Inside information...

Medicamundi allows healthcare professionals and the industry to share inside information on the latest technological developments and their medical applications. Over the last fifty years, Medicamundi has been among the first to present many of the extraordinary developments in healthcare technology in general, and medical imaging in particular. As a result, the Medicamundi archives provide an outstanding record of half a century of development.

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Dear Friends,

It gives me great pleasure to introduce this issue of Medicamundi. The core of this issue deals with a selection of recent developments in interventional procedures and the associated guidance techniques. In several of them, 3D images and live fluoroscopy are combined to show the spatial relationships of the blood vessels, and the progress of endovascular materials such as catheters, probes and stents.

Cone-Beam CT (CBCT) can be used to track interventional needles using the rotation of the C-arm in systems such as the Philips Allura Xper FD20. XperGuide overlays live fluoroscopy on the acquired images, showing the needle path and target in endovascular procedures, or following the progress of a biopsy needle.

“A hybrid” operating room, with a fixed high-end imaging system and all the facilities of a conventional operating room, enables interventional techniques and open surgery to be performed in the same location. A new tool, known as the HeartNavigator, combines planning of optimal X-ray views with live guidance during the procedure.

Although the use of stents is now routine, stent thrombosis can still occur as a result of malapposition or underexpansion. The StentBoost image enhancement tool improves visualization of the stent deployment.

Superposition of CT angiography (CTA) on a live fluoroscopy image provides valuable support for complex procedures. Applications presented in this issue of Medicamundi include introduction of a transanular interatrial portocaval shunt (TIPS) to reduce portal pressure in end-stage liver disease, and translumbar embolization of endoleaks following endovascular aneurysm repair.

MR guidance offers advantages in soft tissue structures such as the liver, for example in guiding the probe for ablation of malignant tumors. Here, the Panorama FPO open MR scanner offers good access and freedom of patient positioning without compromising image quality.

With the acquisition of Respiration, Philips has obtained a strong position in respiratory diseases.

In surgical procedures, the combination of anesthesia and undiagnosed obstructive sleep apnea (OSA) is potentially dangerous. Preoperative screening of patients using an appropriate questionnaire can identify patients at risk.

Another aspect of respiration is the use of inhaled drugs to treat respiratory diseases. Two articles cover the early evolution of nebulizers and the development of the new generation of “intelligent” nebulizers that enable more precise dosage and a patient feedback mechanism.

I trust that this issue of Medicamundi will give you a glimpse of some of the latest developments we are working on at Philips Healthcare, and hope that you will find it both interesting and informative.

Henk van Houten
General Manager Philips Research, Program Manager Healthcare

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Percutaneous transthoracic needle biopsy of pulmonary nodules under XperGuide cone-beam CT guidance
G. Carrafiello, F. Fontana, M. Mangini, F. Piacentino, A. Cani, C. Pellegrino, and C. Fugazzola
Cone-Beam CT, in combination with XperGuide, offers more flexibility than traditional CT or CT fluoroscopy in guiding the needle in percutaneous transthoracic needle biopsy.

Transcatheter aortic valve implantation in a hybrid operating room using HeartNavigator
H. Schröfel, N.H. Bakker and R. van den Boomen
The hybrid operating room meets the requirements for transcatheter aortic valve implantation, with a fixed high-end imaging system, accurate planning and guidance, and the sterility of an operating room.

Visualization of stent malapposition in the mid left anterior descending artery using StentBoost
P.C. Smits and W.F. den Hartog
A 60-year-old female underwent percutaneous coronary intervention. The StentBoost image enhancement tool showed malapposition of the stent, which was corrected by post-dilatation.

Targeting the portal vein with real-time overlay of pre-treatment CTA and live fluoroscopy during TIPS: a case report
G. Maleux, S. Heye, J. Vaninbroukx, K. Zuurmond, and A. Radaelli
In TIPS, the portal and hepatic veins are connected to relieve portal hypertension. Superimposition of CT angiography (CTA) on the live fluoroscopy image aids accurate targeting.

Translumbar type II endoleak embolization using real-time needle guidance and fluoroscopy overlay on pre-treatment CTA
H. Kobeiter, J Mayer, P Degranges, AG Radaelli, JP Becquemin, and A Rahmouni
The authors report on their experience with real-time overlay of C-arm fluoroscopy on pre-treatment CTA in the management of type II endoleaks.

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3D Roadmapping in neuroendovascular procedures – an evaluation

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The 2D Roadmapping technique was introduced in the field of digital angiography more than a decade ago, and has become the standard used in all interventional procedures. This technique is based around the generation of a 2D projected image of the vessels, used for endovascular material guidance, thereby allowing accurate guidance.

The biggest drawback of 2D roadmapping is the fact that this technique requires the acquisition of images and injection of the iodinated contrast every time the C-arm is rotated. Observation from multiple viewing angles is not possible, since 2D roadmapping is based on a static projection. During treatment, however, the advancement of the endovascular material has to be checked from multiple angles. This means that additional imaging is required every time the viewing angle is altered, resulting in an increase in the volume of contrast agent and X-ray dosage.

The 3D Roadmapping technique is basically generated as a composite image in which live 2D fluoroscopy images are superimposed in real time on a 3D vessel reconstruction that has been previously generated from a set of rotational angiography frames. The alignment between these data sets is determined by the calibration acquisition system software, which means that there is no need for any image-based registration.

The composite image is fully flexible in terms of C-arm movement range, and image alignment is maintained when the C-arm is moving, and even when the source-image distance is changed.

We have used 3D roadmapping for neuroendovascular treatment of a range of conditions. This article describes our experience with 3D roadmapping to date, and discusses the characteristics of 3D roadmapping technology.

Material and methods

3D roadmapping was performed during neuroendovascular treatment procedures, including cerebral aneurysm embolization, carotid artery stenosis, and tumor embolization, conducted in Wakayama Rosai Hospital from November 2006 through July 2007. The advantages and disadvantages of 3D roadmapping for neuroendovascular treatment were evaluated in comparison with the conventional 2D roadmapping.

System

The clinical studies in our hospital were performed on a recently installed Philips FD20/10 biplane angio system (Philips Healthcare, Best, the Netherlands). The system is based on two flat detector imaging channels (the frontal channel with a 38 x 30 cm detector and a 2480 x 1920 pixel matrix, and the lateral channel with a 10 x 10 cm detector and a 1024 x 1024 pixel matrix). The pixel pitch is 154 micrometers on the frontal and 184 micrometers on the lateral detector. The flat detectors are mounted on separate C-arms. The frames for the 3D reconstruction are acquired via the frontal channel, with the C-arm rotating around the patient. The acquired frames are sent in real time to a workstation located in the control room. The purpose of the workstation is four-fold: creation of 3D vessel reconstructions, advanced postprocessing on the generated 3D data sets, 2D/3D image registration and display and for the calibration purposes.

Imaging method

3D reconstructions of the vessel anatomy are generated during the rotational motorized movement of the C-arm. The anatomy of interest is located at the system isocenter. The rotational movement covers 240° of the circular trajectory, at a speed of 55 degrees/sec, while
acquiring 120 rotational frames (4 sec acquisition, 30 frames/sec). The rotational acquisitions are sent through the optical link to the workstation in real time. The 3D volume is instantaneously available, i.e. as soon as the last rotational frame is acquired, the 3D reconstruction is displayed on the screen.

Optionally, the 3D reconstructions can be acquired by a roll movement where the C-arm is located beside the table and rotates perpendicular to the longitudinal table axis. The movement range in this case is 180° with the same number of frames (120) acquired.

The rotational acquisitions for generation of 3D reconstructions are always made with the maximum flat detector format (38 x 30 cm), using a 512 pixel matrix. During the acquisitions, a single injection of iodinated contrast agent is applied. In our institution, we usually use a total of 12.5 ml of contrast agent, depending upon the vessel anatomy, its size, its location, and the catheter position. A head support is introduced in order to minimize patient motion during the rotational acquisitions and the remainder of the interventional procedure.

Once the 3D reconstruction has been generated, the performing interventionalist does a visual assessment of the vessel pathology and, if necessary, a geometrical assessment of the vessel portions involved in the pathological process. After that, a working angle is defined which allows for the most convenient access to the pathology. The 3D reconstruction is displayed on the system monitor and is coupled with the C-arm in an interactive fashion: modification of the 3D projection angle in the 3D workstation initiates an automatic movement of the C-arm to that particular position, and vice versa, i.e. modification of the C-arm geometry location is reproduced in the 3D reconstruction.

Pressing the fluoroscopy pedal results in the real-time superimposition of fluoroscopy frames on the 3D reconstruction. This creates an improved 3D perception of the vessel location and the guide wire/catheter location in relation to the vessel. The accurate superimposition of the 2D fluoroscopy data sets onto 3D reconstructions is fully calibrated and self-correcting for misalignments caused by distortion of the image and any imperfections in the C-arm movement. The correction is an extension of the calibration method described by Grass at al. [1].

Virtually every position of the C-arm can be adjusted with this method. The biggest advantage of the method is that it is not dependent on the image content (image-based calibration) but on the calibrated C-arm space. As a result, it allows for the real-time superimposition that tracks the fast movements of the C-arm, without using an algorithm based on image content. The relation between the 2D and 3D anatomy is always maintained, allowing for safer treatment. This enables the user to observe the relationship between the blood vessel and the device from various angles without the need for additional contrast injections.

**Results**

**Clinical cases**

3D roadmapping was used in 20 patients who underwent neurovascular treatment in our hospital from November 2006 to July 2007. Of these patients, eight underwent cerebral aneurysm embolization, five had carotid artery stenting (CAS), four had brain tumor embolization, and three had intraarterial infusion therapy for head and neck cancer.

All of the cerebral aneurysm embolization procedures were performed under general anesthesia. First, a guiding catheter was introduced into the blood vessel and 3D rotational angiography was performed. Then the size of the aneurysm was measured and the relationship between the aneurysm and the blood vessel was evaluated. Based on the same 3D rotational angiography data set, 3D roadmapping was performed, requiring no additional contrast injections. A microcatheter was introduced under the guidance of the 3D roadmapping functionality and a coil was placed within the aneurysm. During this procedure, the position of the frontal C-arm was changed as necessary to select the optimal viewing angle. The position of the coil, presence or absence of a neck remnant of the aneurysm, any straying of the coil into the parent artery and the patency of the parent artery and branches were very well observed. In some cases, the placement of the catheter caused straightening of the parent artery, resulting in a slight mismatch between the roadmap images and the actual vessels.

CAS was performed under local anesthesia. A guiding catheter was introduced and then 3D rotational angiography was performed to measure the vessel diameter. Based on the same 3D data set, 3D roadmapping was performed as an aid to the endovascular procedures, including lesion crossing by a guidewire, intravascular ultrasound (IVUS), percutaneous transluminal angioplasty (PTA) and stenting. In contrast to conventional 2D roadmapping, the 3D technique allowed observation of the cervical vertebrae on
fluoroscopy images. It was thus possible to find the position of the stent with respect to the cervical vertebrae, even when stenting caused severe straightening of the blood vessel. In one case, the patient moved just before the stent was placed and the movement shifted the 3D roadmap image from the actual vessel position. In spite of this change, the stent was accurately placed because the displayed 3D roadmap image allowed us to find the correct stenting position with respect to the cervical vertebrae.

Tumor embolization was performed in patients with meningioma. A guiding catheter was introduced into the external carotid artery and 3D rotational angiography was performed. Based on the same 3D data set, 3D roadmapping was performed to advance a microcatheter into the feeding arteries including the middle meningeal artery. Frequent changes in the C-arm angle allowed the selection of an optimal working angle and the microcatheter successfully reached the desired position in all cases.

Intraarterial infusion therapy for head and neck cancer was performed in three patients. In all of these patients, treatment was successfully completed with no particular problems. The use of 3D roadmapping enabled us to perform these procedures effectively. Some interesting clinical cases are described below.

Case 1
A 67-year-old male underwent CAS for right carotid artery stenosis. The procedure was performed under local anesthesia. A 6 Fr Shuttle sheath was introduced into the right common carotid artery via the right femoral artery. 3D-RA was performed to measure vessel diameters and other parameters. The acquired data were then used for 3D roadmapping. A PercuSurge protection device was employed and the lesion was crossed with GuardWire. IVUS was performed under the guidance of 3D roadmapping (Figure 1a), followed by balloon inflation (Figure 1b) and stenting. Although a slight straightening of the internal carotid artery was observed during the procedure, CAS was performed without problems under 3D roadmapping guidance.
Case 2
A 64-year-old male presented with sudden headache and nausea and proved to have developed a subarachnoid hemorrhage. Angiography revealed the azygos anterior cerebral artery and identified an aneurysm in the distal A2 segment. Embolization of the cerebral aneurysm was performed under general anesthesia. A 6 Fr Envoy was introduced to the right internal carotid artery via the right femoral artery. 3D-RA was performed and the size of the aneurysm was measured. 3D roadmapping was performed using the 3D-RA images. While Hyperform was introduced for neck plasty, a microcatheter was inserted into the aneurysm (Figure 2a). Hyperform and the microguidewire caused mild straightening of the artery but this was not regarded as a significant change. Embolization was successfully performed under 3D roadmapping guidance (Figure 2b).

Case 3
A 59-year-old female with a head injury underwent a head CT scan and was found to have a meningioma. Preoperative tumor embolization was performed. The right femoral artery was punctured under local anesthesia and a 6 Fr Envoy was introduced to the left external carotid artery. 3D-RA images were acquired and 3D roadmapping was performed. Frequent changes in the viewing angle (Figures 3a, b) allowed problem-free advancement of the microcatheter into the distal part of the left middle meningeal artery (MMA) (Figure 3c). PVA was injected through the microcatheter and embolization was successfully achieved.

Discussion
The 2D roadmapping functionality was the standard used in interventional neuroradiology from the early 1980’s [2] and is considered to be one of the most frequently used interventional techniques. It has multiple advantages over the older standard angiographic techniques. The 3D angio technique was introduced in the late 1990’s [3, 4] and is nowadays considered to be the gold standard for interventional assessment of cerebral aneurysms and AVM’s [5, 6, 7].
3D roadmapping superimposes 3D rotational angiography (3D-RA) images, acquired by rotational scanning, on conventional 2D fluoroscopy images. 3D roadmapping was proposed as a method for image guidance in neurovascular interventions by Kerrien et al. in 1998 [8]. In 2005, Soderman et al. reported their clinical experience with 3D roadmapping, although in only one experimental case [9]. This was the report on clinical experience with 3D roadmapping routinely utilized in neuroendovascular treatment.

The 2D roadmapping concept is based on the creation of two runs: the first is a standard contrast run and the second is where the interventional material is advanced. The runs are subtracted from each other. The subtracted image shows the contrast material of the first run, with the interventional devices superimposed on it from the second run. The background information (bone or even embolic material) is removed during the subtraction process. The method suffers from multiple disadvantages: both the runs must be acquired with identical projections, the patient must not move in the interim, the acquisition parameters should be almost equal, and the Source-to-Image Distance (SID) and the magnification must remain unchanged. If the C-arm location is modified, the whole process has to be repeated, which requires additional contrast and slows down the interventional workflow. Due to the difficult anatomy, especially in interventional neuroradiology, this process is done several times, resulting in an increase in the contrast volume and X-ray dose.

We have experienced the benefits of using roadmapping for advancing a microcatheter/microguidewire. The viewing angle must normally be changed during this procedure if the spatial relationship among the blood vessels is complicated. Conventional 2D roadmapping requires additional imaging with contrast agent every time the C-arm is rotated and is likely to require the use of large amounts of contrast agent. This pattern is often seen in single-plane systems because of their single viewing angle.
should be performed at an angle that ensures identification of the dome, neck and parent artery of the aneurysm. Particularly in the case of a wide-necked aneurysm, it is crucial to adopt the correct optimal working angle because the embolization coil can easily stray into the parent artery. Cases exist in which the parent artery is crooked or intricately branched, and where a vessel sometimes directly branches out from the dome. In such cases it is often difficult to select the optimal working angle, so it is often necessary to obtain multiple viewing angles in order to observe the site accurately.

With 3D roadmapping, it is easy to make fine adjustments to the working angle during the procedure, because the 3D display of the blood vessels automatically follows the movement of the C-arm. In addition, 3D roadmapping is able to provide multiple viewing angles without additional image acquisitions, whereas 2D roadmapping requires additional image acquisitions every time the viewing angle is altered. The major benefits of 3D roadmapping will make it essential for performing embolization of cerebral aneurysms. In the case of a vessel directly branching out from a dome, the 3D vessel display assists in understanding the relationship between the dome and the vessel, which cannot be done with 2D roadmapping.

Compared with 2D roadmapping, the only disadvantage of 3D roadmapping is that rotational angiography is required. In some cases, straightening of the blood vessel caused by the advancement of a device (e.g. catheter) and patient movement may result in a mismatch between the actual position of the vessel and that shown on the roadmap image. And of course, if the difference is large, additional 3D roadmapping is required, which requires rotational angiography. Rotational angiography is a more complicated procedure which requires larger contrast volume compared with 2D roadmapping. However, the first 3D roadmapping often makes use of the data from 3D rotational angiography which was performed to measure the vessel diameter and the size of an aneurysm. Therefore, even if a second roadmapping is required, the total contrast volume required for roadmapping is equivalent to that used in a single rotational angiography procedure. For example, in our case of an internal carotid artery procedure, 12.5 ml of contrast agent is used per rotational angiography for 3D roadmapping. Taking into account that 5 to 6 ml is used in one 2D roadmapping procedure, the volume of contrast agent used in 3D roadmapping procedures is almost the same as that used in two 2D procedures.

