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Cardiovascular diseases:
• 3D tools in vascular interventions
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• MRI of the neonatal circulation
• Improved SPECT perfusion imaging
• Patient-specific organ models
• Managing obstructive sleep apnea

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Dear Friends,

Most countries nowadays face high and increasing rates of cardiovascular disease, and heart disease is now the #1 worldwide killer. Many forms of cardiovascular disease can be prevented by healthy lifestyle choices, but if the disease is already present early diagnosis and treatment are quite literally, of vital importance.

In this issue of Medicamundi we present a review of state-of-the-art techniques for detection and treatment. One clear trend is the shift from open surgery to minimally invasive endovascular procedures. These offer a significant reduction in morbidity and mortality, but depend on high-quality imaging.

Even with the most advanced imaging devices, navigation of endovascular devices through the complex three-dimensional architecture of the vascular system can be a problem. This issue provides a showcase of the available solutions.

Every imaging modality has its own role to play. In conventional X-ray, significant advances include the use of live 3D tools, high-resolution distortion-free flat detectors, and a single large display to replace the whole array of monitors in the cath lab.

In CT, coronary CT angiography can provide the physician with a three-dimensional data set, giving the optimum view of plaque, stenoses and occlusions for percutaneous intervention.

In cardiac MR imaging, adenosine stress perfusion and infarct imaging can be used to assess the significance of coronary artery disease and the effects of bypass grafts. Recent advances also allow MRI to be used to study the pretransplant circulations in newborns, offering a greater chance of disability-free survival.

Nuclear medicine already plays an important role in the study of myocardial perfusion. Advances in image reconstruction show significant improvements in image quality, with a diagnostic accuracy equal to that of myocardial perfusion. Advances in image reconstruction show significant improvements in image quality, with a diagnostic accuracy equal to that of

The article should proceed smoothly from start to conclusion, without digressions. As it is an article, rather than a scientific report, the sections should have a flow, rather than be numbered.

The article should not exceed 2500 words, and should be accompanied by a cover letter of not more than 100 words.

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Clinical applications

Application of live 3D tools in vascular interventional radiology

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An accurate morphological assessment of blood vessels and their relationship with interventional devices is essential in the management of vascular lesions, and digital subtraction angiography (DSA) has had a central role in the deployment of interventional procedures. The introduction of three-dimensional rotational angiography (3D RA) and flat panel detector technology has further contributed to diagnostic accuracy, faster procedures, and improved patient care [1-4].

The availability of 3D reconstructions also brings a wealth of 3D tools that can improve current procedural workflows, starting from disease assessment to treatment evaluation, navigation and treatment planning.

However, the use of 3D RA and associated tools in vascular interventional radiology (IR) is, however, not yet common practice. Although evidence of the clinical benefit and reduction in radiation exposure to patient and staff following the use of 3D RA has been extensively reported for vascular lesions of the neck and brain [5-10], there is not enough information in the literature on how the use of 3D tools can improve the (peripheral) vascular IR procedural workflow.

The objective of this article is to provide a showcase of minimally-invasive vascular IR applications where the availability of 3D tools was distinctly beneficial to achieving effective disease management in a busy day-to-day clinical practice.

Materials and methods

In order to provide a suitable range of extraneurologic vascular IR procedures, a total of ten patients were selected retrospectively from over 200 subjects treated between 2006 and 2007 with clinically indicated rotational angiography. The clinical indication was made by the interventional radiologist on a per case basis, based upon his judgment as to whether the 3D tools would help in problem solving or clarification of anatomy, offer potential time savings, possibly reduce contrast agent or X-ray dose to the patient, or uncover a suspected hidden lesion.

All rotational examinations were performed on an Allura Xper FD20 system (Philips Healthcare, Best, the Netherlands) using an automated “two-button” 3D acquisition process. A total of 120 frames were obtained during a 240° rotation for a total scan time of 4 sec and 3D reconstructions with a FOV of 25 x 19 x 25 cm and a matrix size of 128³, and displayed in real time.

For soft tissue visualization, CT-like 3D reconstructions were acquired using the XperCT technique over a scan range of 240°, resulting in 310 frames and a total scan duration of 10 sec. All consequent 3D analyses were also performed live by the physician who carried out the examination.

Clinical results

Vascular stenoses
Three-dimensional imaging is useful in the assessment and grading of vascular stenoses. It can not only provide a view of the anatomy from angles not achievable with 2D imaging, but also help in the detection of hidden stenoses not visible in 2D projections and other diagnostic images (Figures 1, 2).

By using 3D RA and quantitative tools, the radiologist can accurately evaluate the extension and grading of the stenosis and, for example, avoid the need for overlapping stents with the associated extra costs and risks of recurrent stenosis.

Visceral aneurysms
Accurate imaging information is essential in the treatment of aneurysms. Often, this type of information cannot be obtained, either from 2D DSA due to complex angles required to view the aneurysm neck, or from computed tomography angiography (CTA) and magnetic resonance angiography (MRA) because of inadequate spatial resolution, especially for small branch vessels.

- Accurate morphological assessment is essential in the management of vascular lesions.

- Three-dimensional imaging is useful in the assessment and grading of vascular lesions.
Figure 1. Renal artery stenosis in 81-year-old female. The patient was referred for treatment after failed medical management of hypertension.

Figure 1a. Pre-procedure contrast-enhanced MR angiography showing a tight ostial stenosis of the right renal artery (arrows) and a patent left renal artery (dashed arrows).

Figure 1b. Repeat antero-posterior (AP) arteriogram confirming the right renal artery stenosis.

Figure 1c. Selective DSA of the right renal artery showing stenosis (arrows) at the origin of the vessel.

Figure 1d. Selective DSA of the right renal artery showing successful stenting.

Figure 1e. AP view of the 3D RA reconstruction showing unremarkable left renal artery (dashed arrows) and the good post-stent appearance of the right renal artery (arrows).

Figure 1f. Oblique view (RAO -6°, CRAN -52°) revealing the presence of two overlapping vascular segments on the left side, which hide a very tight stenosis of the left renal artery (dashed arrow). The lesion was further confirmed with pullback pressure measurements. After stenting of the left renal artery, hypertension was successfully controlled.

Figure 2. Common iliac artery stenosis in 73-year-old male with history of AAA surgical repair, right nephrectomy, and left renal artery stenosis, now presenting with pain in right leg. No surgical records were available.

