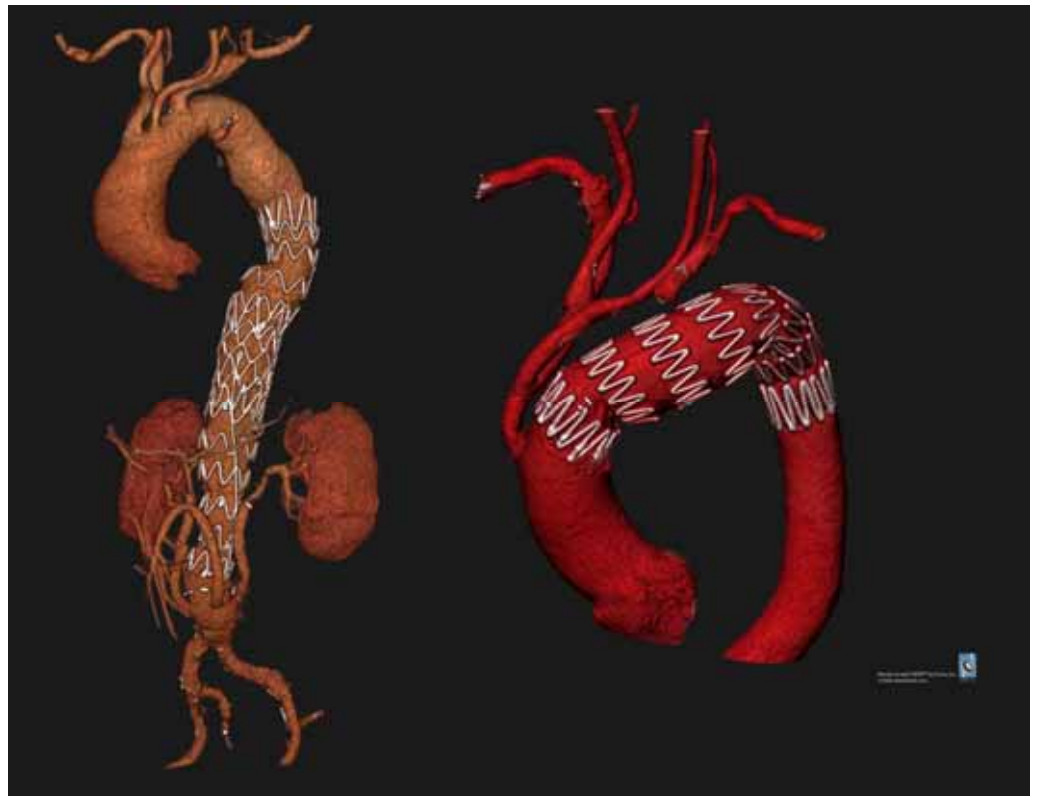


Figure 16: these images obtained with the OsiriX software and the Fovia high definition volume rendering software show stent-grafts placed in the thoraco-abdominal aorta (left) and in the aortic arch (right) to treat less invasively patients with severe aortic aneurysms.

Conclusion

OsiriX software has shown to be adequate in preoperative planning and sizing of patients with thoracic and thoraco-abdominal aortic disease. Moreover it has shown to be non-inferior to the expensive standard imaging workstations even in sophisticated tasks such as the detection of the artery of Adamkiewicz.

This is of great practical utility because it allows to perform accurate and refined post-processing tasks on a given CT dataset in a very resources conscious fashion.

Nowadays cost containment in healthcare without loss of efficacy is not only “trendy” but is becoming mandatory in many geopolitical realities around the world.

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Dept. of Medical Imaging and Information Sciences

Genève University Hospital - CH

The original OsiriX team

for creating and sharing this invaluable tool.