On the other hand, with 3D roadmapping, the angle of the vessel image changes according to the fluoroscopic angle, requiring no additional imaging and thus allowing less contrast agent to be used.

CAS

In carotid artery stenting (CAS), we use 3D-RA to measure the vessel diameter, stenosis diameter and stenosis length. 2D roadmapping would require additional image acquisitions using contrast agent, but reusing the 3D-RA for the 3D roadmapping results in less contrast agent being used. In addition 3D roadmapping, in which 3D-RA is overlaid with a real-time fluoroscopy image, enables us to observe the vessel alongside bones such as the cervical vertebrae. It is thus possible to examine the precise placing position of a stent/balloon, not only with respect to the blood vessel but also with respect to the vertebral body. Since CAS is often performed under local anesthesia and patients are likely to move during the procedure, this can cause errors in the road map and the stent may therefore have to be positioned with reference to the vertebral body. In this case, 3D roadmapping is markedly superior to 2D roadmapping.

Aneurysm embolization

It is especially important in cerebral aneurysm embolization that intraoperative fluoroscopy Figure 3c. The microcatheter speedily arrived at the distal part of the middle meningeal artery (MMA). PVA was injected through the microcatheter and embolization was successfully achieved.
Conclusion

We found 3D roadmapping to be a very useful imaging tool for neuroendovascular treatment. Three-dimensionally displayed roadmapping images reveal the blood vessel structures with great precision. The flexibility of automatic C-arm positioning makes it easy to obtain the best viewing angle from a wide range of rotational angles. It also allows the reduction of use of contrast agent, since additional injections are not required each time the viewing angle is changed.

References


The aim of this study is to evaluate the feasibility of percutaneous transthoracic needle biopsy of pulmonary nodules under XperGuide CBCT guidance.

Materials and methods

Between June 2009 and June 2010, 30 percutaneous transthoracic needle biopsies of pulmonary nodules with XperGuide CBCT guidance were performed in 30 patients (22 males, 8 females, mean age 63.5 years, range 41-86 years). Written informed consent was obtained from all patients.

The skin was prepared with an antiseptic solution and all procedures were performed with local anesthesia (subcutaneous injection of 10 ml of carbocaine 2%). Ten biopsies were performed in the left upper lobe, eight in the right upper lobe, three in the left lower lobe, three in the right lower lobe, two in the lingula and four in the right middle lobe. The mean size of the lesions was 5.5 cm (range 1-11 cm).

During the procedure, heart rate, ECG, oxygen saturation and respiratory rate were continuously monitored, while blood pressure was determined every 4 minutes. An 18 G biopsy needle (Biopsy Bell, Medical Devices, Modena, Italy) was used in all cases (all data are summarized in Table 1).
### Table 1. Study population. Demographic data, lesion size and location, histopathologic findings and complications.

<table>
<thead>
<tr>
<th>Age</th>
<th>Sex</th>
<th>Lesion site</th>
<th>Lesion diam.</th>
<th>Needle</th>
<th>Histopathologic findings</th>
<th>Complications</th>
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<tr>
<td>77</td>
<td>M</td>
<td>left</td>
<td>21 mm</td>
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**Image acquisition**

Images were acquired using a Philips Allura Xper FD20 system. This has a flat panel detector mounted on a C-arm, which can be rotated around the patient for CBCT (XperCT) soft tissue imaging.

In our study we used a 5 s acquisition time for a rotation of 240°, which generates 310 images with a 512 x 512 image matrix and a total reconstruction time of 25 s. Depending on the image matrix and field of view, the highest spatial resolution is 0.4 mm while contrast resolution for the soft tissue is equivalent to 5 HU at a slice thickness of 10 mm.

The reconstructed isotropic soft-tissue volume is displayed automatically on the monitor in the examination room; manipulation and viewing of the image volume can be done directly at the tableside as well as in the control room.
The resulting XperCT images are used in the XperGuide to plan a virtual needle path, choosing the skin entrance site and the destination target site.

**XperGuide**

XperGuide supports percutaneous needle procedures in the interventional suite by superimposing live fluoroscopy on the acquired CBCT images, providing information on the needle path and target. Live 3D image guidance and feedback on any deviations from the desired path gives the operator full control and confidence in guiding the needle along the correct path.

XperGuide indicates the skin to target distance from site to site, and the planned virtual needle path can be viewed on the XperCT slices, to verify its feasibility. Based on the predefined point-to-point path, the system determines the optimal projection for visualizing the needle advancement, and automatically rotates the C-arm to the needle insertion position (“entry point view”).
XperGuide adapts in real time to changes in the angulation or rotation of the C-arm, as well to changes in the field of view; moreover XperGuide software compensates for any parallax distortion in the visualization of the needle path.

**Results**

Technical success was defined as correct deployment of the needle into the lesion. The final diagnosis of benign or malignant nodule was assessed on the basis of biopsy findings, and...
Computed Tomography (CT) guided biopsy of the lung is a widely used diagnostic tool in the management of patients with suspected lung cancer. Computed Tomography fluoroscopy is a computed system for real-time reconstruction of CT images, combining the high spatial resolution of a CT scan with the high temporal resolution of fluoroscopy. Compared with conventional CT, CT fluoroscopy allows real-time needle guidance with fewer needle passes than standard CT-guided procedures [6].

CT fluoroscopy represents the gold standard technique for performing pulmonary nodule biopsies, thanks to the possibility of precise scan selection that allows correct needle deployment. Various studies in the literature [7,8] assessed the efficacy of CT fluoroscopy for interventional procedures in different anatomical sites and stated that CT fluoroscopy is necessary when it is the only imaging technique able to identify and reach the biopsy target.

The rapid identification of the suspected lesion and the simultaneous visualization of the needle tip is the most important advantage of CT fluoroscopy, allowing continuous and accurate monitoring of the needle progression to the target site. For this reason CT fluoroscopy is considered to be a fast, efficient and safe procedure, with a high technical success rate.

Diagnostic accuracy, sensitivity and specificity reported for CT fluoroscopy are 96%, 95%, 100% respectively, compared to 95%, 93% and 100% for traditional CT guidance.

However, CBCT with XperGuide could be considered a good alternative to CT fluoroscopy for pulmonary nodule biopsies, in order to reduce the CT schedule, thanks to its high diagnostic accuracy, sensitivity and specificity. As reported in the literature, CBCT is feasible and safe for percutaneous abdominal and transthoracic needle biopsies with diagnostic accuracy, sensitivity, specificity and incidence of complications of 98.4%, 97%, 100% and 38% respectively [9-10].

This study describes our preliminary experience with percutaneous transthoracic needle biopsies of pulmonary nodules using XperGuide CBCT. As our familiarity with the technique is continuously improving, procedure time is decreasing and we now select smaller lesions for biopsy with the XperGuide system. In 2011, we expect that XperGuide will be used for approximately 40% of all lung biopsies.

The most common complication of a lung biopsy is surely pneumothorax. The pneumothorax rate reported in the literature for the last ten years is 8 - 45%, but most studies report rates lower than 20% [11]. In our experience the pneumothorax rate was 16.6%. This relatively low rate is probably due to the lesions being relatively large and close to the surface: the mean lesion size was 5.5 cm, while 35% of the lesions were close to the pleura, making it unnecessary to pass through areated lung tissue. Deep and small lesions have a much stronger correlation with pneumothorax formation [12].

In conclusion, XperGuide could be useful in Radiology Departments where CT is less available. This would allow CT to be mainly used for diagnostic examinations, with an optimization of resources. In addition, the possibility of performing needle interventions in the angiography room using XperGuide is advantageous, because dedicated staff ensures an optimal compliance and low complications during the procedure.
References


Clinical applications

Transcatheter aortic valve implantation in a hybrid operating room using HeartNavigator

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Philips Healthcare, Best, the Netherlands.

R. van den Boomen

Opened in 1995, the Klinik für Herzchirurgie Karlsruhe (Karlsruhe Heart Surgery Clinic) is a specialist hospital for the treatment of heart disease in adults, carrying out some 2,500 procedures per year. With the introduction of minimally invasive techniques, including aortic and mitral valve replacement, the hospital is regarded as being a center of excellence for the treatment of heart patients. The hospital serves the City of Karlsruhe and the surrounding area, comprising some 400,000 inhabitants, but candidates for transcatheter aortic heart valve implantation (TAVI) are referred from outside the area.

In 2007/2008 our TAVI team visited the leading heart center in Leipzig, Germany (Herzzentrum Leipzig GmbH – Universitätsklinik) to observe the procedures for transcatheter valve implantation. The TAVI team consists of Dr. Schröfel and Dr. Posival (Klinik für Herzchirurgie, Karlsruhe), Dr. Schymik and Prof. Schmitt (Kardiologie Städtisches Klinikum, Karlsruhe), and Dr. Würth and Prof. Gonska (Kardiologie St. Vincentius Kliniken Karlsruhe). It was obvious that the transcatheter procedure offers important advantages over open heart surgery, particularly in older and critically ill patients.

Following a short training course in Leipzig, our team began their own TAVI program in 2008, using a mobile C-arm X-ray system in a conventional operating room. Experts from Leipzig, Prof Sack and Prof Walther, provided assistance and support during the initial phase. During the first nine months, 125 patients were treated, approximately evenly divided between the transfemoral and transapical approach. The results were very encouraging, and the procedure was easy to integrate in the clinical routine.

However, performing TAVI procedures in a conventional operating room is essentially a compromise. The mobile X-ray system cannot provide the high-quality imaging needed to visualize thin guide wires, quantify small vessel diameters, and ensure accurate placement of intravascular devices. Moreover, the limited heat capacity becomes a significant problem in lengthy procedures. Transcatheter implantation of an aortic valve, in particular, demands high-quality imaging and precise navigation,
to ensure accurate positioning. An alternative could be to perform the procedures in a cath lab, but this would not meet all of the requirements for surgery, particularly with respect to sterility.

For this reason, the clinic opted for a “hybrid” operating room.

The hybrid operating room

A hybrid operating room (hybrid OR) is a specialized operating room with a fixed high-end imaging system, enabling interventional techniques and open surgery to be performed in the same location. The hybrid OR needs to be larger than a standard operating room, to allow for the imaging equipment and also to accommodate the multidisciplinary team, including the anesthesiologist, cardiac surgeon, interventional cardiologist, nurses, technicians, etc. [1].

Planning and construction of the hybrid OR demands specialized architectural expertise. The room must meet all the requirements of an operating room, including maintenance of asepsis and laminar airflow, but must also meet the requirements of a radiology room, including lead shielding (2-3 mm) and reinforcement of the ceiling or floor to take the weight of the X-ray system (approx. 650 – 1800 kg).

In our case we were fortunate enough to be able to create an entirely new room for the hybrid OR. This room has an area of 70 m². Together with the technical room, washroom and control room the whole suite has an area of 110 m² (Figures 1, 2).

The hybrid OR was planned and developed in close collaboration with Philips Healthcare, and was brought into use in February 2009. To date, some 500 patients have been treated in the room.

A significant advantage of the hybrid OR is that all technologies for treating patients either surgically or interventionaly are available in the same room. If any complications arise, they can be treated immediately and successfully without needing transport of the patient to a different department. Although the incidence of complications may be small it is good to have all equipment available, so that if a problem occurs during a procedure, it is possible to switch to open surgery immediately without delay. The integrated Alphamaquet operating table allows the room to be used as a normal operating room, with the imaging system parked well out of the way.

Developed in parallel with the hybrid operating room, Philips introduced the HeartNavigator. This is a software solution for routine use, significantly increasing the range of indications. It provides greater accuracy and safety, resulting in faster and easier planning of TAVI procedures. The HeartNavigator is still under development, as part of the close collaboration between Philips and our clinic, but it has already been evaluated in over a hundred patients, where it has proved its value in clinical practice. In fact, our present routine would be unthinkable without it.
Because it provides accurate measurements, the HeartNavigator provides an objective standard for planning and performing the procedure, rather than relying on the subjective judgment of the operator. It helps in the selection of the appropriate size and type of valve, and ensures accurate positioning.

**Hybrid team**
Working in the hybrid operating room requires an interdisciplinary team comprising cardiology, heart surgery, anesthesiology, and ancillary staff including a cardiac technician who operates the HeartNavigator system and the heart/lung machine. It is important to have a dedicated team who are used to working closely together. This ensures the fast reactions needed for efficient treatment. In fact, we say that the hybrid operating room requires a hybrid team.

**Sterility**
The hybrid OR needs to meet the highest standards of sterility, including a laminar air flow ceiling. This places certain demands on the imaging system, which has to be installed in such a way that it is easy to clean and does not interfere with the air flow. The hybrid OR fully meets all sterility requirements of an open OR.

**Other applications**
In principle, our hybrid OR could be used for other applications, but at present it is used 100% for transcatheter aortic heart valve implantation (TAVI), although this is sometimes done in combination with other catheter procedures. There is also provision for combined valve implantation/bypass surgery, but there has been no demand to date.

**Legal requirements**
The German healthcare authorities have strict legal requirements for performing interventional heart valve implantation. The surgeons and cardiologists have to have performed a large number of interventions under supervision in order to acquire the necessary experience and expertise.

**The imaging system**
Mobile C-arms may be adequate for depicting larger stents and catheters, but do not provide the image quality and tube capacity needed for complex cardiovascular procedures. For these reasons, experts recommend the use of fixed C-arms [2].

The hybrid OR at the Klinik für Herzchirurgie, Karlsruhe, is equipped with a Philips Allura Xper FD20 imaging system with an integrated Maquet surgical table. This system has a large-area flat panel detector, which not only provides far higher image quality than an image intensifier system, but also eliminates geometric distortion at the periphery of the image field. This means that accurate measurements can be made anywhere in the image. Motorized movements with joystick control and automated positioning put the X-ray system under the user’s direct control, which is faster and more efficient than relying on an assistant operating a mobile system.

The system is ceiling-mounted, with custom-built ceiling rails that keep the running parts out of the operating field, and do not interfere with the laminar airflow. The system can be positioned anywhere around the operating table (Figures 3, 4), allowing free access to the patient for both transfemoral and transapical procedures.

The rails run almost the complete width of the room, and two-thirds of the length, allowing the system to be parked well away from the operating table when not in use. This eliminates a problem encountered with some systems, in particular bulky floor-mounted systems, where the parking position at the head of the table interferes with the anesthesiologist and the anesthesia equipment.

The flexibility of the Allura Xper FD20 system also makes it suitable for other techniques envisaged for the near future, such as the introduction of aortic stent grafts.

For a surgeon, performing interventions under X-ray control represents a major change in working methods. Instead of working directly with one’s hands one has to learn to work by remote control. There are no short cuts: you simply have to learn it if you are going to work in a team with a cardiologist. On the other hand, the Allura Xper FD20 is very user-friendly. It is easy to learn and easy to work with.

**The operating table**
The Allura Xper FD20 is used in conjunction with a full-specification Maquet surgical table. The designers of the room worked closely with Maquet to ensure that the table is fully integrated with the imaging system, including the Philips BodyGuard collision protection system, without compromising the requirements for surgery.

**Lights, monitors, and other devices**
All lights, monitors and other devices are mounted on long, articulated booms, giving maximum freedom of positioning without interfering with the laminar airflow.

**Valve implantation**
Both transapical and transfemoral approaches are used for transcatheter valve implantation (TAVI), depending on the clinical indications and the patient’s anatomy. The transfemoral approach has the advantage...
Critical phases of the procedure is the final positioning of the device prior to deployment. Incorrect positioning may lead to the device being dislodged, or failing to function correctly, which would require correction by open surgery.

Accurate positioning of the device demands correct alignment of the X-ray system with the valve plane, and perpendicular to the device. Even a slight misalignment can cause foreshortening, and may lead to errors in judging the correct location of the device with respect to the valve plane. The optimal view for the device placement should also show the origins of the left and right coronary arteries, without overlap from the coronary sinus, because they must not be occluded by the implanted device.

However, TAVI demands the highest possible image quality and accurate navigation. One of the most critical phases of the procedure is the final positioning of the device prior to deployment. Incorrect positioning may lead to the device being dislodged, or failing to function correctly, which would require correction by open surgery.

TAVI demands the highest possible image quality and accurate navigation.
Due to variations in the individual aortic root anatomy it is sometimes difficult to find the correct view, so that the search process might involve as many as 20 X-ray acquisitions in different views to arrive at the proper angulation and rotation. This not only costs time but also means additional radiation exposure for the patient, physician and other staff. To assist in planning and positioning, a new tool known as the HeartNavigator (Philips Healthcare, Best, the Netherlands) is under development that allows planning of optimal X-ray views before the start of the procedure, and provides live guidance during the procedure.