Figure 2a. AP view of aortoiliac arteriogram showing patent left renal artery stent and corrugated appearance of abdominal tube graft. Note that both common iliac arteries appear widely patent.

Figure 2b. AP view of color-rendered 3D RA reconstruction after injection of 24 ml of contrast at 6 ml/sec. A portion of an aortoiliac by-pass graft (arrow) appears to superimpose over the common iliac artery.

Figure 2c. Oblique view (LAO 45°, CAUD 27°) of the 3D RA rendering confirms the presence of aortoiliac bypass graft (arrow) and reveals a stenosis at the origin of the right common iliac artery (dashed arrow).

Figure 2d. DSA performed with the same obliquity using synchronization between C-arc and 3D RA reconstruction confirms the presence of approximately 60% stenosis (dashed arrow), along with sluggish flow in a failing aorto-iliac bypass graft. Conventional 2D angiography without 3D guidance had missed this lesion because of overlapping vascular anatomy. The lesion was subsequently treated with a balloon-expandable stent. Following stenting, the patient reported leg claudication had resolved.
Figure 3. Renal artery aneurysm in 55-year-old male.

Figure 3a, b. Selected views of diagnostic 3D MRA showing an aneurysm of the right renal artery. Although spatial resolution is inadequate for confident neck localization and sizing, the image in 3b provides an optimal view of the aneurysm neck. A similar view with 2D DSA would not be achievable as it would have required a very steep crano-caudal oblique angle.

Figure 3c. Surface rendering of a selective 3D RA reconstruction of vascular aneurysm after the injection of 8 ml of contrast using a catheter placed into the right renal artery (captured on the image). The relationship between aneurysm and feeding vessels could be visualized at any angle. The aneurysm is isolated and shaded in blue using an automatic detection algorithm implemented in the computer-assisted aneurysm analysis tool. The visualization helps in the quantification of aneurysm size and shows how all three vessels feeding the kidney (arrows) arise from the aneurysm sac.

Figure 3d. Additional view offering a better depiction of the posterior vessel branch (dashed arrow). As endovascular repair with coils/covered stents was not a good option due to risks of non-target embolization, the patient was referred to a transplant surgeon for bench surgery and auto-transplantation along with a 3D RA video file to help them plan the best method of vascular repair. This resulted in minimizing the ischemia time of the explanted native kidney during repair, as much of the repair planning could be done prior to surgery.

Figure 4. IVC filter removal in 44-year-old male.

Figure 4a. 2D AP venography showing IVC and Cordis OptEase IVC filter.

Figure 4b. A magnified view of the filter suggests the correct positioning of the hook (arrow) in the middle of the vein’s lumen.

Figure 4c. 2D AP fluoroscopy showing an unsuccessful attempt to capture the filter’s hook using a snare.

Figure 4d. Four-second 3D RA reconstruction showing spine, tilted IVC filter and its relationship with the snare used to capture the hook.

Figure 4e. Lateral (84°) 2D fluoroscopy optimally showing filter tilting. The exact lateral angle was selected from the 3D image.

Figure 4f. Lateral (84°) 2D digital subtraction venography further exposing the relationship between the filter and the IVC. The filter is not only tilted but the hook (arrow) is also embedded into the vessel wall. Snare retrieval would have been physically impossible, and would have inevitably led to numerous unsuccessful attempts.
Three-dimensional RA offers high spatial resolution and can achieve a detailed 360° view of the vessels of interest. Computer-assisted aneurysm analysis tools can also be used to automatically define the aneurysm sac, calculate its dimensions and analyze its relationship with the surrounding vessels, facilitating both diagnostics and interventional planning (Figure 3).

Inferior vena cava filter removal

Most retrievable inferior vena cava (IVC) filters incorporate a “retrieval hook” that is used to capture the filter and, when properly placed, are typically removed with a snare and sheath within minutes. However, the removal process often requires several snare attempts and lengthy fluoroscopic exposures. Even symmetric filters, while appearing untilted in standard 2D venograms, may hide a significant degree of tilt, which is often revealed by unusual projection angles [11]. Our approach is therefore to routinely perform a rapid, 4 sec 3D RA at the start of the procedure to achieve a fast and confident removal, even in complex cases (Figure 4).
Figure 6. Uterine fibroid embolization in 44-year-old female.

Figure 6a. 3D RA surface rendering showing complex bilateral supply of uterine arteries to the fibroid. The origin (arrow) of the left uterine artery (LUA) and other branches of the right and left common iliac arteries (RCIA and LCIA, respectively) are here visualized.

Figure 6b. Same view of cropped 3D RA surface rendering, which provides a cleaner outlook of the LUA origin (arrow).

Figure 6c. Oblique view of cropped 3D RA surface rendering showing the origin (dashed arrow) of the right uterine artery (RUA).

Figure 6d. Same view of gradient-rendered 3D RA volume. The advanced vascular analysis tool is used here to better assess the RUA morphology.

**Vascular malformations**

Three-dimensional RA offers detailed anatomical information that enables the radiologist to untangle the tangled web of vessels surrounding an arteriovenous malformation (AVM). A comprehensive treatment plan based on 3D RA is achieved with a single run and helps to minimize the number of 2D DSA and fluoroscopic images required during treatment.

The availability of 3D RA reconstructions makes it possible to quickly identify the AVM nidus, unravel the intricate vascular configuration of the feeding vessels, select the optimal working projections to access all feeding vessels, and achieve a complete embolization (Figure 5).

**Uterine fibroid embolization**

Uterine fibroid embolization (UFE) is an important application making use of 3D imaging [12]. Most interventional radiologists perform abdominopelvic aortography with additional, randomly chosen oblique selective internal iliac angiograms in hopes of localizing the origin of the uterine artery and guiding superselective catheterization of this vessel.

Figure 7. Uterine fibroid embolization in 41-year-old female.

Figure 7 a-d. Snapshots recorded during live 3D navigation with dynamic 3D roadmap. A single 3D reconstruction was used throughout the embolization procedure. The magnification and projection angle of the live fluoroscopy were automatically transferred to the 3D reconstruction so as to preserve their matching. The blending of the two types of data could also be controlled to, for example, highlight vascular landmarks or boost catheter visualization.
However, additional 2D angiographic roadmaps in other angles are often required. This increases procedural radiation dose, contrast administration and time. Our approach is instead to acquire one 3D RA at the beginning of the procedure to select optimal projections showing the origin of feeding vessels, produce 2D or, more efficiently, dynamic 3D roadmaps and swiftly access the feeding arteries with no need of additional contrast or DSA runs prior to embolization (Figures 6, 7).