HeartNavigator

The HeartNavigator system is currently being evaluated in our clinic, but has already been shown to provide a real benefit. It is very easy to find the correct plane showing all three cusps of the aortic valve, and to align the imaging system accordingly. Consequently, the working procedure is much faster and the fluoroscopy times are correspondingly shorter, resulting in less radiation exposure and the use of less contrast agent.

Planning the procedure with the HeartNavigator is almost entirely objective, rather than the conventional subjective judgment we used in the past, so that even less experienced staff can perform safe and accurate planning.

Three years ago, TAVI was still in the realms of investigation and research, but has now become a widely accepted procedure in Europe. HeartNavigator helps to integrate TAVI in the clinical routine. The initial planning takes a little time, but this is more than compensated for by the faster procedure and greater accuracy.

Pre-operative CT angiography data are entered into the system on the day before the planned procedure. The CT data are automatically segmented to identify the aortic root, coronary ostia, the aortic valve, the left ventricle and the valve plane running through the bottom of the three cusps (Figure 5).

The segmentation results can be inspected and corrected if necessary. After segmentation the required X-ray projections are planned by positioning a simulated X-ray view that is based on a 3D rendering of the CT data with the same perspective as that of the X-ray system. Views are automatically locked to be in line with the valve plane. The planned views are then stored for use during the procedure.

A major advantage of the HeartNavigator is the ability for the physician to perform precise measurements.
The manual measurements are greatly facilitated by the automatic detection of the valve plane (Figure 6), which ensures that measurements are performed without foreshortening.

**Planning the procedure**

Four views are displayed showing the segmented CT data from different viewpoints. Point-to-point measurements can be performed in any of the views, and an appropriate valve can be selected from a library of valve types and dimensions (Figure 7).

**Live guidance**

During the procedure, the planned views can be recalled and the X-ray system moves automatically to the planned projection. A 3D rendering of the CT data is displayed with the same perspective as the X-ray system and any rotations of the X-ray system are automatically followed by the CT rendering.

After the views have been selected, the C-arm can be automatically steered to the planned views without needing angiography. The CT data and the live fluoroscopy are registered, and the CT image is overlaid on the live fluoroscopy image (Figure 8). To register the CT data to the X-ray system, two short acquisitions are needed from different angles. The registration can be easily performed by the physician at tableside using a touch screen with a sterile cover.

The fused overlay visualization shows the relation between the device as seen on X-ray with the anatomy as seen on CT. The rendering of the CT data shows only the outline of the aortic root (red line) to avoid interference with the X-ray image.

**Case study**

A 76-year old female patient presented with severe calcified aortic stenosis grade III, leading to valve insufficiency (indicated by echocardiography). Following a previous infarction she had been treated for triple vessel disease by multiple bypass surgery, and had received a biventricular pacemaker implantation for AV-block type II.

At the time of presentation the patient was suffering from hypertension, diabetes IIb, carotid artery stenosis, and slightly limited left-ventricular function (60% ejection fraction).

Discussion by the interdisciplinay heart team concluded that the patient was not a suitable candidate for open surgery due to severe comorbidities, associated with a high surgical risk (Euroscore 34.5). The patient was referred for TAVI and, based on CT screening of the iliac vessels, a transapical approach was selected.

To prepare for the procedure, HeartNavigator
good positioning of the valve with respect to the left coronary ostium but also showed a severe paravalvular leak grade I-II (Figure 12). Balloon post-dilatation resulted in a good result with no significant residual leak (grade 0-I) (Figure 13).

Treatment resulted in marked reduction of valve insufficiency and the patient was without adverse events at two months postoperatively.

Conclusion

Interventional techniques for aortic valve implantation offer important advantages over open heart surgery, particularly in older and critically ill patients who are unsuitable candidates for open surgery. Both transapical and transfemoral approaches may be used, depending on the clinical indications and the patient’s anatomy.

Transcatheter Aortic Valve Implantation (TAVI) has the advantage of being minimally invasive, but demands the highest possible image quality and accurate navigation. These demands are often beyond the capacity of a mobile surgical C-arm system but, on the other hand, a conventional cath lab would not meet all of the requirements for surgery, particularly with respect to sterility.

For this reason, we opted for a “hybrid” operating room, with a fixed high-end imaging system, enabling interventional techniques and open surgery to be performed in the same location. To assist in procedure planning and navigation, a new tool known as the HeartNavigator (Philips Healthcare, Best, the Netherlands) is used that allows planning of optimal X-ray views before the start of the procedure, and provides live guidance during the procedure.
Figure 10. HeartNavigator overlay during balloon deployment. Red outline marks the aortic root derived from the CTA.

Figure 11. HeartNavigator overlay during final positioning of the valve.

Figure 12. Angiography after initial valve deployment. Arrow 1 indicates sufficient distance between offspring of the LCA and the valve device. Arrow 2 paravalvular leak.

Figure 13. Angiography after balloon post-dilatation showing no residual paravalvular leak.

References


Clinical applications

Visualization of stent malapposition in the mid left anterior descending artery using StentBoost

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One of the problems of percutaneous coronary intervention (PCI) is subacute stent thrombosis. Malapposition and underexpansion of the stent are believed to be the major factors causing stent thrombosis [1], but these conditions are not always easily assessable on angiographic images. Although Intra Vascular Ultrasound (IVUS) can be used to give a conclusive answer on the presence of malapposition and underexpansion, it adds additional time and costs to the procedure.

In the following case, the deployment and apposition of the stent were visualized with StentBoost [2,3,4] (Philips Healthcare, Best, the Netherlands). This is an interventional tool designed to enhance the visibility of stents in relation to the surrounding vasculature.

To obtain a StentBoost image, the user acquires a short cine run which is then automatically processed. The first two seconds of the acquisition is without contrast followed with a short contrast injection for about two to three seconds. The software automatically detects the balloon markers of the stent delivery system, which are used to stabilize the images and to correct for motion between them. The stabilized and motion-corrected images are then superimposed to create an enhanced image of the stent. Finally, a subtracted image is generated from the enhanced stent image and the corresponding vessel image.

Case study

Percutaneous coronary intervention was performed in a 60-year-old female patient, diagnosed with a non ST elevation acute coronary syndrome with a complex lesion in the mid left anterior descending (LAD) artery, using a 3.0 x 23 mm Cypher™ stent. The stent was deployed with a pressure of 18 bar for 20 seconds.

After the initial deployment, a StentBoost acquisition was performed (Figure 1), which showed malapposition of the stent (Figures 1b, 1c, 2a). It was decided to post-dilate the stent with a 3.5 x 15 mm Maverick™ balloon inflated to 16 bar for 30 seconds. The result was checked with StentBoost, which showed correct apposition of the stent with the vessel wall (Figures 1d, 2b).

StentBoost acquisition only takes a couple of seconds at normal cine dose and the result is almost instantly available without any user interaction. By providing a stabilized subtracted image of both stent and vessel, the visibility was improved, both of the malapposition and of the calcification that probably caused the poor deployment.

Malapposition and underexpansion of the stent are believed to be the major factors causing stent thrombosis.
References


Figure 1:
StentBoost images after initial stent deployment.
Figure 1a.
Image showing the vessel alone.
Figure 1b, c.
Images of the enhanced stent overlayed with the corresponding vessel showing malaposition (arrow).
Figure 1d.
Enhanced image of the stent showing calcified plaque (arrows).

Figure 2.
Close up of StentBoost images.
Figure 2a.
Image after initial stent deployment showing malaposition (arrow).
Figure 2b.
Image after post dilation showing correct apposition of the stent with the vessel wall.
Clinical applications

Superimposition of pre-treatment CTA and live fluoroscopy for targeting the portal vein in TIPS: a case report

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Transjugular intrahepatic portosystemic shunt (TIPS) has emerged as a minimally invasive alternative to surgery in patients with end-stage liver disease and concomitant severe portal hypertension [1]. To reduce portal pressure in these patients, an intra-hepatic connection is created between the portal vein and the hepatic vein after the advancement of an endovascular needle from the jugular vein. This procedure is normally performed under fluoroscopic control and guided by a 2D wedged venography with the use of carbon dioxide (CO₂) [2], but this does not provide optimal information on the 3D relationship between the hepatic vein and the target point on the portal vein. As a result, several attempts are often needed to access the portal vein. The following case report shows the clinical benefits of CT roadmap technology in guiding portal vein puncture during TIPS.

Diagnosis

The patient is a 44-year-old female, with a history of alcoholism and hepatic cirrhosis, presenting with portal hypertension, significant ascites and recurrent esophageal variceal bleeding.

Treatment

To reduce portal pressure the patient was referred to the Interventional Radiology unit for Transjugular Intrahepatic Portosystemic Shunt (TIPS). The main difficulty of TIPS lies in the intrahepatic catheter puncture from the right hepatic vein to the right portal vein. Furthermore, the long-term success of a TIPS placement depends on the precise measurement of the stent-graft length and the selection of an optimal view angle for its deployment.

Data import

In order to visualize the portal vein and guide the intra-hepatic puncture, we used the Multimodality Roadmap feature of the Philips Allura Xper FD20 system. This technology allows clinicians to synchronize live fluoroscopy with previously acquired MR or CT data and helps in navigating vascular structures that would otherwise be difficult to visualize with intra-operative imaging tools, or would require significantly higher doses of ionizing radiation or contrast agent.

Patients undergoing TIPS are often scanned using a computed tomography angiography (CTA) protocol to assess the extent of complications due to portal hypertension and analyze portosystemic collaterals.

Image registration

Before the start of the procedure, the CTA data were loaded into the Philips Workspot 3D workstation (Figure 1). After positioning a Colapinto needle in the hepatic vein, we acquired a low-dose cone-beam CT data set (XperCT, Philips Healthcare) without contrast injection. Using dedicated software in the Workspot workstation, we registered the CTA and XperCT data to find spatial mapping between 2D and 3D images.

A fused visualization of the real-time X-ray fluoroscopy stream and the 3D CTA data was then displayed to target the portal vein during puncture.

Portal vein puncture

The portal vein was accessed at the first shot and correct matching of CTA and intra-procedural imaging was verified by injecting a short puff of iodinated contrast (Figure 2). The CTA roadmap was further exploited to guide catheterization of the portal vein and balloon expansion of the newly created intra-hepatic connection (Figure 3).
Figure 1. Thick-slab MIP rendering of portal vein enhanced CTA of patient’s abdomen.

Figure 2. Snapshot acquired during portal vein puncture based on live fluoroscopy overlay over CTA. Successful needle puncture from hepatic vein into portal vein (arrow) and correct matching were verified with a puff injection of iodinated contrast (arrowheads).

Figure 3. Balloon dilatation of intra-hepatic shunt. Note discrete notch in the balloon between portal vein and liver (arrow).

Figure 4. Introduction of marking pigtail catheter for stent-graft sizing prior to device deployment.
Stent-graft deployment
In order to obtain an assessment of stent size and length, a calibrated pigtail catheter was then introduced prior to deployment of a Viatorr® stent-graft (Gore) (Figure 4). Our protocol involves the acquisition of a 3D rotational portography (3D-RA) (Figure 5) to select an optimal view angle for stent-graft sizing. Using the dynamic 3D Roadmap function, the same portal 3D-RA can also be used as a roadmap to guide stent-graft deployment (Figure 6).

Discussion
When TIPS is performed with only 2D angiography, multiple punctures are often necessary to access the portal vein. This may lead to higher radiation exposure, more contrast agent, and longer procedure times, with the risk of further harm to the liver tissue.

Several techniques have been proposed to solve the difficulty of intrahepatic catheter puncture from the right hepatic vein to the portal vein. Rose et al. [3, 4] proposed the use of three-dimensional ultrasound (3D US). 3D US provides real-time positional and directional information that may help to detect technical errors and altered anatomy. The authors showed that 3D US could confidently determine if the portal vein entry site was functionally intrahepatic and claimed a significant improvement in needle pass efficiency. However, portal vein access still required an average of four needle passes. In addition, a second clinician was required to manipulate the ultrasound head at a site remote from the interventionalist, and two out of nine patients showed diagnostic uncertainties in the 3D US results.

Piliere et al. [5] and Jomier et al. [6] worked with a new model-to-image registration algorithm, where CT or MR images are registered with two fluoroscopic projection images. Based on image data from seven patients, these studies first showed that liver deformation during TIPS is less than 3 mm during both respiration and needle passage, and that the location of an unseen target point can be predicted to within 3 mm. This suggests that rigid registration between pre-operative and intra-operative images may be enough to provide useful image guidance in clinical practice. The method was then evaluated on three patients for needle guidance and showed promising results. However, the technique relies on the availability of a bi-plane system to acquire two 2D views simultaneously, and the feasibility of the 2D/3D registration is limited to cases with obvious radiopaque structures within the liver (i.e. gallstones). These limitations are overcome when 3D/3D registration (e.g. using intra-operative 3D cone-beam CT) is considered.

Adamus et al. [7] also proposed a method based on two 2D projections, but in this case acquired with a monoplane system at two different time points. The method involves the calculation of a 3D path from two lines drawn by the user on two 2D CO² portograms obtained at projections of 0° and 30° right anterior oblique. This path is overlaid onto the live fluoroscopy in order to guide portal vein puncture. Although the method showed good results in three out of four patients considered in the study, the prototype software only showed a 3D path overlay and did not include background anatomical information, limiting live feedback to the user on any mismatch due to breathing or patient motion. In addition, important structures such as bile ducts are not seen on the 2D CO² portograms [8] and therefore injury may still occur during puncture.

The advantages of using a CT overlay as a roadmap is a more confident navigation during liver puncture. 3D/3D registration using intra-operative cone-beam CT is more accurate than registration with 2D images and provides a better planning and navigation environment.

In conclusion, real-time CT overlay on fluoroscopy is a promising technique and may improve efficiency and confidence during TIPS procedures.
Figure 5. Portal 3D RA used to select best view angle for stent-graft sizing and deployment.

Figure 6. Snapshot acquired during deployment of Viatorr® stent-graft (arrows) using dynamic 3D Roadmap.

References


Clinical applications

Translumbar type II endoleak embolization using real-time needle guidance and fluoroscopy overlay on pre-treatment CTA

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Translumbar embolization is an efficient therapeutical option in the case of sac enlargement in AAA.

Figure 1. The Interventional Suite at Henri Mondor University Hospital.

Translumbar type II endoleaks consist of persistent retrograde perfusion of the aneurysm sac after Endovascular Aneurysm Repair (EVAR) through unoccluded collateral arteries [1]. Translumbar embolization is an efficient therapeutical option in the case of sac enlargement in abdominal aortic aneurysm (AAA) [2]. This technique requires precise puncture of the sac within the endoleak location while avoiding damage to healthy organs and to the endograft.

The choice of image guidance technique can be challenging. Endoleaks are optimally visualized with cross-sectional imaging such as computed tomography (CT) while needle control is better achieved with real-time imaging such as fluoroscopy. Live C-arm fluoroscopy overlay on pre-acquired CT angiography represents the new generation of imaging technology, offering the guiding capabilities of fluoroscopy with the contrast resolution of CTA. When combined with needle guidance software such as XperGuide (Philips Healthcare, Best, the Netherlands) [3], it can provide a clear target during needle advancement and avoid additional injection of iodinated contrast to visualize the endoleak. We report on our experience in the clinical use of this technique in the treatment of type II endoleaks.

Materials and methods

An 81-year-old male was referred to our department for a type II endoleak following EVAR, with a sac enlargement larger than 10 mm. The endoleak was located on the posterior wall and originated from the lumbar arteries. It was clearly visible on CT angiography and its location was difficult to access intra-arterially due to a severe stenosis of both internal iliac arteries.

We decided to plan the intervention with the XperGuide software and verify the feasibility of a translumbar approach by drawing the puncture path on the diagnostic CTA image, because this optimally shows shape and volume of the targeted endoleak (Figure 2a). In general, we recommend the use of delayed phase CTA, although in this specific case we used the arterial phase because it still offered a good depiction of the endoleak and a better spatial resolution in the sagittal and coronal planes, which are used to guide needle puncture.

During intervention, the patient was placed in the prone position. Although needle planning can be performed before intervention, the predetermined optimal path should always be verified after image fusion with an intra-operative low dose cone-beam CT scan (XperCT, Philips Healthcare, the Netherlands) without
contrast agent as organ shift or patient torsion may have occurred between the CT room and the interventional suite. This has the additional advantage of allowing the pre-acquired CTA to be registered with the live fluoroscopy image. Consequently, we could use the CT data as background overlay during fluoroscopy-guided needle puncture, and guide the needle towards the endoleak with greater confidence (Figure 2b).

The relation between the 2D fluoroscopy and the CTA is maintained during C-arm movements (angulations and rotations), table panning, changes in source-image distance, and modifications in image size.

The puncture was performed under local anesthesia through a 20 G needle, and success was confirmed by blood reflux and endoleak visualization after direct injection of 5 cc of contrast agent. Embolization was then performed with Onyx 18 liquid embolic agent (eV3 Neurovascular, Irvine, California, USA) in order to fill the endoleak and possibly get reflux into the collaterals. Technical success was assessed by absence of blood reflux in the needle. The patient was then observed for 24 hours before being discharged.