Transarterial chemoembolization
The combination of live 3D tools is particularly valuable in transarterial chemoembolization (TACE) procedures to identify the vessels feeding the tumor, define treatment approach and chronology, and achieve a smooth catheter placement in the feeding vessels. In addition, soft tissue information obtained with the XperCT technique can be used to confirm treatment completion by comparison with pre-treatment CTA or MRA.

CT-like imaging in the interventional suite enables the interventional radiologist to promptly tackle possible tumor residuals and improves the clinical workflow eliminating the need of moving the patient to a CT unit (Figure 8).

Conclusion
The availability of 3D tools is indispensable in a busy day-to-day clinical practice and can be routinely used in synergy with 2D imaging to help the physician achieve more effective disease management and faster procedural workflow for a variety of applications. We encourage the use of 3D tools to achieve fast and confident decisions with a potential reduction in contrast agent administration and radiation dose to patient and staff.

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References


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Catheter ablation of persistent AF: integrating advanced imaging and mapping solutions

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Atrial fibrillation (AF) is a growing indication for catheter ablation and is increasingly being performed in many EP centers. Although acceptable short and long term results have been reported for both paroxysmal and chronic atrial fibrillation, these are typically from high-volume centers with considerable institutional and operator experience. Currently there is a huge unmet need, comprising patients who are unable to have an ablation due to the lack of centers, and the lack of operators able to perform an ablation. This is in part due to the complex anatomy of the left atrium and the long learning curve necessary to perform safe and effective ablation. Complications, while rare, can be devastating. These include cardiac perforation, diaphragmatic paralysis and stroke. Additionally, even in experienced centers, recurrence of AF or atrial tachycardia (AT) is common, due in part to reconnection of the pulmonary veins.

Several studies have previously demonstrated that outcomes are better when procedures are performed in high-volume centers by high-volume operators, yet this does not answer the question as to how to perform more procedures. One potential solution is to make the procedure easier, reducing the time required to perform the ablation itself, and shortening the learning curve. To this effect a number of different technologies are being developed, from balloon-based catheters to advanced imaging and mapping solutions.

Ablation strategies

Catheter ablation of AF is dependent upon the substrate. Several studies have demonstrated that isolation of the pulmonary veins alone results in long-term freedom of AF for the majority of patients with paroxysmal AF [1-5]. However, this usually requires more than one procedure, due to recurrence of pulmonary venous (PV) conduction. The mechanisms underlying PV reconduction are unknown, but it is likely due to ineffective lesion delivery during the initial procedure. This may be due to poor catheter stability, inability to achieve transmural lesions, and acute tissue edema causing both temporary isolation and limited power delivery to underlying tissue [6].

Paroxysmal AF: pulmonary vein isolation
Isolation of the pulmonary veins is usually sufficient to treat the majority of patients with paroxysmal AF. Electrical isolation of the pulmonary veins requires ablation of the muscular sleeves that extend from the pulmonary veins into the left atrium. This can be performed in a targeted manner, at the ostium of the pulmonary vein and utilizing a circular mapping catheter to help localize the location of these electrically conducting sleeves.

An alternative method is to isolate the veins using a circumferential lesion either around both veins (typically on the right side) or single veins (typically for the left veins, due to the left anterior appendage being superior to the left superior pulmonary vein), at a more proximal location, the so-called antrum [7-12]. The endpoint of either technique is complete electrical isolation of the pulmonary veins [13]. Antral ablation has the benefit of destroying more atrial tissue, thus including non pulmonary vein sources, which tend to be clustered in this region, which is especially important in patients with chronic AF, but it is more difficult to achieve pulmonary vein isolation than with an ostial segmental approach.

One of the difficulties in achieving PV isolation is the variable anatomy of the pulmonary veins. The normal left atrium has four pulmonary veins draining into it (right and left superior and inferior veins). However, common variants include an additional right middle vein (seen in 23% of cases), common ostia (for example a left common ostia is seen in 35% of cases). Less
common are pulmonary veins that connect to the left atrium by its roof, yet isolation of such veins is required for a successful outcome [14-16].

**Persistent atrial fibrillation**

For patients with persistent and long-lasting persistent AF, isolation of the pulmonary veins alone is insufficient to achieve long-term freedom from AF. Different strategies have been tried with varying degrees of success, all of which aim to alter the atrial substrate.

Initially linear lesions were tried, typically a line connecting the left and right superior pulmonary veins, and a line connecting the mitral annulus to the left inferior pulmonary vein. However, the success rates of this procedure were unsatisfactory.

A different method targeted areas harboring complex fractionated atrial electrograms (CFAE), which was initially reported to result in acceptable rates of freedom from AF, but subsequent studies have not borne out these initially promising results [2, 17]. However, there are a number of studies that demonstrate that a combination of these techniques can provide good results. Pulmonary vein isolation in combination with ablation of CFAE, linear lesions with a procedural endpoint of AF termination and validation of all lesion sets performed, with additional ablation as required to achieve pulmonary vein isolation and conduction block across all linear lesions, has been shown to result in excellent medium to long term freedom from AF [18-20].

It should be noted that patients with persistent atrial fibrillation tend to require more than one procedure, predominantly due to recurrence of regular atrial tachycardias that can be effectively mapped and ablated. In two recent studies utilizing this combined approach for patients with persistent AF, sinus rhythm was maintained in 81% of patients at 20 months in one study [20] and in a different study 88% of patients were in sinus rhythm with a median of 34 months follow up [18].

Although this ablation strategy results in excellent results in terms of freedom from AF, the exact mechanism by which it is successful is not completely understood. Ablation of CFAE is relatively non-specific, as was shown in one study that extensively investigated which electrogram characteristics resulted in either termination of AF or a significant prolongation of AF cycle length [21]. This study demonstrated that only a gradient of activation (a difference inactivation from one bipole to another of at least 70 ms, possibly representing a small circuit) and the duration of continuous fractionation were associated with a slowing or termination of AF. However, the positive and negative predictive value for continuous activity of >70% of the time window was 51% and 73% for favorable ablation regions. The presence of temporal gradient of activation was predictive of favorable ablation regions with positive and negative predictive values of 62% and 66% respectively.

There is obviously a long way to go before we fully understand the mechanisms underlying chronic AF, and although algorithms based on dominant frequency analysis have shown some promise [22] in the latter study this did not predict a favorable outcome from ablation [21].

**Advanced imaging solutions**

All of the above strategies require integration of an understanding of the anatomy of the left atrium and pulmonary veins with specific electrogram characteristics. The standard imaging technique in many laboratories is simple fluoroscopy. While this allows visualization of the ablation and mapping catheters, the operator has to have a high level of experience to understand the anatomy of the left atrium, as this is not directly visualized. This has led to different imaging modalities being used to help the operator.

Pre-procedural CT of the left atrium and pulmonary veins results in a high quality image that can be used at the time of the ablation [23] either by overlaying the three-dimensional shell on the live fluoroscopy screen or by integrating the shell into an electroanatomical mapping system (CARTOMERGE or NavX Fusion). Although this technique results in a high quality 3D representation of the left atrium and other cardiac chambers, registration of the 3D shell is sometimes difficult due to changes that have occurred between the scan taking place and the ablation procedure. For example the patient’s rhythm may have changed from sinus to AF, the fluid status of the patient is likely to be different, and perhaps most importantly, the patient’s position on the operating table is different from that during the CT scan.

**Three-dimensional atrigraphy (3D ATG)**

To overcome the difficulties outlined above, and to reduce the radiation dose to the patient, a three-dimensional atrigraphy (3D ATG) procedure has been developed, based on three-dimensional rotational angiography (3D-RA) [24]. This uses the same C-arm system (Philips Allura Xper FD10) as that used...
Figure 1. Three-dimensional atrigraphy (3D ATG).

Figure 1a. Preparation. The left atrium is isocentred; this is done by using the close relationship of the carina (red arrow) to the roof of the left atrium, and the coronary sinus catheter (white arrow) which defines the inferior margin of the left atrium. In a lateral view the upper margin of the spine (red line) is used to define the posterior border of the left atrium.

Figure 1b. Angiorotation. Radiopaque contrast has been injected into the right atrium, and after allowing for transit through the pulmonary vasculature, the C-arm rotates around the patient, acquiring images of the left atrium.

Figure 1c,d. Segmentation. The left atrium is autosegmented, but care is taken to check that it is correct and all the anatomical detail has been gained from the scan, such as the left atrial appendage.

Figure 1e. Registration. The 3D shell is automatically registered to the patient. However, this is always checked in case the patient has moved. Here the ablation catheter has been looped in the left atrium and excellent apposition to the wall of the left atrium of the overlaid shell is seen.

Figure 2. Mapping atrial tachycardia

Figure 2a. 12-lead ECG demonstrating atrial tachycardia (arrows point to the p waves).

Figure 2b,c,d. Taking points. Using EP, navigator points are taken within the left atrial shell. These images show the first point. The point is tagged in an AP view, and a line of sight shows where on the 3D shell this can be (anterior or posterior). The electrophysiologist can tell the operator where the catheter is, and this can be checked using orthogonal views.
Figure 2e. Checking the electrograms. The tagged point from the EP navigator is immediately associated with the electrical activity that is being recorded by the ablation catheter. On the BARD Labsystem Pro (C.R. Bard’s Electrophysiology Division), this electrical signal is then checked to ensure correct annotation with regard to the reference channel.

Figure 2f. Final activation map. When several points have been taken throughout the left atrium a color-coded map can help identify the mechanism of the atrial tachycardia. In this case the tachycardia was due to a small circuit localized on the anterior left atrium (orange) with later activation of the rest of the left atrium (purple). Ablation at this point resulted in tachycardia termination.
routinely for fluoroscopy in the EP lab. In this procedure, the left atrium is placed at the isocenter, and then contrast agent is injected into the heart, either from the inferior vena cava/right atrial junction, the pulmonary vein, or directly into the left atrium. The C-arm then rotates around the patient in a 240° scan lasting four seconds. This creates a three-dimensional data set similar to a CT scan that can be read by the EP navigator.

Automatic segmentation of the left atrium is performed, and this is checked and manually corrected as necessary. Following this the 3D shell is automatically overlaid on the real-time fluoroscopy image (Figure 1). A benefit of this system is that registration is not required, as long as the patient has not moved, given that the scan has been performed using the same equipment, under identical circumstances, and within a short period of time. Registration accuracy can be rapidly checked, normally by placing a catheter within the superior pulmonary veins and looking for the drop off between the pulmonary vein ostium and the left atrial body.

Following this step the ablation can then be performed with the operator being able to see the location of critical structures such as the ostia of the pulmonary veins, the ridge between the left atrial appendage and the left superior vein, and any anomalous pulmonary veins. The direct visualization of these structures obviously aids catheter placement, and helps avoid

Figure 3. Assessment of conduction block. Linear lesions are often required in the ablation of persistent atrial fibrillation.

Figure 3a. Following pulmonary vein isolation (pink tagged points) a roofline is performed with ablation from the right superior to the left superior pulmonary vein.

Figure 3b. By pacing the left atrial appendage, which is anterior to the roofline, the line can be checked for conduction block. If the line is blocked activation cannot spread over the roof and down the posterior wall. Instead, activation passes down the anterior wall of the left atrium and up the posterior wall. Here a map is made using the ElectroNav (Philips Healthcare/C.R. Bard’s Electrophysiology Division) system. Activation can be seen ascending the posterior wall, with the latest activation being next to the roofline, indicating block has been achieved and no further ablation is necessary.

Figure 3c. Roofline block. Here in the BARD LabsystemPro, the same line of block is seen from a superior view, with a clear line of early activation on the anterior aspect of the roofline and very delayed activation on the posterior side of the line.
potentially dangerous areas, such as the posterior wall with the underlying esophagus (which can be visualized and segmented with the 3D rotation), and helps to determine the level of isolation of the pulmonary veins (antral or ostial).