Results

Translumbar embolization of type II endoleaks under real-time needle guidance with overlay of fluoroscopy on pre-treatment CTA was feasible and technically successful. The total procedure time was 40 minutes and we used a total of 5 cc of iodinated contrast throughout the intervention. This technique allowed for puncturing the endoleak accurately and without damage to the endograft while avoiding bony structures and vital organs during needle advancement.

Accurate needle positioning was further documented by acquiring an XperCT image and fusing it with the pre-acquired CTA (Figure 3a). The distance between final tip position and
target of the planned needle path was 6 mm. A final XperCT image was acquired to document the shape and size of the embolic agent, its position with respect to the endograft, and the complete coverage of the endoleak (Figure 3b). The patient experienced no pain during the intervention.

**Discussion**

Selection of the best image guidance modality for translumbar embolization of type II endoleaks can be challenging. CT-guidance is efficient [4, 5] but may be limited and does not offer real-time control. Fluoroscopy provides real-time guidance but requires multiple incidences [2] and does not show the abdominal organs. Real-time overlay of fluoroscopy and cone-beam CT offers real-time control, and combines an easier access to the patient via fluoroscopy with the volumetric information and contrast resolution of cone-beam CT [6, 7], but requires either intra-arterial or intravenous injection of up to 100 cc of iodinated contrast for direct visualization of the endoleak.

Most patients undergo a CTA examination during diagnostic work-up and the possibility of reusing a pre-acquired CTA data set rather than a new contrast-enhanced cone-beam CT scan makes it possible to avoid a new contrast agent injection (apart from the 5 cc injected into the sac to confirm endoleak puncture) and reduce radiation exposure. We use a low-dose cone-beam CT protocol without contrast agent to acquire the volume necessary for image co-registration.

The reduction of iodinated contrast administration is particularly important in patients with abdominal aortic aneurysms, who represent an older population more prone to renal function impairment.

According to our experience, the registration between CTA and non-contrast XperCT works well and the matching between CT and fluoroscopy is accurate in clinical practice. The patient lies supine for CTA and prone for embolization. This means that some organs move under the influence of gravity. However, the resulting mismatches induced during registration did not significantly influence the procedures, because the bone landmarks, the aorta and the endograft do not move significantly relative to each other from prone to supine. The mismatches essentially involved the anterior abdominal wall and the gut.

In conclusion, our experience shows the potential of image fusion and cone-beam CT needle guidance in translumbar embolization of type II endoleaks. Currently, this is our preferred technique for the percutaneous management of type II endoleaks. We hope that this preliminary experience and the analysis of larger cohort of patients will further support the use of this technique for patients requiring translumbar embolization of type II endoleaks.

**References**


Clinical applications

MR-guided ablative therapy of malignant liver tumors employing the Panorama HFO open MR scanner

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Percutaneous ablative therapy

Primary and secondary malignant hepatic tumors are some of the most common tumors worldwide. Unfortunately, chemotherapy and radiation therapy are ineffective treatment methods. Surgical resection is considered the only potentially curative option, however only a few patients are surgical candidates [1, 2].

Besides locoregional treatments by chemoperfusion or chemoembolization, several percutaneous image guided treatment alternatives have been introduced. These ablation techniques offer the advantage of reduced morbidity and mortality, as well as lower procedural costs when compared with traditional surgical methods. They can also be performed on an outpatient basis, repeated over time, or combined with other anticancer treatments [3, 4].

Substantial tumor kill is achieved by directly applying chemicals such as ethanol or acetic acid, temperature changes using liquid nitrogen or NO₂ for cryosurgical ablation or radiofrequency ablation (RFA), and laser interstitial thermotherapy (LITT) for coagulative necrosis [3, 5]. In addition, local radiation was introduced recently [6-8].

To enable access to the liver tumors, ultrasonography (US) or computed tomography (CT) are most commonly used. However, both methods have their limitations.

US is limited by the need for an acoustic window. CT is limited to single plane imaging and by the fact that both the patient and the staff are exposed to ionizing radiation. Further on, CT is hampered by the limited soft tissue contrast in native fluoroscopic sequences and the inability to perform heavily angulated approaches. Hence magnetic resonance imaging is considered as an attractive alternative for guiding the intervention. It combines excellent soft tissue contrast, achieved without ionizing radiation, and arbitrary slice selection for biopsies in delicate locations.

General working groups have tested closed bore, high-field MRI for image-guided needle placement. However, in these systems, access to the patient is severely limited and needle repositioning has to be performed outside the magnet, with intermittent acquisition of images [9].

Finally, open low-field MRI has been tested for MR fluoroscopy in liver intervention [10-12], but image quality has never been acceptable, hence this kind of intervention was never translated into routine clinical use.

The interventional technique for implantation of the ablative device

In recent years, open MR systems have been introduced with high field strength, such as 1.5 T (employing a short magnet with a wide opening) or 1.0 T, as applied by our own working group. The latter magnet is configured in a doughnut design, using two superconductive coils as part of a yoke to generate a vertical magnetic field, with specific challenges and opportunities [13-15]. This magnet design gives high temporal stability and spatial homogeneity of the magnetic field. Due to the vertical orientation of the magnetic field, solenoid type coils can be used for imaging, allowing good signal-to-noise ratio and signal homogeneity. The patient table can be moved in the lateral direction, allowing positioning of the field of view into the isocenter of the magnet for all anatomies. In this way, off-center imaging in left-right direction can be avoided altogether. A large left-right aperture of 160 cm, and 45 cm in the AP direction, gives sufficient space for the patient and for the interventional radiologist in the direct vicinity of the volume of interest.
images, whereas malignant focal liver lesions do not exhibit T1 shortening. This increases image contrast and thus lesion visibility compared with plain investigations. Peak liver signal intensities are seen 15–20 min after injection followed by a plateau of constant signal intensities for approximately 2 hours. This extended imaging window provides ample time for minimally invasive liver interventions [16-18].

To perform the procedure, the patient is placed in supine position. Depending on the intended percutaneous access route and the position of the target inside the liver, the patient position is rotated up to 30° towards, occasionally, a lateral decubitus position. This maneuver helps optimizing the presumed angle between needle and the vertical B\textsubscript{0} field for improved visibility of the needle, despite susceptibility effects [19].

To determine the position of the target lesion at the beginning of the intervention, breath hold static transversal images of the liver are obtained with a T1-weighted, fat signal-saturated 3D high resolution isotropic volume examination (THRIVE) with a flip angle of 12°, a repetition (TR) of 5.4 ms and an echo time (TE) of 2.6 ms. A voxel size of 1.5 x 2 mm and a slice thickness of 3 mm are chosen.

Sixty-five slices in a breath-hold time of 17 s are sufficient to cover most livers. For interactive dynamic imaging in fluoroscopy mode, a T1 weighted gradient echo sequence (T1-FFE) with a flip angle of 35°; a TR/TE of 11 and 6 ms is used. The voxel size is 2.0 x 2.4 mm and the slice thickness 8 mm. Images are acquired with a rate of 1 image per second. First of all, the skin entry site is determined with the finger pointing method. In case of interfering ribs or interposed pulmonary recessus the entrance point is determined more caudal to the lesion.

The finger tip and the centre of the lesion are used to define an arbitrarily angulated plane showing the entrance point and the lesion in one image.

A second plane is then adjusted perpendicular to the first one in order to follow the pathway of the needle in two orthogonal perspectives (Figure 2). After determining the entrance point with the finger method, the patient is moved outside the magnet, the selected area is sterile draped, local anesthetic is administered and the skin incision is made. Then the patient is moved back into the scanner, the needle is inserted in the incision hole and pushed forward with guidance of the two perpendicular planes.

Interactive software allows switching between viewpoints while imaging continuously.
Disappearance of the needle tip from the imaging plane caused by deviation from the intended path can, in interactive continuous imaging mode, be corrected by alternating between the two imaging planes. In addition, the technician can diligently modify the orientation of the imaging plane according to the needle path.

After final positioning of the needle in the lesion the correct placement can be documented with a repetitive THRIVE sequence perpendicular to the needle pathway using 15 slices, to increase the signal-to-noise ratio in a single breath hold of 4.8 s.

Finally, fat suppressed T2W-TSE sequences (TR/TE 1600 and 110 ms) in axial orientation with a slice thickness of 6 mm and an acquisition time of approximately three minutes can be added to rule out post-interventional hematoma or bilioma.

**Percutaneous tumor ablation using radiofrequency or brachytherapy**

In our institution, the most frequently used ablation methods are brachytherapy and radiofrequency ablation, hence these two methods are described in more detail.

Alternating electric current operating in the radiofrequency range can produce a focal thermal injury in living tissue. Shielded needle electrodes are used to concentrate the energy in the selected tissue. Each device consists of a needle, an electrical generator and a ground pad. The generator outputs an ablation signal with a fundamental frequency of 460 kHz +/- 5%. It has to be placed outside the MR scanner room using an extension cable as the construction incorporates ferrous materials. Although the generator is working at a much lower frequency than the MR system, a broad spectrum of harmonics is produced up into the range of tens of MHz. To prevent interaction between the RF generator and the MR scanner, the RF current must be filtered. This can be done with a low-pass filter in a filter box where the Faraday cage shielding the MR scanner room is entered [20, 21].

Using the open MR Panorama system, the probe can be placed accurately in the center of the lesion. RFA is performed by continuous heating under temperature control and the ablation procedure is continued until the mean temperature of all thermal probes is 105 °C. After the RFA cycle we perform the T2-weighted TSE sequence to check whether the thermal ablation is complete, as the treated lesion shows a signal loss on the T2-weighted images [22, 23].

It would be desirable to have the additional use of MR-thermometry in order to determine the exact ablation zone and to monitor the heating more precisely. An online tool using the Proton Resonance Frequency (PRF) method with suppression of artifacts from respiratory movement is under development.

Tumors ideal for RFA are smaller than 3 cm in diameter, completely surrounded by hepatic parenchyma, 1 cm or deeper within the liver capsule, and at least 2 cm away from large hepatic or portal veins. Subcapsular liver tumors can be ablated, but their treatment is usually associated with greater procedural and postprocedural pain. Tumors adjacent to large blood vessels are more difficult to ablate completely because the blood flow in the vessels cools the adjacent tumor, thus limiting the extent of the ablation. A single ablation takes 8–20 minutes, hence the treatment is limited to patients with three lesions or less in order to minimize the time for the interventional procedure.

Recently a local radioablative high-dose-rate (HDR) brachytherapy technique in which an iridium-192 source is temporarily inserted through catheters has been presented [8]. The therapeutic effect of this technique is not influenced by the cooling of surrounding large vessels and is not limited by tumor size.

For puncture of the lesion an 18-gauge MR-compatible needle with a length of 150 or 200 mm is used. Positioning of the needle is carried out under real-time image guidance as described above. Exchange of the needle with an angiography sheath is performed using the Seldinger technique, for safety reasons without simultaneous imaging and outside the magnet. Brachytherapy catheters are then positioned in the sheath. Final THRIVE images are transferred to a treatment planning system to determine the
Another study, focusing on MR guided biopsies, demonstrated, with high accuracy, pinpoint punctures even for small lesions [25]. Hence we shifted our indications for MR guided ablation to earlier stages with smaller tumors, below 1 cm. What contributes to the good results is the fact that the technique requires just a basic interventional package and skills common among radiologists who regularly perform percutaneous procedures with ultrasound or CT guidance. No external devices, dedicated monitoring or extra software for calculating coordinates are necessary.

Of course, data are based solely on reports from a single institution. Also, there is ample room for improvement: there are still difficulties in communication and further developments of MR compatible interventional devices are necessary. But we predict that this new technique will be implemented effectively in clinical routine and have great value in oncology therapy.

**Assessment of the role of MR guided tumor ablation using the Panorama HFO**

The MR guidance technique for treatment of non-resectable malignant liver lesions has drawn increasing interest since its introduction in our clinic two years ago. In 2009 almost half of the interventions were shifted to the MR unit and more than 160 patients were treated under MR guidance using the open system.

The recently published study by Ricke et al. [24] demonstrated a technical success rate of 97% and a local control rate at three months of 96%. Superiority of lesion detection compared to plain CT imaging was unmistakeable.

What contributes to the good results is the fact that the technique requires just a basic interventional package and skills common among radiologists who regularly perform percutaneous procedures with ultrasound or CT guidance. No external devices, dedicated monitoring or extra software for calculating coordinates are necessary.

Of course, data are based solely on reports from a single institution. Also, there is ample room for improvement: there are still difficulties in communication and further developments of MR compatible interventional devices are necessary. But we predict that this new technique will be implemented effectively in clinical routine and have great value in oncology therapy.

### Table 1: Parameters for diagnostic and fluoroscopic dynamic imaging of the liver

<table>
<thead>
<tr>
<th>sequence</th>
<th>TR (ms)</th>
<th>TE (mm)</th>
<th>Flip</th>
<th>Voxel (cm)</th>
<th>SD (ms)</th>
<th>FOV (mm)</th>
<th>time (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>THRIVE</td>
<td>5.4</td>
<td>2.6</td>
<td>12°</td>
<td>1.5 x 2</td>
<td>3</td>
<td>30 x 30</td>
<td>161</td>
</tr>
<tr>
<td>T1 FFE</td>
<td>11</td>
<td>6</td>
<td>35°</td>
<td>2.0 x 2.4</td>
<td>8</td>
<td>30 x 30</td>
<td>102</td>
</tr>
<tr>
<td>T2 TSE fs</td>
<td>1600</td>
<td>110</td>
<td>90°</td>
<td>1.2 x 1.3</td>
<td>6</td>
<td>30 x 30</td>
<td>180</td>
</tr>
</tbody>
</table>

TR = repetition time  
TE = echo time  
SD = slice thickness  
FOV = field of view  
THRIVE = fat saturated 3D high resolution isotropic volume examination  
FFE = fast field echo imaging  
TSE = turbo spin-echo  
fs = fat saturation

1) acquisition time for 3D whole liver scan in breath hold  
2) acquisition time for 1 image/slice (frame rate)
References


Clinical applications

**Perioperative management of obstructive sleep apnea patients**

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Obstructive sleep apnea (OSA) is one of the most common medical conditions identified in the last 50 years. It is caused by repetitive, partial or complete obstruction of the upper airway and is characterized by episodes of cessation of breathing during sleep. The incidence of OSA is quite varied depending on sex, age, and the criteria of diagnosis.

OSA affects 2 – 26% of the general population [1]. The perioperative management of patients with OSA begins with preoperative identification, after which plans are made to tailor specific intraoperative and postoperative care. The STOP or STOP Bang questionnaires are useful screening tests for OSA [2, 3]. Identification of patients at high risk may help to optimize the preoperative status and to define the goals for perioperative therapy.

In this review article, we present functional algorithms for the perioperative management of patients with OSA based on the present clinical evidence, and a collation of expert knowledge and practices. These recommendations may be useful for the healthcare team, i.e. primary care physicians, surgeons and anesthesiologists, in decision-making for managing patients with OSA in the perioperative period.

**OSA and postoperative complications**

In the general population, OSA is known as an independent risk factor for increased mortality and morbidity [4, 5]. The presence of OSA is known to increase the occurrence of comorbid conditions and postoperative complications [1, 6].

In a recent retrospective study of elective non-cardiac procedures, the occurrence of postoperative complications was observed in 44% of patients with OSA versus 28% in patients with no OSA[1]. The most commonly observed complication was oxygen desaturation (17% in patients with OSA versus 8% with no OSA). Conditional logistic regression revealed that OSA and preexisting stroke had a hazard ratio of 2 (1.25-3.19) for the occurrence of postoperative complications [1].

An increased risk of postoperative complications was also observed in OSA patients undergoing upper airway, joint arthroplasties and cardiac procedures [7-10]. In another study, Chung and coworkers observed that the patients who had apnea-hypopnea index (AHI) > 5 on preoperative polysomnography had a higher incidence of postoperative complications [3]. Interestingly, it was observed that OSA patients undergoing surgery had higher AHI and oxygen-desaturation index scores on the third postoperative night compared to the first postoperative night or preoperatively [11]. The significance and implications of this had not been explored.

**Diagnosis of OSA**

The clinical symptoms of OSA can be classified into diurnal and nocturnal symptoms (Table 1). There are various risk factors that predispose to the occurrence of OSA. The diagnosis of OSA is established by an overnight sleep study, polysomnography, which is considered to be the gold standard. However, polysomnography may not be ideal as it is expensive and requires trained personnel. This is further complicated by the long waiting lists at the sleep clinics. Thus it is important for the healthcare professional to have a useful screening tool that may help in the diagnosis and management of OSA. With the increasing number of morbidly obese patients, it is imperative that OSA should be evaluated and treated to minimize the occurrence of postoperative complications.

**Screening for OSA prior to surgery**

It is estimated that 82% of men and 92% of women with moderate-to-severe sleep apnea have not been diagnosed. A substantial proportion of these patients present for surgery and may have an increased risk of perioperative complications.
risk of OSA [13]. Although validated in primary care settings, the Berlin Questionnaire is a complicated scoring system with a large number of questions.