A recent two-center study comparing CARTO XP Electroanatomical Navigation System to 3D ATG with over 90 patients recruited has demonstrated equivalent results using both systems in terms of acute and short term procedural success, with equivalent fluoroscopy times whether using the fluoroscopy-based system or the CARTO system [25]. Although these images, whether CT, 3D ATG or electroanatomic systems, intrinsically make the operator feel more comfortable when ablating in the left atrium, it is less certain whether this translates into clinical benefit.

A retrospective study utilizing CARTOMERGE suggested that there was a clinical benefit to using the system [26]. However, in a later study by the same group no clinical benefit was seen, leading to the conclusion that a successful procedure is guided by electrical isolation of pulmonary veins rather than the technology used to achieve it [27].

While this could be seen as disappointing in terms of the benefit of imaging systems there are two important caveats. First, a learning curve was seen when using the CT overlay in the former study and, secondly, these studies are typically performed by experienced operators. As was discussed earlier there is a large population of patients who simply do not have access to a trained electrophysiologist who is capable of performing these difficult procedures, and any technology that lessens the learning curve has to be advantageous. Additionally, most complications occur when operators are learning a new technique, and as AF ablation will be increasingly performed throughout the world, these imaging techniques should help avoid unnecessary complications due to a lack of experience.

Integration with EP recording systems
Although 3D ATG has clear advantages over CT-based systems, one of its limitations is that it only provides anatomical information. Electrophysiology is the integration of discrete anatomical structures with discrete electrical properties. The integration of this information is what allows the electrophysiologist to successfully treat patients. For example, a common atrial tachycardia post AF ablation is peri-mitral re-entry, whereby electrical activation goes around the mitral annulus. To effectively terminate this arrhythmia a line of block between two electrically isolated areas has to be made to stop this circuit. Commonly this is between the electrically isolated left inferior pulmonary vein and the lateral mitral annulus.

In order to ablate this effectively the electrophysiologist has to perform several tasks: first, the activation wavefront needs to be mapped, then entrainment maneuvers need to be performed, in which pacing in or close to the circuit is able to capture and overdrive the circuit, and finally a line of block needs to be created, and any gaps identified.

This process thus requires integration of anatomy (the mitral annulus, the isthmus where the line of conduction block is going to be made) with electrophysiological data (wavefront of activation, the results of entrainment, and identification of conduction delay but not block).

We are currently working with C.R. Bard’s Electrophysiology Division and Philips Healthcare on a software prototype whereby the electrical data from the EP recording system is displayed in a color-coded format on the 3D overlay. This potentially allows rapid recognition of the direction of the wavefront for regular atrial tachycardias (Figure 2) and allows for color-coded entrainment mapping. This has been shown to be of benefit in a recent study, and easily demonstrates presence or absence of conduction block across linear lesions (Figure 3).

Additionally the software allows for dominant frequency mapping in atrial fibrillation, and wavelet analysis to try and localize areas that are critical to the AF process.

Future improvements
Although there have been huge technological advances in the EP laboratory over the last few years, the future holds even more promise.

Currently the overlaid 3D shell is static, whereas in practice the heart is moving, both due to cardiac contraction and to diaphragmatic movement. Real-time visualization of this movement will make catheter placement even more accurate, and possibly help to avoid inadvertent ablation within the pulmonary veins that can result in the complication of pulmonary vein stenosis.

Perhaps the most interesting possibility is the ability to integrate new information onto the 3D shell. For instance, areas of fibrosis could be
References


Conclusion

Ablation of persistent AF is a difficult task, both to learn and to subsequently perform. The use of advanced imaging and mapping solutions will hopefully shorten the learning curve and make the procedure safer and more effective, leading to improved outcomes for patients and a greater number of patients being able to be treated for this debilitating condition.


Up to the early 1990s, the only alternative treatment to open surgery was watchful waiting in combination with controlling blood pressure [2]. In 1991, Parodi et al. [8] in Argentina and Volodus et al. in the Ukraine [9] first reported on Endovascular Aneurysm Repair (EVAR) using a stent-graft. In this procedure, the surgeon places the endovascular prosthesis into the aorta by the femoral or iliac arteries. Compared with conventional open surgery, EVAR has proved to be a less invasive procedure with shorter procedure duration, reduced blood loss and a shorter hospital stay [10]. Patients usually go home within three days of treatment as opposed to a week or more with the conventional treatment.

A meta-analysis of three randomized clinical trials [11 - 13] showed a 30-day mortality rate of 1.6%. That is significantly lower than the 30-day mortality rate of 4.7% for open repair. In addition, there is a lower incidence of perioperative pulmonary complications, hemorrhage, graft infection and colonic ischemia associated with EVAR [14].

Today, the EVAR procedure, developed and refined over the past eighteen years, offers a minimally invasive alternative to open surgery. First introduced by Dubost et al. in 1952 [7], open aortic surgery has evolved and become the gold standard for treatment of AAAs. The technique does, however, involve laparotomy with the need for temporary aortic cross clamping to allow placement of an aortic graft over the area of the aneurysm.

Most AAA patients are elderly, often in the poor physical condition that accompanies old age. Thus there is severe morbidity and mortality associated with the open surgery technique.

Abdominal aortic aneurysms usually display no symptoms. Often, doctors only detect an AAA during a routine medical examination for some other complaint. Once found, if the aneurysm is larger than 5 cm, is growing by more than 1 cm a year, or is causing pain, then surgery is often the only choice for the patient. There is as yet no definite identified cause for the condition. Other than atherosclerosis, other factors associated with AAA disease are [6]:

- being a male
- smoking
- high blood pressure
- family history of AAA.

Previously, once the need for surgical intervention was determined, the only surgical choice available was open abdominal surgery. A critical element in assessing the need for, performing and following up on any endovascular procedure is good imaging.

At the University Medical Center (UMC) in Utrecht, the Netherlands, the Veradius mobile C-arm with flat detector has been undergoing extensive clinical evaluation. In the Department of Vascular Surgery, this new system is already proving to be a valuable tool in advancing the endovascular repair of abdominal aortic aneurysms.
The stent-graft up through the iliac artery to the site of the aneurysm. The stent-graft consists of a tube of polyester (Dacron®) or PTFE material supported by a metal skeleton frame. Stent-grafts are now available in various sizes and lengths to allow for different patient anatomies and aneurysm sizes. Usually the caudal end of the stent-graft is bifurcated to allow placement across the iliac arch as a preventive measure against stent-graft migration.