The American Society of Anesthesiologists taskforce on OSA developed a tool in 2006 to help assist anesthesiologists in identifying patients with OSA. It comprises a 14-item checklist categorized into physical characteristics, history of airway obstruction during sleep, and complaints of somnolence [14]. We were able to demonstrate that the sensitivity of the American Society of Anesthesiologists checklist was 79% at AHI of > 15 and 87% at AHI > 30 [3].

A significant step forward in the screening of patients for OSA was the development of a more concise and easy-to-use bedside screening tool abbreviated as the STOP Questionnaire (S: Snore loudly, T: daytime Tiredness, O: Observed to stop breathing during sleep, P: high blood Pressure) (Table 2a). The STOP Questionnaire has been validated in surgical patients at preoperative clinics. The sensitivity of the STOP questionnaire with AHI > 15 and > 30 as cut-offs were 74% and 80% respectively. The specificity at similar AHI levels was 53% and 49% respectively [2].

When combined with body mass index (BMI), age, neck circumference, and gender, the STOP Questionnaire had a high sensitivity, especially for patients with moderate to severe OSA. This combined version is commonly referred to as the STOP-Bang Questionnaire (B: BMI > 35kg/m2, A: Age > 50 years, N: Neck circumference > 40cm, G: male Gender) (Table 2b). The use of the STOP-Bang Questionnaire improved the sensitivity to 93%, and 100% at AHI cut-offs of >15 and >30 respectively, making it an ideal screening tool with a high sensitivity level. The specificity of the STOP-Bang Questionnaire at similar AHI levels was 43% and 37% respectively.

In the preoperative clinic, the STOP Questionnaire was used to screen 211 patients, 27.5% of whom were classified as being at high risk of OSA [2]. Ramachandran and coworkers analyzed the accuracy of clinical screening methods in the diagnosis of OSA in a meta-analysis [15]. The authors identified 26 different clinical prediction tests with 8 in the form of questionnaires, and 18 algorithms, regression models or neural networks. The STOP-Bang Questionnaire as a preoperative screening test was described as a user-friendly and excellent method to predict severe OSA (AHI >30). The linear scale and the simple acronym make the

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### Diurnal Symptoms
- Daytime sleepiness
- Memory and concentration dysfunction
- Sexual dysfunction
- Gastroesophageal reflux
- Behavioral irritability (irritability, depression, chronic fatigue, delirium)
- Road traffic accident

### Nocturnal symptoms
- Heavy persistent snoring, worse in supine position or after alcohol or sedatives
- Apnea with limb movement, witnessed by bed partner
- Sudden awakening with noisy breathing
- Accidents related to sleepiness
- Nocturnal sweating
- Wake up with dry mouth
- Nocturnal epilepsy
- Nocturia

### Signs
- Edematous soft palate and uvula
- Long soft palate and uvula
- Decreased oropharyngeal dimensions
- Nasal obstruction
- Maxillary hypoplasia
- Retrognathia
- Central adiposity and increased neck circumference
- Hypertension and other cardiovascular consequences

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Table 1. Symptoms and signs of OSA. Adapted from Chung F, et al. [12].

[12]. The screening tools may assist in the diagnosis of OSA when associated with a high index of clinical suspicion.

Snoring is a prime symptom of OSA and is almost 100% sensitive, however it lacks specificity and has a low positive predictive value. The Berlin Questionnaire is a 10-item self-reporting instrument (5 on snoring, 3 on excessive daytime sleepiness, 1 on sleepiness while driving, and 1 inquiring history of hypertension). The details pertaining to age, gender, weight, height, and neck circumference are also recorded. A study screening preoperative patients using the Berlin Questionnaire determined that it had a sensitivity of 69% and a specificity of 56% in surgical patients [3]. The Berlin Questionnaire identified 24% of patients presenting for elective surgery as having a high risk of OSA [13]. Although validated in primary care settings, the Berlin Questionnaire is a complicated scoring system with a large number of questions.
STOP-Bang Questionnaire practical and easy-to-use in the preoperative setting. STOP-Bang is now widely adopted as a screening tool for OSA in primary care settings, preoperative clinics and sleep clinics.

Various other screening modalities including the modified Mallampatti score of 3 or 4, or a waist circumference of more than 40 inches, have been correlated well with an increased AHI [16, 17]. Nocturnal oximetry may be a sensitive and specific tool to detect OSA in surgical patients. Our recent investigation showed that there was a strong correlation between nocturnal oximetry and the AHI from polysomnography [11]. The ODI measured by nocturnal oximetry had a sensitivity of 75-95% and a specificity of 67-97% as compared to AHI. The availability of various screening modalities and an increasing awareness of the occurrence of OSA may lead to more patients being diagnosed with this challenging condition.

Preoperative optimization of patients with known or suspected OSA

It is imperative to recognize that the postoperative complications are mitigated with adequate preoperative preparation and optimization. There are a substantial percentage of patients diagnosed with OSA who are often prescribed continuous positive pressure (CPAP) or bilevel positive airway pressure (BiPAP) devices. The current use of CPAP or BiPAP should be noted with special care on compliance to therapy. Patients should be advised to bring their CPAP devices to the hospital on the day of surgery for postoperative use. A subset of patients may need reassessment preoperatively, especially patients with a known diagnosis of OSA but lost on follow-up, recent exacerbation of OSA symptoms, those who have undergone OSA-related airway surgery, or have been non-compliant with CPAP. Despite limited evidence, experience suggests that restarting preoperative CPAP may be beneficial on non-compliant patients.

The American Society of Anesthesiologists task force on the management of OSA recommends that patients with moderate and severe OSA who have been on CPAP therapy should continue with CPAP in the postoperative period [14]. Precautions should be taken in anticipating the possibility of having a difficult airway. Most patients may be obese and appropriate care should be taken to prevent desaturation. It is useful to employ short-acting anesthetic drugs, less soluble inhalational agents, titrate opioids, and minimize sedation. In patients with anticipated difficult airways, awake extubation may have to be performed preferably in a 30° to 45° head-up position (Table 3).

The routine perioperative care may be adequate for patients with mild OSA. If patients have any co-morbidities, they should be optimized. It is important that anesthesiologists discuss the implications of OSA along with the anesthetic options. Patients may benefit by the modifications of anesthetic technique such as avoidance of general anesthesia in favor of a central neuraxial or a peripheral nerve block.

Management of OSA after surgery

This can be discussed broadly based on whether patients are planned to be managed as an ambulatory surgical patient or as an inpatient.

---

**Table 2a. The STOP questionnaire.**

<table>
<thead>
<tr>
<th>Question</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Snoring: Do you snore loudly (loud enough to be heard through closed doors)?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Tired: Do you often feel tired, fatigued, or sleepy during daytime?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Observed: Has anyone observed you stop breathing during your sleep?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Blood Pressure: Do you have or are you being treated for high blood pressure?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. BMI: BMI more than 35 kg/m2?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Age: Age over 50 years old?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Neck circumference: Neck circumference greater than 40 cm?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Gender: Male?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*High risk of OSA: answering yes to 2 or more questions.*

*Low risk of OSA: answering yes to less than 2 questions.*

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**Table 2b. The STOP-Bang scoring model.**

<table>
<thead>
<tr>
<th>Question</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
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<td></td>
<td></td>
</tr>
<tr>
<td>8. Gender: Male?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*High risk of OSA: answering yes to 3 or more items*

*Low risk of OSA: answering yes to less than 3 items*
Management of patients scheduled for ambulatory surgery
It is presently unclear as to the degree of severity of OSA which is appropriate for patients to be managed as ambulatory surgical patients. Although some centers do perform surgeries on OSA patients as ambulatory surgical patients, evidence is still lacking. Controversy exists as to whether OSA patients should be treated on an ambulatory basis.

Currently the American Society of Anesthesiologists Advisory Guidelines on the perioperative management of patients with obstructive sleep apnea suggests that superficial surgeries or minor orthopedic surgery using local or regional techniques, and lithotripsy, may be done on an ambulatory basis. Due consideration must be given to the type of surgery, associated comorbidities, patient’s age, severity of OSA and the treatment status, anticipated use of postoperative opioids, the type of anesthesia (local vs general vs nerve blocks with or without sedation) and home care [14]. However, preliminary research from our group show that patients with regional anesthesia also have elevated apnea hyponea index and oxygen desaturation. This may imply that OSA patients need to be treated with CPAP [18].

Patients may be discharged to home provided that there is no moderate or severe OSA, no recurrent adverse events in postanesthesia care unit (PACU) such as apnea or desaturation, and no requirement of postoperative opioid. However, it is important to realize that ambulatory surgical facilities managing OSA patients should have transfer arrangements to an inpatient facility, and be equipped to handle the potential problems that may arise while dealing with OSA patients.

Management of patients scheduled for hospital stay
The 2006 American Society of Anesthesiologists guidelines were essentially directed by expert consensus in the absence of good scientific evidence. The guidelines recommend that the postoperative destination should be based on risk factors and a weighted scoring system [14]. The patient’s risk is determined based on the severity and treatment of OSA, the type of surgery and anesthesia, and the need for postoperative opioids. The final total risk score will be the guide for the anticipated requirement for postoperative monitoring of patients [14].

We recommend that the occurrence of recurrent respiratory events in PACU can be used as a reliable indicator to determine whether the known or suspected OSA patient requires continuous postoperative monitoring. The PACU respiratory event is defined as either an apnea for $\geq 10$ s (1 episode needed for yes), bradypnea of $< 8$ breaths per minute (3 episodes needed for yes), pain-sedation mismatch, or desaturations to $< 90\%$ (3 episodes needed for yes) in one 30-minute time block. The event is considered significant when any of one of them occurs in two separate 30-minute time blocks [19]. This will make it possible to identify the majority of OSA patients that require further monitoring. It is highly likely that these patients may require CPAP therapy.

We detected a novel finding that patients with OSA have a more profound increase in AHI on postoperative night 3 and return to preoperative levels on night 7 [20]. Further research on this concept may provide a better insight into the monitoring and management of patients with OSA.

Special considerations for postoperative management

Postoperative analgesia
OSA is one of the major risk factors contributing to the occurrence of respiratory depression [21]. The use of opioids can be a special concern in patients with OSA, as most opiates including morphine, meperidine, hydromorphone, and fentanyl cause a dose-dependent reduction of respiratory drive, respiratory rate, and tidal volume that in turn can lead to hypventilation, hypoxemia, and hypercarbia [22]. Sedatives, anesthetics and analgesics may selectively compromise respiratory function in OSA patients. The general recommendation is that opioids and other drugs with central respiratory and sedating effects should be avoided, if possible. It is imperative to minimize the use of opioids in diagnosed or suspected OSA patients.

The use of morphine in OSA has been deleterious with reports of respiratory depression and even death. Also, there may be genetic factors that may play a role in having differing effects on opioid induced respiratory effects. Postoperative oxygen desaturations were 12 to 14 times more likely to occur in OSA patients receiving oral or parenteral opioids as opposed to those receiving non-opioid analgesic agents [23].

Alternative to opioid therapy
There is an accumulating evidence to suggest that the use of multimodal analgesia may be more beneficial in patients with OSA in minimizing the opioid-related side effects and providing effective analgesia as well. There are a plethora of medications that can be used, such as nonsteroidal anti-inflammatory drugs,
acetaminophen, tramadol, ketamine, gabapentin, pregabalin, clonidine, and dexamethasone. Caution should be advocated while using some of these drugs like gabapentin with the side effect of sedation. Dexmedetomidine has been particularly beneficial because of the opioid-sparing effect and the lack of respiratory depression [24].

The American Society of Anesthesiologists guidelines recommend regional anesthesia to reduce the possibility of negative adverse events associated with systemic opioids. The use of nonsteroidal anti-inflammatory analgesics is strongly recommended [14]. The use of nerve blocks with or without catheters with local anesthetics obviates the need for systemic opioid analgesics. However, caution should be exercised in using neuraxial opioids in patients with OSA as there are reports of postoperative respiratory arrest in a case series of three patients [25]. Patients with OSA may be at an increased risk of perioperative complications with the use of strong opioids even after a regional anesthetic [26].

### Evidence for using perioperative CPAP

CPAP exerts its beneficial effects by acting as a pneumatic splint and prevents the obstruction to airflow during sleep. Nasal CPAP is commonly used and reduces the occurrence of apnea or hypopnea. The use of CPAP alleviates the symptoms of day-time sleepiness, restores the quality of life, improves vigilance, concentration and memory, lessens fatigue, decreases health care usage and reduces road traffic accidents [21].

Evidence surrounding the perioperative use of CPAP is not available. However, considering the low level of invasiveness of the CPAP, a short-time preoperative trial in patients with severe OSA may be worthwhile. The American Society of Anesthesiologists task force recommends that patients continue with their routine CPAP through the perioperative period.

Well-controlled studies demonstrating the beneficial effects of CPAP in the postoperative period are lacking. Limited evidence of a retrospective trial, however, does suggest that postoperative CPAP reduces airway obstruction, reduces major postoperative complications and shortens the hospital stay [21].

There are various questions concerning the use of CPAP that presently remain unanswered, especially regarding the optimum duration or specific surgical procedures. However, logic dictates that clinicians should have a low threshold to use CPAP on patients in the postoperative period. The patients are better advised to get their own CPAP device to the hospital on the day of surgery.

### Conclusion

The combination of anesthesia and undiagnosed OSA can be potentially dangerous and places the patients at an increased risk of perioperative complications and postoperative morbidity. Screening of patients with the STOP-Bang Questionnaire will identify patients at risk of OSA. Combining preoperative screening of OSA and identifying recurrent PACU respiratory events will allow risk stratification of diagnosed or suspected OSA patients for more focused postoperative care. Practical guidelines based on the current best evidence and expert opinion may guide anesthesiologists in the perioperative management of these OSA patients.
References


Clinical applications

The early evolution of nebulizers

M. Sanders  Founder of www.Inhalatorium.com, Dunstable, Bedfordshire, UK.

Inhaled treatments of respiratory diseases have a long history, and these treatment modalities seem to have emerged independently in different cultures. The earliest references to inhalation devices that we have found are from the Ebers papyrus in Egypt (~1554 BC). The inhalation of chromones was practiced in Assyria at an early stage (~650 BC) and somewhat later in Greece, Hippocrates (460-377 BC) described an inhalation apparatus [1]. In India the Ayurvedic practice of inhaling the smoke of burning stramonium and hemp by pipe, and in China the inhalation of the smoke from burning opium had been developed. In South and Central America natives developed the practice of smoking tobacco and similar plants.

Throughout the evolution of inhalers, drugs available for treatment of respiratory diseases seem to have been the drivers behind the development of new inhalation systems like pipes, straws, vaporizers and atomizers.

In the following text we have picked examples of atomizers and nebulizers to highlight the evolution of the nebulizer from the 1850’s to the 1950’s. Due to the limited space available in a single article we have focused on major developments and inventions, and used these as examples. As both authors collect old inhalers and old published material in this field, the examples are somewhat selective, based on availability in our collections. One of these is available on the web [2].

Atomization of liquids

The technology used for atomization of liquids – that is the reduction of the liquid into a fine spray – in the early atomizers was based on the Bernoulli principle described by the Dutch-Swiss mathematician D. Bernoulli in 1738, in his work Hydrodynamica [3]. The theorem stated that when a liquid or a gas is forced through a tube with a constriction, the speed of the liquid or gas is greatest at the constriction and the pressure on the sides of the tube is least at that point. The total energy, which is the sum of kinetic energy of flow and pressure energy, is constant in the tube. The Italian physicist G.B. Venturi used this principle some decades later to provide suction by forcing water through a constriction [3]. The same principle was later applied to air jet streams providing the basis for the design of air jet atomizers and nebulizers (Figure 1).

An early example of the Venturi principle is the atomizer developed by the German physician Bergson in 1862. The design was known as the “Bergson tubes” and was embodied in a device he called the “Hydrokonium” (Figure 2). It consisted of two tubes that interfaced at right angles, with one tube taking a feed from a reservoir of liquid drug while the other had a jet of air passed through it. The air jet was generated...
the Bergson tubes with a double rubber squeeze-bulb arrangement was further improved and popularized by a number of inventors. Atomizer designs based on the Siegle atomizer were popular throughout the nineteenth century in Europe, USA and Japan.

Bergson’s approach was further improved by the German physician E. Siegle who applied for a patent in 1864 for a Steam Spray Producer (Figure 3). Instead of using a squeeze-bulb arrangement the jet was created using steam from a small boiler [5]. The atomizer design based on the Bergson tubes with a double rubber squeeze-bulb arrangement was further improved and popularized by a number of inventors. Atomizer designs based on the Siegle atomizer were popular throughout the nineteenth century in Europe, USA and Japan.

The evolution of the modern nebulizer developed for aerosolization of liquids can be traced through...
available published sources to the mid-nineteenth century and the evolution of the atomizers. The early nebulizers were often referred to as “apparatus for the pulverization of liquids” and were in essence atomizers. In the literature the terms “nebulizer” and “atomizer” seem to have been used synonymously during the nineteenth century. In the Oxford English Dictionary the term “nebulizer” was included in 1872, and both terms have the same definition and are attributed to the late nineteenth century [6]. We agree with May in his definition of a nebulizer as a “baffled spray cloud-producing device” [6]. The early atomizers – for example perfume atomizers - lacked a baffle system which would have created an aerosol with small droplets (<5 µm in diameter), and therefore a respirable aerosol.