The stent-graft must cover the aorta interior wall correctly and exclude any further flow into the aneurysm sac, while ensuring that there is no obstruction of the renal or iliac arteries. The interior wall of the stent-graft then acts as an artificial lumen, taking the pressure off the aneurysm sac, the contents of which will thrombose in time.

The stent-graft is compressed into a sheath for delivery, which is removed once the stent-graft is in the correct placement area. The skeleton metal frame, in trying to revert to full size, gives firm fixation without the need for sewing. Precise placement of the stent-graft before deployment is therefore essential.

To ensure correct placement, the procedure is carried out under fluoroscopic control. With a conventional image intensifier, the convex input screen produces pincushion distortion at the edge of the image field (Figure 2). When the area of interest is confined to the center of the image this is not a problem. However, the EVAR procedure requires a large distortion-free image, because undistorted estimates of the distance between the renal arteries and the proximal part of the stent-graft, and between the distal part and the iliac arteries, are needed to assure correct placement.

**Veradius with flat detector**

The VerADIUS is a next generation of the versatile mobile C-arm system in which a thin, flat detector replaces the conventional image intensifier (Figure 1). The flat detector frees up valuable space and provides several advantages over the conventional image intensifier technology, including:

- a higher dynamic range, able to differentiate a larger range of grayscale values to provide clearer images with better contrast
- no distortion due to the earth’s magnetic field when rotating the C-arm, because of the direct digital conversion of X-rays
- no pincushion distortion, because the convex image intensifier input screen is replaced by a truly flat detector.

The VerADIUS is equipped with a stand monitor that allows the operator to position the flat detector easily and accurately, saving valuable X-ray dose and time.

**Method**

At the UMC, patients are mainly under general or epidural anesthesia during the EVAR procedure. The individual patient’s physiology or preference determines the choice of anesthesia. The patient’s anatomy, especially in the case of obese patients, can also affect the ability to image the aneurysm area clearly. Experience to date indicates that the VerADIUS with flat detector is having a positive effect on improving imaging during the EVAR procedure.

The procedure involves inserting the stent-graft, often called an endograft, in through the femoral artery. From there the surgeon guides the stent-graft up through the iliac artery to the site of the aneurysm. The stent-graft consists of a tube of polyester (Dacron®) or PTFE material supported by a metal skeleton frame. Stent-grafts are now available in various sizes and lengths to allow for different patient anatomies and aneurysm sizes. Usually the caudal end of the stent-graft is bifurcated to allow placement across the iliac arch as a preventive measure against stent-graft migration.

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occlusion. With the improved image quality provided by the Veradius, the stent-graft can now be positioned as close as 1 mm to the renal artery, making it possible to treat patients who previously could not undergo the EVAR procedure because of the proximity of the aneurysm to the renal artery.

The medical personnel have noted that using Veradius with the flat detector also improves communication in the operating room. This is because it is less obtrusive and so does not block eye contact between members of the operating team. Now, for example, it is possible for the surgeon to see clearly the anesthetist stationed at the head end of the patient. This aids communication at the most critical stage of the procedure, so that the anesthetist can control the patient’s breathing while the stent-graft is being maneuvered into exactly the right position.

Conclusions

In the future, the ageing population is expected to lead to a rise in the number of patients presenting with AAA. Endovascular repair
techniques will need to be constantly improved to meet the increased demand. New stent-graft designs will allow treatment of patients who are now excluded because of physiology, age or aneurysm location. In addition, imaging techniques need to be improved to meet the imaging requirements of these new developments.

The Veradius mobile C-arm with flat detector is an example of this improvement in imaging technology. Designed to give excellent quality at low X-ray dose, the flat detector has several advantages over image intensifiers. The flat detector has a wider dynamic range, providing improved brightness and contrast, and fewer distortion artifacts.

The clearer, sharper images give the vascular surgeon working with AAA cases greater confidence and freedom to select and use new stent-graft designs. As a result, more patients will undergo less invasive procedures, with the consequent decrease in risk, and an improved quality of life.

Over the last decade, EVAR has gained increased worldwide application for the treatment of abdominal aortic aneurysms. In comparison with the open surgery, EVAR is significantly less invasive and the outcome of the first randomized trials supports the use of EVAR in patients.

In the future, new stent graft technologies will probably extend the application and durability of EVAR. The first results with fenestrated grafts are promising for patients with short aneurysm necks, and with the use of these, migration rates are expected to be lower. In all cases, image quality will continue to play a key role in the success of AAA treatments, and the Philips Veradius with flat detector appears to be an important step in this direction.

Case studies

Case 1
An abdominal ultrasound examination revealed an asymptomatic saccular abdominal aortic aneurysm in a 73-year-old male patient who had presented with an unrelated complaint. The anatomy of the aneurysm was judged to be suitable for endovascular repair.

A bifurcated stent-graft was inserted via the left femoral artery, and positioned with the stent still retracted just below the renal arteries. A control angiogram was made (Figure 3a) to check the stent-graft position before deployment. The radiopaque markers indicate the proximal end of the covered part of the stent-graft.

After deployment of the bare stent, the second limb of the bifurcated stent-graft was inserted and deployed. The result of the procedure is shown in Figure 3b. The aneurysm is fully excluded by the bifurcated graft, while the renal and internal iliac arteries remain patent, as planned.

Case 2
An 85-year-old male patient presented with an asymptomatic abdominal aortic aneurysm. The anatomy of the aneurysm was judged to be suitable for endovascular repair.
Figure 4. Case 2. An asymptomatic saccular abdominal aortic aneurysm in an 85-year-old male patient.

Figure 4a. Positioning the proximal part of the stent-graft.

Figure 4b. Deployment of the right and left limbs of the bifurcated stent-grafts.

Figure 4c. Because the longest available stent-graft was too short for this patient, the right limb was extended with an extensor cuff.

Figure 4d. Final angiogram showing satisfactory exclusion of the aneurysm.
The main body of the bifurcated stent-graft was inserted via the right femoral artery and the proximal part of the stent-graft was placed in the desired position (Figure 4a).

Because the lumen of the aorta was rather narrow (the aneurysm was filled with thrombus) the vascular surgeon decided to cannulate the short left limb first, before deployment of the right limb of the stent graft. Then, both the right and left limbs of the bifurcated graft were deployed (Figure 4b). Because the longest available stent-graft was too short for this patient, the right limb was extended with an extensor cuff (Figure 4c). Figure 4d shows the final angiogram with satisfactory exclusion of the aneurysm.

References


Interventional procedures performed with cardiovascular X-ray systems such as the Philips Allura Xper are becoming more and more sophisticated. Physicians are using smaller devices in increasingly complex anatomies, and are often comparing diagnostic information from multiple sources to help guide their intervention. In Medical Advisory Boards organized by Philips over the last few years, many physicians expressed a strong desire to be able to organize and control all this information and guide the interventional tools in a clear way at the tableside. Improving the presentation of information on the monitors was therefore on the “Top Five” list of requirements expressed at recent Medical Advisory Boards.

Currently, images and data are displayed on an array of three, four or six monitors, possibly extended with an extra set of two. The allocation of images to the monitors, i.e. what image is seen on what monitor, is fixed: a specific monitor is always dedicated to a specific application.

Recently, a high-resolution 56” (142 cm) color monitor has been developed, with a display area greater than that of six standard monitors. The new monitor brings a great deal of new flexibility to the user with respect to the conventional monitor setup, in terms of both image location and image size (Figure 1).

Images and data from up to 16 different sources can be connected to the system, with up to eight data sources displayed on the large monitor simultaneously in various sizes, (ranging from 35 - 420% of the regular size). A SuperZoom function with advanced image-sharpening algorithms lets clinicians magnify images and make out fine details without having to move closer to the display. They can also select one of a choice of 24 different on-screen layouts to suit the way they work, change it at any time during the procedure, and customize the layouts by switching sources. In addition, they are able to manage multiple video sources on one screen from the tableside.

Philips has incorporated this new monitor technology in the FlexVision XL display system for cardiovascular application and the EP cockpit XL display for electrophysiology.

These products comprise the medical grade 56” Philips LCD eight-megapixel color monitor, with a touchscreen User Interface available both at tableside and in the control room.

**User studies**

In order to assess the clinical benefits of the large monitor and to obtain feedback from the users, Philips organized several studies. The results of two of them form the basis of this article.

First, a Medical Advisory Board for NeuroRadiology was organized by Philips Healthcare Best at the SNIS Conference in July 2008. A total of 12 neuroradiologists participated in several focus groups.

Secondly, qualitative data were obtained from four hospitals in a Field Test study. These were felt to provide a representative cross section of the different clinical segments:

1. Fondation Ophtalmique Adolphe de Rothschild, Interventional Neuroradiology Department, Prof. Moret.
2. Deutsches Herzzentrum Berlin, ElectroPhysiology Department, Prof. Dr. Fleck.
3. Harborview Medical Centre Seattle, Interventional NeuroRadiology Department, Dr. Ghodke.
4. Baptist Cardiac & Vascular Institute Miami, Radiology Department, Dr. Katzen.

In Berlin, Seattle and Miami the large monitor setup was also used occasionally by interventional cardiologists in order to get customer insights from that clinical segment as well.
Results

The users were asked to assess the use of the large monitor according to the following criteria:

- flexible switching
- enlarged images
- image quality
- room layout
- ergonomics
- ease of operation

Flexible switching

When focusing on the need to organize and control information at tableside, it appeared that some users really appreciated the ability to switch and swap information and monitor layouts. One physician mentioned: “At the beginning of the procedure I would like to have an overview of all available data sources, but as I proceed I prefer to focus on one live monitor”.

However, not all clinical information is relevant at all times; the physician is sometimes bothered with an excess of less relevant data which can be tiring to look at. There appears to be a clear need to select and deselect different data sources at specific moments in time.

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Enlarged images

Both from the Medical Advisory Board and from the Field Test it seemed that the ability to enlarge the images was one of the clearest benefits. Dr. Mattias Roser, an EP resident doctor in the Deutsches Herzzentrum Berlin, evaluating EP cockpit XL, stated: “This is really helpful, I look in one direction and I have all relevant information in front of me without having to turn my head. You don’t have to look down and right or up and left like you would have to with less integrated systems”.

With the large 56” monitor it is possible to display the relevant data directly in the field of view, in contrast to the conventional fixed monitor format.

From the Field Test it was clear that the possibility to connect 16 different data sources was also a real benefit, with the prospect of connecting more sources in the future. In addition to the regular cath lab sources of the CV Allura system, there is a need to connect other imaging modalities (e.g. ultrasound), PACS, or even non-clinical information sources (e.g. scheduling) as well.
clinical advantages of FlexVision XL. Even the maximum possible enlargement of 420% was highly appreciated by all clinical segments in the studies.

Professor Moret, director of Neuroradiology at the Foundation Rothschild in Paris, France, who has been testing the FlexVision XL in the Field Test, said: “I have found the FlexVision to be a great help as it allows me to enlarge images, giving me the level of detail that I need during complex neuroradiology procedures. The technology gives me a better appreciation of the vessel structure in the brain.” (Figure 2).

Appreciation of the enlarged images was not restricted to the neuroradiology domain. For Dr. Gerds-Li, Deutsches Herzzentrum Berlin, the most striking feature of the EP cockpit’s XL screen is that the images are so large that the XL screen genuinely delivers a new EP lab experience. “In EP interventions in particular, we have to work a lot with intracardiac electrograms. With the XL screen, we can enlarge the signals and analyze them more precisely,” says Gerds-Li. With the area available, the preference seems to be not to zoom into a detail of a clinical image, but to enlarge the complete image, keeping all the clinical context available (Figure 3).

In addition to the appreciation of enlargement, reduction in image size was also found to be useful. In the words of one user: “I need my reference images to support me, but I do not need to see them continuously. They can be located as a small thumbnail on the side which I can resize on request” (Figure 4). This user insight resulted in the availability of a direct Superzoom button: on the User Interface a specific source can be zoomed in and out with only one click, without having to change into a complete new screen layout.

On the other hand, because of this resizing, a few physicians also mentioned that they have difficulties “eyeballing” between screens or lose their natural interpretation of sizes and measures. Therefore it can be clinically relevant to be able to display the different image sources in the regular sizes as well. Based on this feedback, some standard layouts with regular sizes are incorporated in the FlexVision XL and EP cockpit XL products.