**From atomizers to nebulizers**

An early example of the use of a baffle to create aerosol was described by the American physician G. Evans (1891) who claimed that “the first direct attempt to convert liquids into spray, however, was made in 1849 by Auphan, at Euzet-les-Bains in France, who forcibly projected a fine stream of mineral water against the wall of a small room, filling the space with mist or spray, which he caused his patients to inhale” [7].

Auphan’s ideas were further developed by another French physician, J. Sales-Girons, who developed a series of portable inhalation devices that applied the same principles to achieve atomization (Figure 4). He presented his device – a reservoir for the medication solution, an air pump, a small jet nozzle and an impaction plate – at the Paris Academy of Medicine in 1858 [8]. The pump forced the liquid through the nozzle where it was atomized against the plate. The Academy considered whether the fine spray was capable of reaching the bronchial tubes and, after due deliberation, they confirmed that it would and A. Trousseau stated that “Sales-Girons has rendered a great service to the world at large by his invention of the treatment by pulverization.” The nebulizer went through several iterations but was manufactured and marketed [8].

Somewhat later, descriptions and drawings of nebulizers designed with baffles were presented in the books by the German physician L. Waldenburg (1862), the American physician S. Solis-Cohen (1867), and the French physician A.A.M. Moeller (1882) [9-11]. Common for these early nebulizers was the use of compressed air to exert pressure on the liquid, and the liquid spray was directed against a tube-shaped surface (baffle) to create a respirable aerosol. The compressed air was usually created by a manually operated pump. In his book Moeller presents a nebulizer with an early tube shaped baffle designed by his colleague Dr Lewin (Figure 5). The nebulizer developed by Solis-Cohen incorporated a gravity-fed adaptation to the Bergson tubes. The use of baffles was discussed in detail in his book [10].

By 1884 G. Evans, having also recognized the problem of large droplets produced with the Bergson tube design, set about inventing a device to overcome this. His work, published in 1891, showed a more sophisticated arrangement that prevented larger droplets being emitted [7].

An important landmark in the 1860’s was the inclusion of inhalants. This was described for the first time in 1864 in the American “Medical Formulary” and in 1867 in the British Pharmacopoeia. Five inhalants were listed; vapor acidi hydrocyanici (vapor of hydrocyanic acid), vapor chlori (vapor of chlorine), vapor coniae (vapor of hemlock), vapor creasoti (vapor of creosote), and vapor iodi (vapor of iodine). This reflected the rising importance and popularity of inhaled drugs and stimulated a vast number of inventive ideas by both physicians and medical device manufacturers, which thrived in an unregulated market (Figure 6).

The late 19th century was a period when the availability of new raw materials such as hard rubber created many possibilities for the development of new nebulizers. Advertising became a means of marketing the new nebulizers, and numerous unrestricted claims were made as
to the curative properties of various inhaled drugs. The world was also changing for the physician, as scientists and engineers were moving towards the forefront of the development of inhaled drug delivery and pharmaceutical companies were beginning to emerge.

**Jet nebulizer with handbulb, compressor or oxygen**

In the early 20th century the clinical effects of adrenalin (epinephrine) in asthma were identified and documented. D.M. Kaplan and J.J.M. Bullowa, working in New York, identified the value of hypodermic administration of adrenalin in asthma in 1903-04, and this became the foundation of what we can consider modern drug inhalation therapy [12].

In 1910 A. Ephraim published a paper in the Berliner Klinische Wochenschrift on the treatment of asthma attacks with adrenalin, either instilled or sprayed through a bronchoscope [13]. L Pick, in 1911, reported successful nebulization of adrenalin in two patients and it rapidly became standard therapy, administered by a hand-held nebulizer [14]. The same year G. Zuelzer published a paper in the Berliner Klinische Wochenschrift on the delivery of adrenalin by the Spiess’s drug nebulizer, made by Dräger in Lübeck, Germany, with either compressed air or oxygen [15]. The availability of domestic electrical supplies permitted machines to be developed utilizing this form of power, and the Pneumostat is an example of an early compressor (Figure 7). In the early days of compressors it was not unusual for the pharmacist to own the device and patients would come to pharmacy to inhale the contents of their ampoule in the shop. In 1926 C. Sachse described the Spiess-Dräger nebulizer in more detail, claiming that both drug output and droplet size could be regulated [16].

The administration of adrenalin by nebulization apparently spread over Europe fairly rapidly. In 1929 P.W.L. Camps wrote in the Guy’s Hospital Reports that “About three years ago I had three obstinate cases of asthma, who, tired of my

![Image of a nebulizer](www.inhalatorium.com)

**Figure 7. An advertisement for the Pneumostat electrical compressor-nebulizer-facemask combination from 1935.**

**Figure 8. The DeVilbiss No. 40 jet nebulizer.** Note the design of the body of the nebulizer which acts as a baffle forcing larger droplets to deposit on the glass wall opposite the mouthpiece.
They designed a glass nebulizer that created droplets smaller than 1 micrometer (µm) and used oxygen at a flow of 8 L min⁻¹. An extra orifice was designed in the nebulizer to facilitate air entrainment. They mention that even small nebulizers like the Vaponephrin or the DeVilbiss No. 40 (Figure 8) could be used as the droplet size was less than 1 µm.

H.A. Abramson published a paper in Annals of Allergy in 1946 on “Principles and Practice of Aerosol Therapy of the Lungs and Bronchi” [23]. He defines the terms “aerosol”, “atomization” and “nebulization” and argues that “The word 'nebulization' should be restricted to the special type of atomization in which the large particles are removed by the introduction of a suitable baffle into the construction of the atomizer”.

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In 1946, A.L. Barach et al. published their paper on treatment with nebulized penicillin [22].

G.F. Harsh published his paper on “A comparative study of commercial nebulizers” in 1941. He compared the performance of various nebulizers and found that the DeVilbiss No. 40 provided the most uniform delivery of medication.

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The modern nebulizers

The development of new nebulizers and other inhalers after the 1950’s is relatively well covered in most textbooks in the field. The characterization of inhalers including nebulizers have become a science with relatively clear demands for respirable aerosols, and in some cases defined delivered doses of aerosol to the patient. The jet nebulizer has been developed from the compressor-driven constant output jet nebulizer into breath-enhanced jet nebulizers and further into small portable jet nebulizers. The early ultrasonic nebulizer has been developed into small portable ultrasonic nebulizers, and further into portable mesh-based ultrasonic nebulizers.

The recent introduction of an “intelligent” mesh based nebulizer - the I-neb Adaptive Aerosol Delivery (AAD) System (Philips Respironics) - represents the latest patient-focused nebulizer technology (Figure 10). It has been designed to adapt to the patient’s breathing pattern in order to minimize the potential for errors and waste of drug during the inhalation of drugs [25]. The I-neb AAD System is described in another article in this issue of Medicamundi [26].

Annals of Allergy in 1948 [24]. Fifteen different jet nebulizers were compared regarding output per squeeze with the rubber bulb, the capacity of the bulb, droplet size and nebulization time. The amount of solution delivered by one compression was highly variable, ranging from 0.4 mg to 13.0 mg. For the DeVilbiss No. 40 nebulizer the figure was 1.6 mg. The nebulization time for the delivery of 1 mL ranged from 31 s to 450 s with compressed air. The droplet size was determined using an ocular micrometer in a microscope. The “median” droplet size ranged from 8 to 29 µm whereas the “largest” droplets ranged from 40 to 308 µm.

The AsthmaNefrin nebulizer had the smallest droplet size at 8 µm (Figure 9). It is interesting that the early testing of droplet or particle size could range from 0.3 to 308 µm in two different papers published in the same journal two years apart. Abramson does not give any additional information on the technique used for the particle size measurements reported in his paper, so the reason for the difference remains unknown.
References


Inhalation of aerosolized drugs is the primary route of administration in the treatment of most respiratory disorders. By delivering the inhaled drug to the lungs the onset of action is fast, and the systemic side-effects less than with other treatment modalities. Today three different inhalation systems are commonly used: nebulizers, pressurized metered dose inhalers (pMDIs) with or without valved holding chambers and dry powder inhalers (DPIs). Nebulizers may be used to administer large doses of drugs, drug mixtures and most importantly drugs not currently available for use in pMDIs or DPIs. For these reasons conventional constant output nebulizers are often used for the delivery of solutions or suspensions of antibiotics, anticholinergics, bronchodilators, corticosteroids, mucolytics and other drugs.

Conventional nebulizers

When using conventional constant output nebulizers as aerosol systems, the inhaled amount of drug is primarily a function of the patient’s breathing pattern, and in particular the duty cycle, i.e., inspiratory time / sum of inspiratory and expiratory times. The duty cycle of a single breath is usually given as TI / TTOT (TI = inspiratory time; TTOT = sum of inspiratory and expiratory times). The TI/TTOT ratio has been shown to be highly variable and range from 0.25 to 0.55 [1]. For example, with a TI = 1 s and a TTOT = 3 s, the respiratory frequency would be 20 breaths/minute and the total inspiratory time per minute would be 20 s. The patient would in this case inhale aerosol during 20 s per each minute of nebulization (~33%) and the rest of the nebulizer’s drug output (~67%) would be lost to the environment. Many new drugs have a narrow therapeutic window, are rather expensive and are not available as pMDIs or DPIs. The delivery of these drugs requires an inhalation device which delivers a precise amount of aerosol with minimal waste and caregiver exposure. The conventional constant output nebulizer can obviously not meet these demands.

The AAD technology

The Adaptive Aerosol Delivery (AAD) technology was developed in the nineties as a basis for the development of nebulizers designed to minimize the variability of the inhaled amount of aerosol, and the waste of aerosol to the environment [2-3]. The aim was to create a dosimetric nebulizer with precise dose delivery that adapted to the patient’s variable breathing patterns. The AAD System nebulizers were therefore designed to analyze the breathing patterns of the individual patient and to time the pulse of aerosol into 50% of each inspiration based on this analysis. The analysis of the breathing patterns continues throughout the treatment, and the AAD System nebulizer continually adapts the pulse of aerosol to changes in the breathing pattern.

The first AAD System nebulizer designed based on the AAD technology was the HaloLite AAD System developed in cooperation with Astra (AstraZeneca, Lund, Sweden) and launched in 1997 [4]. The second was the Prodose AAD System developed in cooperation with Schering AG (Bayer Schering Pharma AG, Berlin, Germany) and launched in 2002 [4]. The basic atomization technology in these AAD Systems was based on jet nebulizer technology. Results of both in-vitro and clinical studies suggested that the HaloLite and Prodose AAD System nebulizers could deliver precise and reproducible doses of aerosol, and that the AAD System nebulizers were superior to conventional jet nebulizers in terms of lung deposition, elimination of waste of aerosol to the environment and patient adherence to treatment [4].

The I-neb AAD System

The 3rd generation AAD System nebulizer – the I-neb AAD System (Figure 1) - is a portable, small (150 x 65 x 45 mm, h x w x d), lightweight (210 g), and virtually silent mesh nebulizer [5]. The main parts are the body (battery charger not shown), the medication chamber assembly with the mesh and the drug guide, and the
subsequent breath. A pressure sensor and a flexible valve are used to monitor the patient’s inspiratory flow pattern. Depending on variations in the patient’s breathing pattern the pulse time is continuously monitored and adjusted by the AAD algorithm.

The aim of the AAD TIM algorithm is to provide the patient with an optimal target time for each slow and deep inhalation and thereby reduce the nebulization time. The TIM mouthpiece has been designed with an inhalation valve to restrict the inspiratory flow to a slow and deep inspiration at ~15 L/min [6]. The initial inhalation target time is set at 3 s - equivalent to an inhaled volume of ~0.75 L – and when that inhalation target time has been reached, a vibrator signals the end of the inhalation period.

Built into the body are the electronics, the LCD screen, the piezo element connected to the horn, the pressure sensor, the radio frequency antenna for the AAD Disc (contains information on power level, drug lot number, drug code and expiration data), the infrared transmitter/receiver for I-neb Insight, the battery, buzzer, the vibration device for tactile feedback, and the Patient Logging System (PLS).

The I-neb AAD System algorithms

Algorithms for two different breathing modes have been built into the I-neb AAD System, these are the Tidal Breathing Mode (TBM, Figure 2) and the Target Inhalation Mode algorithms (TIM, Figure 2). The breathing mode is selected by choosing one of two mouthpieces, and the specific mouthpiece is recognized by the electronics of the I-neb AAD System [6]. The TBM mouthpiece is selected for patients breathing tidally during the treatment, which is suitable for most patients from 2 years to adults. The TIM mouthpiece is selected to guide the patient - through feedback - to make a slow and deep inhalation through the mouthpiece, which is suitable for patients from 8 years to adults with moderate to good lung function.

The TBM algorithm continuously records the patient’s breathing pattern, and continuously predicts the length of the patient’s next inhalation. Aerosol is pulsed at the beginning of the next inhalation and ends after 50% of the predicted inhalation time has expired. For the prediction of the length of the next inspiration, the average length of the past three inspirations is used by the AAD algorithm. The I-neb AAD System will therefore only deliver aerosol on the fourth breath of a new treatment, after which the average inspiration time is updated after each subsequent breath. A pressure sensor and a flexible valve are used to monitor the patient’s inspiratory flow pattern. Depending on variations in the patient’s breathing pattern the pulse time is continuously monitored and adjusted by the AAD algorithm.

The aim of the AAD TIM algorithm is to provide the patient with an optimal target time for each slow and deep inhalation and thereby reduce the nebulization time. The TIM mouthpiece has been designed with an inhalation valve to restrict the inspiratory flow to a slow and deep inspiration at ~15 L/min [6]. The initial inhalation target time is set at 3 s - equivalent to an inhaled volume of ~0.75 L – and when that inhalation target time has been reached, a vibrator signals the end of the inhalation period.

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the inspiration. Aerosol is delivered during the first 2 s of the 3 s inhalation target time and is followed by inspiration without aerosol during the remaining 1 s to ensure that the aerosol is inhaled deep into the lung and not exhaled. The goal is to guide the patient to extend the length of the inhalation target time to ~80% of the forced vital capacity (FVC). When the patient has set the optimal inhalation target time, the algorithm will adjust it to meet the patient’s efforts on each inspiration. The achieved length of the inhalation target time is filed in the memory for subsequent treatments at the end of the treatment.

### Aerosol generation and the mesh

The aerosol generation used on the I-neb AAD System is based on a vibrating mesh technology including (Figure 3) an ultrasonic horn driven by a piezo element and a platinum mesh with ~7000 holes with an average diameter of 2 µm [6]. The drug formulation fills the gap between the horn and the mesh by gravity, and is pumped through the mesh by the vibrations of the horn. The droplet size of the aerosol delivered through the mesh has been determined using a solution of salbutamol (albuterol) and an impactor, showing a mass median aerodynamic diameter of 3.9 µm and a fine particle fraction of 67% [7]. This means that the aerosol is well within the respirable range. The piezo element has been designed with a variable power range (1-15) to adapt the output rate to the demands of the drug formulation (viscosity, surface tension, volume to be delivered) and the patients being treated (treatment times).

### Clinical experience

In the European Union the I-neb AAD System is approved as a general purpose nebulizer, and in the USA for the delivery of drugs that are approved for use with the I-neb AAD System. The I-neb AAD System is presently used in Europe for the treatment of patients with cystic fibrosis (CF) to deliver colistimethate sodium (Promixin; Profile Pharma Ltd, UK), an antibiotic for treatment of pseudomonas aeruginosa, and in Europe and the USA for the treatment of pulmonary arterial hypertension to deliver iloprost (Ventavis; Bayer AG/Actelion Pharmaceuticals Ltd), a pulmonary vasodilator [4, 9]. The I-neb AAD System has also been used by pharmaceutical companies in a number of clinical studies of new drugs. Apart from these a number of clinical studies have been run to evaluate the I-neb AAD System in terms of patient acceptability, lung deposition, ease of use and satisfaction.

An evaluation of the acceptability of the TIM breathing maneuver was performed in 20 patients with CF during up to eight simulated nebulizer treatments with 10 min pauses between the...
nebulizations [10]. In the study the patients’ inspiratory times were increased over successive breaths using auditory and tactile (vibratory) feedback built into a prototype I-neb AAD System. Ninety percent felt that the instructions were easy to understand, 65% that the vibratory feedback was pleasant at the end of the first treatment, and 50% found the procedure to be comfortable. Most patients felt that the breathing maneuver was easy to understand (90%) and use (80%), but that the duration of the inspiration was too long (100%) at the end of the final treatment. Ninety percent were able to comply with the breathing maneuver, whereas two patients with FVC values of <1.75 L could not. The mean nebulization time decreased from 288.4 s to 141.6 s during the first and final treatments, respectively. This was the first clinical study of the TIM breathing maneuver and provided early evidence of the acceptability of the maneuver.

A handling study of the I-neb AAD System was performed (42 patients with CF, 12-57 years) to evaluate compliance with the correct use of the I-neb AAD System, and nebulization times [11]. Based on a questionnaire at the end of the study, ease of use with the I-neb AAD System was evaluated as a secondary outcome. For this 3-month study the I-neb AAD System nebulizers were supplied in both TBM and in TIM, with the patients trained to use the TIM maneuver for delivery of all their inhaled drugs. The patients could change to the TBM maneuver if they felt uncomfortable with the TIM maneuver. A total of 10,240 complete treatments were recorded during the study and of these 88% were in TIM. Compliance with the correct use of the I-neb AAD System was 97.6%, whereas the mean treatment time for complete treatments in TIM was 4.20 min, and in TBM 6.83 min. The questionnaires showed that >77% of the patients scored the I-neb AAD System in TIM as either very easy, easy or acceptable to use.

In a randomized, open-label, crossover study, lung deposition following administration of a radiolabelled aerosol from the I-neb AAD System with the TBM and TIM breathing patterns in 12 healthy subjects was evaluated [12]. The mean lung deposition was significantly higher in TIM (73.3%) than in TBM (62.8%) expressed as percent of the ex-mouthpiece dose, and the mean exhaled fractions were low (< 1%) for both breathing patterns. The nebulization time was significantly shorter in TIM (3.0 min) than in TBM (4.7 min). The combination of a high lung deposition, minimal loss of aerosol during exhalation, and short nebulization times makes the I-neb AAD System especially valuable to patients that are on multiple daily nebulization treatments, are using drugs that should not be wasted into the room air, or would benefit from a more efficient delivery system.

We have also compared the I-neb AAD System in TBM with the patients’ previous conventional nebulizers in a multicenter study design including 98 patients with chronic obstructive pulmonary disease (COPD, aged 53–80 years) [13]. The primary outcome variables included ease of use and satisfaction assessed after 3 months of use.
of the I-neb AAD System (assessed at visit 2) and after 3 months of use of the patient’s previous nebulizer system (assessed at visit 1). The evaluation of the ease of use and satisfaction was based on matched questions from pre- and post study questionnaires. Quality of life was assessed at visits 1 and 2 using a validated Chronic Respiratory Questionnaire (CRQ) with dyspnea, emotional function, fatigue, and mastery domains. The patients’ responses favored (P ≤ 0.001) the I-neb AAD System compared with their previous nebulizer system on the ease of use and satisfaction questions. Significant (P ≤ 0.015) improvements in the CRQ dimensions of dyspnea and fatigue were also reported with the I-neb AAD System compared with the patients’ previous nebulizer systems.

Conclusions

The main customers for pulmonary drug delivery are the patients, the clinicians, the healthcare system payers and the investors. New inhalation devices – such as the I-neb AAD System - must therefore provide a sustainable competitive advantage by providing a treatment modality that meets the patients’ and the clinicians’ demands, is cost effective to meet the demands of the payers and extends the commercial life of an existing drug or creates a new marketing opportunity to meet the investors’ demands. The design and the capabilities of the I-neb AAD System have to be continuously expanded to meet these requirements, such as the development of the TIM AAD algorithm to reduce patient treatment times, and the Insight Online home monitoring system which enables the patients to upload data from home via the internet allowing the clinical team to optimize the therapy. The advantages of effective drug delivery and patient monitoring from the I-neb AAD System are now being recognized as the way forward for controlled delivery of inhaled pharmaceuticals and adopted as good practice in clinical guidelines [14]^

References

IntelliSpace Portal: access to data and processing from any location

The IntelliSpace Portal enhances workflow throughout the department with access to data, processing, and collaboration tools from any location. Data from different imaging modalities requires different types of processing. At the same time the amount of information and the complexity of processing are growing.

**Access anywhere**

The IntelliSpace Portal enables the radiologist to focus on analysis and diagnosis. It removes the requirement to go to the “right” location to deal with data and processing, because the processing capabilities and data are available where the radiologist prefers to work.

In a traditional workflow setup for advanced processing, each workstation serves a specific imaging modality. In more richly equipped hospitals, advanced processing may only be available in certain processing rooms. In contrast, the Intellispace Portal is a multimodality server, providing data and processing capabilities for CT, MR and NM exactly where they are needed, so that the radiologist’s preferred location becomes a state-of-the-art workspot.

Thus, both the radiologist and the technical staff can work without being hampered by constraints of location, specific workstation capabilities or data availability, resulting in greater efficiency and smoother workflow.

**Collaborative workflow**

The IntelliSpace Portal enables the radiologist to communicate on advanced results with direct peers or referring physicians. Both the sender and the receiver see the same results on their screens, allowing real-time collaboration on specific cases.

**Dedicated applications**

IntelliSpace Portal not only addresses the core needs in image and data processing, but also offers new dedicated tools for emerging needs in oncology and musculoskeletal imaging.

In the Oncology package, Tumor Tracking gives clear analysis of the progress of lesions over time, to help determine the effectiveness of treatment. Tumor Tracking can be used with a mix of MR, CT and NM data, with fusion or superimposition of images from different modalities. In this respect, the ability of MR to show the soft tissue surrounding the tumor is an important benefit.

Cartilage Assessment is another new clinical package of the IntelliSpace Portal. Cartilage Assessment helps assess cartilage tissue integrity from the MR T2 relaxivity values. The measurement tool in this package partitions the cartilage into equal segments, providing a reproducible manner of relaxivity quantification.

**Simplified administration**

A hospital or MRI center with an IntelliSpace Portal only has a single processing system to maintain. The facility’s own computers are turned into workstations, limiting the number of “boxes” in the hospital. The IntelliSpace Portal is scalable and can serve from small MRI practices up to enterprise-wide deployment.
3D roadmapping in neuroendovascular procedures – an evaluation
H. Okumura, T. Terada, D. Babic, R. Homan, and T. Katsuma

3D roadmapping superimposes 3D rotational angiography onto conventional 2D fluoroscopy images. It shows the spatial relationship of vessels and endovascular materials, and does not require additional image acquisitions for each new viewing angle. The effectiveness of the technique was evaluated by monitoring visualization of the catheter position during various endovascular procedures, including cerebral aneurysm embolization, carotid artery stenting, and tumor embolization. The authors conclude that 3D roadmapping is a useful imaging tool for neuroendovascular treatment. It has the potential to shorten the overall procedure time and to reduce the total volume of the iodinated contrast material used.

Percutaneous transthoracic needle biopsy of pulmonary nodules under XperGuide cone-beam CT guidance
G. Carrafiello, F. Fontana, M. Mangini, F. Piacentino, A. Cani, C. Pellegrino and C. Fugazzola

Image-guided percutaneous transthoracic needle biopsy is an accurate diagnostic technique for the evaluation of pulmonary nodules. However, it is very much dependent on the imaging technique employed.
Cone-Beam CT (CBCT) offers more flexibility than traditional CT or CT fluoroscopy in following the progress of the needle to the target site. It is available in C-arm systems such as the Philips Allura Xper FD20, providing three-dimensional (3D) CT-like images. XperGuide overlays live fluoroscopy on the acquired CBCT images, showing the needle path and target. The authors present their experience with percutaneous transthoracic needle biopsy of pulmonary nodules under XperGuide CBCT guidance.

Transcatheter aortic valve implantation in a hybrid operating room using HeartNavigator
H. Schröfel, N.H. Bakker, and R. van den Boomen

Interventional techniques for aortic valve implantation offer important advantages over open heart surgery, particularly in older and critically ill patients. Transcatheter Aortic Valve Implantation is minimally invasive, but demands the highest possible image quality and accurate navigation, together with the sterility of an operating room. For this reason, the hospital opted for a “hybrid” operating room, with a fixed high-end imaging system, enabling interventional techniques and open surgery to be performed in the same location. A new tool known as the HeartNavigator combines planning of optimal X-ray views before the start of the procedure with live guidance during the procedure.

Visualization of stent malapposition in the mid left anterior descending artery using StentBoost
P.C. Smits and W.F. den Hartog

Malapposition and underexpansion are major factors causing stent thrombosis. In this case report a 60-year-old female underwent percutaneous coronary intervention of the mid left anterior descending artery. The StentBoost image enhancement tool was used to improve the visualization of the stent deployment and apposition. After initial stent deployment, StentBoost showed malapposition of the stent. Post dilation was performed resulting in a correct apposition. StentBoost is an attractive new tool to visualize the deployment and apposition of stents and to improve the visibility of the arterial walls.

Superimposition of pre-treatment CTA and live fluoroscopy for targeting the portal vein in TIPS: a case report
G. Maleux, J. Vaninbroukx, K. Zuurmond, and A. Radaelli

Transjugular intrahepatic portosystemic shunt (TIPS) is a minimally invasive alternative to surgery in patients with end-stage liver disease and concomitant severe portal hypertension. To reduce the portal pressure, an intra-hepatic connection is created between the portal vein and the hepatic vein. This is normally done under fluoroscopic control, but this does not provide optimal information on the 3D relationship between the vessels.
Superimposition of CT angiography (CTA) on the live fluoroscopy image provides clinicians with additional information on the vascular structures, resulting in more accurate targeting of the portal vein and less radiation exposure to patient and staff.
**Translumbar type II endoleak embolization using real-time needle guidance and fluoroscopy overlay on pre-treatment CTA**

*H. Kobeiter, J. Mayer, P. Degrange, J.P. Becquemin, A. Rahmouni, and A.G. Radaelli*

Endoleaks are the most common complication following Endovascular Aneurysm Repair (EVAR). The most frequent are type II endoleaks or collateral perfusion of the sac. Translumbar embolization of type II endoleaks has been shown to be an effective therapy. It involves accurate placement of a needle into the aneurysmal sac and is typically done under CT or fluoroscopy. Real-time overlay of C-arm fluoroscopy on pre-treatment CTA is now available to the interventionist, combining real-time needle control with optimal visibility of the targeted endoleak. The authors report on their experience with this image-guided technique in the management of type II endoleaks.

**MR-guided ablative therapy of malignant liver tumors using the Panorama HFO open MR scanner**

*F. Fischbach, M. Ludewig, K. Jungnickel, and J. Ricke*

Primary and secondary malignant hepatic tumors are some of the most common tumors worldwide. In inoperable cases local ablation techniques like radiofrequency ablation and brachytherapy are preferred for palliative treatment. For guiding the probe or catheter, MR is advantageous because of soft tissue contrast, multiplanar imaging and lack of radiation exposure. The Panorama HFO offers good access to the patient while maintaining reasonable image quality. This article shows that ablation techniques of the liver using the Panorama HFO for guidance are feasible and that the probe can be placed accurately in the center of a lesion.

**The early evolution of nebulizers**

*K. Nikander and M. Sanders*

Inhaled treatments of respiratory diseases have a long history, and seem to have emerged independently in different cultures. Throughout the evolution of inhalers, drugs available for treatment of respiratory diseases seem to have been the drivers behind the development of inhalation systems such as pipes, straws, vaporizers and atomizers. The authors have picked examples of atomizers and nebulizers to highlight the evolution of the nebulizer from the 1850’s to the 1950’s. The nebulizer emerged from the atomizer design by the addition of baffles to break the spray into a respirable aerosol which could be inhaled and deposited in the lungs.

**The I-neb Adaptive Aerosol Delivery (AAD) System**

*J. Denyer and K. Nikander*

Shortcomings of conventional nebulizers in terms of drug delivery have led to the development of “intelligent” nebulizers. Based on the Adaptive Aerosol Delivery technology, the I-neb AAD System has been designed with vibrating mesh technology and a unique metering chamber design for precise drug delivery with minimal waste of aerosol. Two breathing pattern algorithms are built into the device, one for the Tidal Breathing Mode (TBM), and one for slow and deep inhalations, the Target Inhalation Mode (TIM). A key feature of the AAD technology is the patient feedback mechanisms that are provided to guide the patient on delivery performance.

**Perioperative management of Obstructive Sleep Apnea Patients**

*R. Subramanyam and F. Chung*

Obstructive sleep apnea (OSA) is characterized by episodes of cessation of breathing during sleep. The combination of anesthesia and undiagnosed OSA is potentially dangerous, with an increased risk of perioperative complications and postoperative morbidity. Preoperative screening of patients using an appropriate questionnaire can identify patients at risk of OSA, while combining preoperative screening with identification of recurrent post anesthesia respiratory events will allow risk stratification of diagnosed or suspected OSA patients. The authors present functional algorithms for perioperative management of patients with OSA. These may be useful to primary care physicians, surgeons and anesthesiologists in decision making.
Évaluation de la cartographie 3D dans les procédures neuro-endovasculaires
H. Okumura, T. Terada, D. Babic, R. Homan et T. Katsuma

La cartographie 3D superpose l’angiographie rotationnelle 3D à des images fluoroscopiques 2D classiques. Cette technique met en évidence les relations spatiales entre les vaisseaux et les matériaux endovasculaires, et ne nécessite pas d’acquisitions d’images supplémentaires pour chaque nouvel angle de visualisation. L’efficacité de cette technique a été évaluée au moyen d’un contrôle visuel de la position du cathéter au cours de différentes procédures endovasculaires, notamment l’embolisation d’anévrismes cérébraux, l’implantation de stents dans l’artère carotide et l’embolisation de tumeurs.

Les auteurs concluent en affirmant que la cartographie 3D est un outil d’imagerie utile pour les traitements neuro-endovasculaires. Elle a notamment la capacité de raccourcir le temps de procédure global et de réduire le volume total du produit de contraste iodé utilisé.

Biopsie d’aspiration percutanée transthoracique à l’aiguille des nodules pulmonaires guidée sous tomodensitométrie à faisceau conique avec XperGuide
G. Carrafiello, F. Fontana, M. Mangini, F. Piacentino, A. Cani, C. Pellegrino et C. Fugazzola

La biopsie d’aspiration percutanée transthoracique à l’aiguille guidée par imagerie constitue une technique de diagnostic précise pour l’évaluation des nodules pulmonaires. Néanmoins, son efficacité dépend beaucoup de la technique d’imagerie utilisée.

La tomodensitométrie à faisceau conique (CBCT) offre plus de possibilités que la fluoroscopie CT pour suivre la progression de l’aiguille vers le site visé. Elle est disponible dans les systèmes à arceau tels que le Philips Allura Xper FD20, qui fournit des images semblables aux images tomodensitométriques en trois dimensions (3D). XperGuide superpose la fluoroscopie en temps réel sur des images acquises par CBCT, montrant ainsi le chemin de l’aiguille et sa cible.

Les auteurs présentent leur expérience de la biopsie d’aspiration percutanée transthoracique à l’aiguille des nodules pulmonaires guidée par CBCT avec XperGuide.

Implantation d’une valve aortique transcathéter dans un bloc opératoire hybride équipé de HeartNavigator
H. Schröfel, N.H. Bakker et R. van den Boomen

Les techniques d’intervention pour l’implantation de valves aortiques offrent des avantages importants par rapport à la chirurgie à cœur ouvert, notamment chez les patients âgés et gravement malades. L’implantation de valves aortiques transcathéter est peu invasive, mais elle nécessite la meilleure qualité d’image possible et une navigation précise. De plus, elle doit être pratiquée dans un bloc opératoire stérile.

Par conséquent, l’hôpital a opté pour un bloc opératoire “hybride”, doté d’un système d’imagerie haute de gamme fixe, permettant d’utiliser les techniques d’intervention ou de pratiquer une chirurgie ouverte. Un nouvel outil portant le nom de HeartNavigator associe la planification d’incidences radiographiques optimales avant le début de la procédure avec un guidage en temps réel pendant la procédure.

Visualisation de la mal-apposition du stent dans l’artère interventriculaire antérieure à l’aide de StentBoost
P.C. Smits et W.F. den Hartog

La mal-apposition et la sous-expansion constituent des causes majeures de thrombose du stent. Dans la présente observation, une femme de 60 ans a subi une intervention coronaire percutanée de l’artère interventriculaire antérieure. La technique d’amélioration des images StentBoost a été utilisée pour améliorer la visualisation du déploiement du stent et son apposition. Après un déploiement initial du stent, StentBoost a mis en évidence une mal-apposition du stent. Une dilatation a ensuite permis de rectifier l’apposition. StentBoost est un nouvel outil intéressant permettant de visualiser le déploiement et l’apposition des stents et d’améliorer la visibilité des parois artérielles.

Observation de la superposition d’une ATDM de prétraitement avec une fluoroscopie en temps réel pour le ciblage de la veine portale dans un TIPS
G. Maleux, J. Vanisbrouck, K. Zuurmoud et A. Radaelli

Le shunt portosystémique intrahépatique transjugulaire (TIPS) est une alternative peu invasive à la chirurgie chez des patients atteints d’une maladie hépatique au stade terminal et d’hypertension portale grave concomitante. Pour réduire la tension portale, une connexion intrahépatique est créée entre la veine portale et la veine hépatique. Cette procédure a lieu généralement sous contrôle fluoroscopique mais ce dernier ne fournit pas d’images 3D optimales sur la relation entre les vaisseaux.

La superposition de l’angiographie par tomodensitométrie (ATDM) avec l’image fluoroscopique en temps réel fournit aux praticiens des informations supplémentaires sur les structures vasculaires, permettant un ciblage plus précis de la veine portale et une exposition réduite au rayonnement pour le patient et le personnel médical.
Évolution des nébuliseurs depuis leur origine

K. Nikander et M. Sanders

Les traitements des maladies respiratoires par inhalation sont très anciens et semblent s'être développés de façon indépendante dans différentes cultures. Tout au long de l'évolution des inhalateurs, les médicaments mis à disposition pour le traitement des maladies respiratoires semblent avoir entraîné le développement de systèmes d'inhalation comme les pipes, les pailles, les vaporisateurs ou les atomiseurs.

Les auteurs ont sélectionné quelques exemples d'atomiseurs et de nébuliseurs pour mettre en évidence l'évolution du nébuliseur des années 1850 à 1950. Le nébuliseur est un atomiseur auquel on a ajouté des deflecteurs pour transformer la pulvérisation en un aérosol respirable pouvant être inhalé et déposé dans les poumons.

Système I-neb AAD (Adaptive Aerosol Delivery)

J. Denyer et K. Nikander

Les défauts des nébuliseurs classiques en termes d'administration de médicaments ont conduit au développement de nébuliseurs "intelligents". S'appuyant sur la technologie AAD (Adaptive Aerosol Delivery, administration d'aérosol adaptative), le système I-neb AAD a été doté de la technologie de maille vibratoire et d'une chambre de mesure unique pour une administration précise de médicament avec une perte minimale d'aérosol. Par ailleurs, deux algorithmes de types de respiration sont intégrés à l'appareil, l'un pour le mode de respiration courante (TBM ou Tidal Breathing Mode), l'autre pour le mode d'inspiration cible (TIM ou Target Inhalation Mode), qui correspond à des inspirations lentes et profondes. Enfin, l'un des points forts de la technologie AAD réside dans les mécanismes de retour d'information au patient, qui le guident pour l'administration du médicament.

Emboliisation translombaire des endofuites de type II à l'aide du guidage de l'aiguille en temps réel et de la superposition des images fluoroscopiques sur une ATDM de prétraitement

H. Kobeiter, J. Mayer, P. Desgranges, J.P. Becquemin, A. Rahmouni et A.G. Radaelli

Les endofuites constituent la complication la plus classique des réparations endovasculaires des anévrismes. Les plus fréquentes sont les fuites de type II ou la perforation collatérale de la poche.

L'embolisation translombaire des endofuites de type II s'est révélée efficace. Elle implique le positionnement correct d'une aiguille dans la poche anévrismale et elle est généralement effectuée sous tomodensitométrie ou fluoroscopie. La superposition en temps réel de la fluoroscopie avec arceau à l'ATDM de prétraitement est désormais proposée à l'intervenant, associant un contrôle de l’aiguille en temps réel à la visibilité optimale de l’endofuite ciblée.

Les auteurs font part de leur expérience relative à la gestion des endofuites de type II guidée par imagerie.

Traitement ablatif guidé par IRM des tumeurs hépatiques malignes à l’aide du système d’IRM ouverte

Panorama HFO

F. Fischbach, M. Ludewig, K. Jungnickel et J. Ricke

Les tumeurs hépatiques malignes primaires et secondaires font partie des tumeurs les plus répandues dans le monde. Dans les cas inopérables, les techniques d’ablation locale comme l’ablation par radiofréquence et la curiethérapie sont préférées pour les traitements palliatifs. Pour le guidage de la sonde ou du cathéter, l’IRM est avantageuse du fait du contraste des tissus mous, de l’imagerie multiplanaire et de l’absence d’exposition au rayonnement. Le Panorama HFO permet d’accéder facilement au patient tout en conservant une qualité d’image raisonnable. Cet article montre qu’il est possible de réaliser l’ablation du foie avec guidage par Panorama HFO et que la sonde peut être placée de façon précise au centre d’une lésion.

Prie en charge périopératoire des patients atteints d’apnée obstructive du sommeil

R. Subramanyam et F. Chung

Le syndrome d’apnée obstructive du sommeil (SAOS) se caractérise par des épisodes de pauses respiratoires pendant le sommeil. L’association d’une anesthésie et d’un SAOS non diagnostiqué est potentiellement dangereuse, avec un risque accru de complications périopératoires et de morbidité postopératoire.

Le dépistage préopératoire des patients à l’aide d’un questionnaire approprié peut permettre d’identifier les patients présentant un risque de SAOS. Par ailleurs, l’association de ce dépistage préopératoire à l’identification d’événements respiratoires post-anesthésiques récurrents permet de détecter les patients présentant des risques de SAOS diagnostiqué ou suspecté.

Les auteurs présentent des algorithmes fonctionnels pour la gestion périopératoire des patients atteints du SAOS. Ces algorithmes peuvent permettre aux médecins de soins primaires, aux chirurgiens et aux anesthésistes de prendre des décisions plus facilement.
3D-Roadmapping bei neuroendovaskulären Verfahren – eine Bewertung
H. Okumura, T. Terada, D. Babic, R. Homan und T. Katsuma

Mit dem 3D-Roadmapping können herkömmliche 2D-Fluoroskopiebilder mit 3D-Rotationsangiographie überlagert werden. Es zeigt die räumliche Beziehung von Gefäßen und endovaskulären Materialien und erfordert keine zusätzliche Bildfassung für jeden neuen Betrachtungswinkel.

Die Effizienz des Verfahrens wurde durch die Überwachung der Visualisierung der Katheterposition bei verschiedenen endovaskulären Eingriffen bewertet, z.B. Embolisation eines Hirnaneurysmas, Einbringen eines Stents in die Arteria carotis und Embolisation von Tumoren.

Die Autoren kommen zu dem Schluss, dass 3D-Roadmapping ein nützliches Bildgebungswerkzeug für neuroendovaskuläre Verfahren ist. Es kann die Gesamtdauer des Verfahrens verkürzen und das Gesamtvolumen des verwendeten jodhaltigen Kontrastmittels verringern.

Perkutane transthorakale Nadelbiopsie der Lungenknoten unter Kegelstrahl-CT-Führung mit XperGuide
G. Carrafiello, F. Fontana, M. Mangini, F. Piacentino, A. Cani, C. Pellegrino und C. Fugazzola

Bildgeführte perkutane transthorakale Nadelbiopsie ist ein präzises Diagnoseverfahren zur Beurteilung von Lungenknoten. Sie hängt jedoch in starkem Maße vom verwendeten Bildgebungsverfahren ab.

Kegelstrahl-CT (CBCT) bietet beim Verfolgen des Vordringens der Nadel zum Zielpunkt mehr Flexibilität als herkömmliche CT oder CT-Fluoroskopie. Sie ist bei C-Bogen-Systemen verfügbar, z.B. dem Philips Allura Xper FD20, das dreidimensionale CT-ähnliche Bilder liefert. XperGuide überlagert die erfassten CBCT-Bilder mit Live-Fluoroskopie und zeigt dabei den Pfad und das Ziel der Nadel.

Die Autoren berichten über ihre Erfahrungen mit perkutaner transthorakaler Nadelbiopsie von Lungenknoten unter CBCT-Führung mit XperGuide.

Transkatheter-Aortenklappenimplantation in einem Hybrid-Operationssaal mit dem HeartNavigator
H. Schröfel, N.H. Bakker und R. van den Boomen


Visualisierung einer Stent-Malapposition im mittleren Teil des RIVA mit StentBoost
P.C. Smits und W.F. den Hartog


Überlagerung einer vor der Behandlung vorgenommenen CTA und einer Live-Fluoroskopie zum Anzielen der Pfortader bei einem TIPS: ein Fallbericht
G. Maleux, J. Vaninbroukx, K. Zuurmond, und A. Radaelli


Die Überlagerung des Bildes der Live-Fluoroskopie mit CT-Angiographie (CTA) liefert den Ärzten zusätzliche Informationen zu Gefäßstrukturen, was ein genaueres Anzielen der Pfortader und eine geringere Strahlenbelastung für Patient und Mitarbeiter ermöglicht.
Die frühe Entwicklung von Verneblern
K. Nikander und M. Sanders


Vernebler entstanden aus Zerstäubern durch Hinzufügen von Einsätzen, die das Spray in ein lungengängiges Aerosol umwandeln, das inhaliert und in der Lunge abgelagert werden kann.

Das AAD-System I-neb
J. Denyer und K. Nikander


Translumbale Embolisation von Typ-II-Endoleaks mit Echtzeit-Nadelführung und Überlagerung einer vor der Behandlung vorgenommenen CTA mit einer Fluoroskopie
H. Kobeiter, J. Mayer, P. Desgranges, J.P. Becquemin, A. Rahmouni und A.G. Radaelli


Die Autoren berichten über ihre Erfahrungen mit diesem bildgeführten Verfahren bei der Behandlung von Typ-II-Endoleaks.

MR-geführte ablative Therapie bei malignen Lebertumoren mit dem offenen MR-Scanner Panorama HFO
F. Fischbach, M. Ludewig, K. Jungnickel und J. Ricke


Perioperative Behandlung von Patienten mit obstruktiver Schlafapnoe
R. Subramanyam und F. Chung

Obstruktive Schlafapnoe (OSA) ist durch Atemaussetzer während des Schlafs gekennzeichnet. Die Kombination von Narkose und undiagnostizierter OSA ist potenziell gefährlich und bietet ein erhöhtes Risiko für perioperative Komplikationen und postoperative Morbidität.


Die Autoren stellen Funktionsalgorithmen für die perioperative Behandlung von Patienten mit OSA vor. Diese können Hausärzten, Chirurgen und Anästhesisten die Entscheidungsfindung erleichtern.
Evaluación de los mapas tridimensionales en procedimientos neuroendovasculares
H. Okumura, T. Terada, D. Babic, R. Homan y T. Katsuma

Los mapas tridimensionales, que superponen las imágenes obtenidas mediante angiografía rotatoria tridimensional y las imágenes fluoroscópicas bidimensionales, muestran la relaciónespacial entre materiales vasculares y endovasculares. Además, no requieren imágenessuplementarias para cada nuevo ángulo de visualización. Se evaluó la eficacia de esta técnica mediante controlando la posición del catéter en diversos procedimientos endovasculares: embolización de un aneurisma cerebral, colocación de un stent en la arteria carótida y embolización tumoral. Los autores concluyen que los mapas tridimensionales constituyen una herramienta de adquisición de imágenes útil para los tratamientos neuroendovasculares, que puede acortar la duración de la intervención y reducir el volumen total del contraste yodado.

Implantación de válvula aórtica transcatóter en quirófanos híbridos mediante HeartNavigator
H. Schröfel, N.H. Bakker y R. van den Boomen

Las técnicas quirúrgicas de implantación de válvulas aórticas tienen ventajas significativas con respecto a la cirugía a corazón abierto, especialmente en ancianos y pacientes graves. La implantación de válvula aórtica transcatóter es una técnica mínimamente invasiva que, no obstante, requiere la utilización de los medios más sofisticados de adquisición de imágenes y una guía precisa, así como un entorno quirúrgico estéril. Por todo ello, el hospital ha optado por un quirófano ‘híbrido’, provisto de un sistema de adquisición de imágenes de gama alta, en el que se pueden llevar a cabo estas técnicas quirúrgicas así como también cirugía abierta. La nueva herramienta denominada HeartNavigator combina la planificación de las imágenes radiológicas óptimas prequirúrgicas con la guía en tiempo real intraquirúrgica.

Biopsia transtorácica por punción percutánea de nódulos pulmonares guiada por el TAC XperGuide cone-beam
G. Carrafiello, F. Fontana, M. Mangini, F. Piacentino, A. Cani, C. Pellegrino y C. Fugazzola

La biopsia transtorácica por punción percutánea guiada por imágenes es una técnica de diagnóstico precisa para la evaluación de nódulos pulmonares. Sin embargo, depende en gran medida de la técnica de imágenes empleada. El equipo Cone-Beam CT (CBCT) proporciona mayor flexibilidad que la TAC o la fluoroscopia tradicionales en cuanto al seguimiento del avance de la aguja hacia su objetivo. Esta técnica, disponible en sistemas de arco en C, como por ejemplo Philips Allura Xper FD20, proporciona imágenes TAC tridimensionales (3D). El XperGuide superpone las imágenes por fluoroscopia en tiempo real con las imágenes adquiridas mediante CBCT y muestra la ruta que sigue la aguja y el objetivo. Los autores exponen su experiencia con la biopsia percutánea transtorácica de los nódulos pulmonares guiada mediante el XperGuide CBCT.

Visualización de la posición errónea de un stent en la arteria descendente medio-anterior izquierda con StentBoost
P.C. Smits y W.F. den Hartog

Una posición incorrecta y expansión incompleta son las principales causas de la trombosis de stent. En este caso clínico publicado, una mujer de 60 años fue sometida a una intervención coronaria percutánea en la arteria descendente medio-anterior izquierda. Se utilizó la herramienta StentBoost para mejorar la visualización de la implantación y posición del stent. Tras la implantación inicial del stent, StentBoost mostró una posición incorrecta del mismo. Se llevó a cabo una postdilatación hasta lograr una correcta posición. StentBoost constituye una nueva e interesante herramienta de visualización de la implantación y posición de stents que mejora la visión de las paredes arteriales.

Superposición de imágenes obtenidas mediante angiografía por TAC antes del tratamiento y fluoroscopia en tiempo real para la visualización de la vena porta durante el procedimiento de TIPS: un caso clínico
G. Maleux, J. Vaninbroukx, K. Zuurmond y A. Radaelli

El shunt transyugular intrahepático portosistémico (TIPS) es una alternativa, mínimamente invasiva, a la cirugía en pacientes con insuficiencia hepática terminal e hipertensión portal severa concomitante. Para reducir la presión portal, se establece un comunicación intrahepática entre la vena porta y la vena hepática. Habitualmente, esta intervención se efectúa con control fluoroscópico, sin embargo, este método no proporciona unos datos óptimos sobre la relación tridimensional entre los vasos. La superposición de imágenes obtenidas mediante angiografía por TAC sobre las imágenes fluoroscópicas en tiempo real proporciona al personal clínico datos suplementarios sobre las estructuras vasculares, lo que resulta en una localización más precisa de la vena porta y una menor exposición a la radiación tanto del paciente como del personal clínico.
Emboliación translumbar de una endofuga tipo II con guiado de la aguja en tiempo real y superposición de fluoroscopía sobre angiografía con TAC previa al tratamiento
H. Köbieter, J. Mayer, P. Desgranges, J.P. Becquemin, A. Rahmouni y A.G. Radaelli

Las endofugas constituyen la complicación más común tras una reparación endovascular de un aneurisma (EVAR). Las más frecuentes son las endofugas tipo II o perfusión colateral del saco.
En la emboliación translumbar de las endofugas tipo II, que ha demostrado ser una terapia eficaz, se coloca de forma precisa una aguja en el saco aneurismático con la ayuda, habitualmente, de un TAC o fluoroscopía. La superposición en tiempo real de una fluoroscopía con arco en C sobre la angiografía con TAC realizada antes del tratamiento se encuentra ahora a disposición de los especialistas. Esta técnica combina el control en tiempo real de la aguja con una visibilidad óptima de la endofuga a tratar.
Los autores describen su experiencia con esta técnica guiada por imágenes en el tratamiento de endofugas de tipo II.

Terapia de ablación guiada por RM de tumores hepáticos malignos con el equipo abierto Panorama HFO
F. Fischbach, M. Ludewig, K. Jungnickel y J. Riché

Los tumores hepáticos malignos primarios y secundarios son uno de los tumores más comunes en todo el mundo. En casos inoperables, se utilizan como tratamiento paliativo técnicas locales de ablación, como la ablación por radiofrecuencia o la braquiterapia. La resonancia magnética ofrece una serie de ventajas para la guía de la sonda o el catéter gracias al mejor contraste de los tejidos blandos, a las imágenes multiplanares y a la ausencia de exposición a radiaciones. El Panorama HFO proporciona un excelente acceso al paciente manteniendo una calidad de imágenes aceptable. Este artículo demuestra que se pueden llevar a cabo las técnicas de ablación hepática con el sistema Panorama HFO como guía y que se puede colocar la sonda de manera precisa en el centro de la lesión.

Manejo perioperatorio de pacientes con apnea obstructiva del sueño
R. Subramanyam y F. Chung

La apnea obstructiva del sueño se caracteriza por la presencia de episodios de interrupción de la respiración durante el sueño. La combinación de anestesia y de una apnea obstructiva del sueño no diagnosticada puede resultar muy peligrosa, ya que aumenta el riesgo de complicaciones perioperatorias y la morbilidad postoperatoria.
Un cribado preoperatorio de los pacientes mediante el uso de un cuestionario apropiado puede ayudar a identificar a los pacientes con riesgo de sufrir esta dolencia. La combinación de este cribado preoperatorio con la identificación de eventos respiratorios postanestesia recurrentes permitirá la estratificación de los riesgos de los pacientes que padecen apnea obstructiva o que pudieran padecerla. Los autores presentan algoritmos funcionales para el manejo perioperatorio de pacientes con apnea obstructiva del sueño, que pueden resultar útiles a los médicos de atención primaria, los cirujanos y los anestesiólogos a la hora de tomar decisiones.