Image quality
Image quality was under continuous scrutiny throughout the complete development process and was a topic of evaluation in the studies. When enlarging images, it is crucial to guarantee optimal image quality and full sharpness. In the Field Test this was evaluated with different clinical users in different clinical environments. All physicians and assistants interviewed were very satisfied or even impressed by the image.
quality realized by this monitor. However, the universal LCD panels are glossy and therefore some hospitals mentioned issues with light reflection. Based on this feedback, a protection screen was developed, optimized with an anti-reflection treatment to reduce this problem to the minimum.

Room layout
The regular monitor ceiling suspension is nowadays perceived as bulky: it takes up space around the table and may block the freedom of movement of the personnel. In addition, it is not uncommon for equipment to bump into it or for fluids to be spilled onto it.

Enlarging the images allows the monitor suspension to be positioned further from the table. Dr. Katzen, BCVI Miami, evaluating FlexVision XL in the Field Test, stated that this was a potential benefit for endografts or other procedures where operators are on both sides of the table. When the monitor is further from the table, this provides better patient access and better freedom of movement for the personnel, and also more room to position other equipment, such as lighting, on the ceiling (Figure 5).

Some physicians expressed their concern about the risk of breaking the monitor; this would have a larger impact than breaking one of the current multiple monitors. This user insight led to the development of a hardened glass anti-reflective protective screen fully integrated in the monitor, which should protect it against impact and scratching, and should make the monitor easy to clean.

Ergonomics
Currently, the ergonomic working position of the physician is far from ideal. First of all physicians are wearing rather heavy lead aprons for a substantial period of time. Secondly, a physician often bends over the table to get a close look at the images. Back pain related to the use of monitors has been experienced by many of the physicians in the studies.

Feedback indicated that the enlarged images are more relaxing and comfortable to view. The images can be shown in a sufficiently large size, directly in the field of view, so that the physician does not have to bend forward to take a closer look (Figure 6). Better ergonomics was one of the first things that Dr. Gerds-Li, Deutsches Herzzentrum Berlin, noticed when the XL screen was introduced. “In the past, I regularly had to lean over the patient in order to see the details of an electrogram or an angiogram. This can be tiring. Today I can look at the XL screen for hours if necessary.” Ergonomics are further enhanced by the ability to move the XL screen in multiple directions. “The screen can be maneuvered seamlessly so that every examiner is able to place it in the position that suits him best,” says Dr. Goetze, Deutsches Herzzentrum Berlin.
and optimized user interface, designed to make it easier to configure the presets.

Physicians usually only select those personalized presets at the procedure start; during the procedure the physicians rarely switch a complete monitor layout. Instead, it seems desirable to change the content of such a preset (monitor layout) by swapping and switching information. For diagnostic purposes, it can be desirable to have the X-Ray Live and X-Ray Reference together; while for performing a 3D Rotational Scan it can be desirable to have X-Ray Live and the 3D workstation together.

The user interface on the touchscreen was assessed as being intuitive and easy to use, being optimized to swap and switch sources by a single click. In the same philosophy, the Superzoom functionality is designed as a single-click operation.

Conclusion

From the several studies it is clear that the large screen offers multiple advantages in the CV interventional lab, ranging from contributing to better clinical practice to greater comfort for the physician. Flexible switching of information and significant enlargement of images on the screen were perceived as very beneficial for clinical practice.

Furthermore, the large screen makes it possible to improve the room layout and ergonomic working positions, so that the interventional lab becomes a more comfortable environment to work in. Finally, the clinical users reported excellent image quality and the assessed the switching workflow on the touchscreen at the tables as intuitive and user friendly.

Dr. Jin-Hong Gerds-Li, specialist for complex electrophysiological (EP) interventions at Deutsches Herzzentrum Berlin (DHZB), stated his preference for his working place with the large monitor: “We have to leave our EP lab from time to time to perform interventions in other DHZB cath labs. It is not easy because I am now used to EP cockpit XL. You suddenly feel five years older in an ordinary cath lab.” Having those intermediate studies in different phases of the development seems to have added a useful contribution to the development of the final product. All in all, the clinical users were very satisfied about FlexVision XL (for CV) and EP cockpit XL (for EP).

Ease of operation

The usability of the monitor was evaluated extensively in the Field Test. On one hand, the system should offer maximum flexibility. On the other hand, it should remain easy to operate. It is sometimes difficult to balance these two considerations.

The physician can make personalized presets on the touchscreen at the tableside, meaning that the user can select a specific preset (e.g. AVM or Diagnostic, personalized for the upcoming procedure) and the monitor layout will change accordingly. However, the workflow to create those personalized presets was not always clear. This resulted in the development of an improved
Coronary CT angiography in percutaneous coronary intervention

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Lenox Hill Heart and Vascular Institute of New York is among the leading cardiovascular care programs in the United States, providing a continuum of progressive care from diagnosis to treatment and recovery. As a major center of coronary and percutaneous intervention, it has been a pioneer in the integration of coronary computed tomographic angiography (CCTA) into the catheterization laboratory.

**Background**

Selective invasive coronary angiography (ICA) is the gold standard for the detection of coronary artery disease. However, in addition to being invasive in nature, it has well documented shortcomings [1, 2]. Because of its insufficient sampling, the three-dimensional coronary tree is viewed and displayed in limited two-dimensional standard angiographic views. These views are subjectively chosen, causing significant intra- and inter-observer variability [3]. As a result, lesions are either missed or underestimated [4], resulting in incorrect stent selection (diameter and length) and inaccurate placements.

Some of these shortcomings are addressed by rotational angiography [5], in which data is collected via pre-defined isocentric arcs of the C-arm for each of the coronary arteries, thereby presenting the user with a panoramic view of the anatomy. However, like invasive coronary angiography, it is also a lumenogram, depicting planar projections of the contrast-filled lumen, rather than the vessel itself. Important quantitative information such as cross-sectional lumen area, size, distribution and composition of plaque and remodeling of the vessel wall remain unavailable [1].

Intravascular ultrasound (IVUS) addresses all the above shortcomings. With its ability to provide cross-sectional imaging of both the coronary lumen and the wall, it enables:

- measurement of the minimum luminal area along with the minimum luminal diameter
- plaque quantification and characterization
- identification of vessel wall remodeling.

However, in addition to being invasive in nature, IVUS is limited to the more proximal and mid coronary segments and the cost limits its routine use.

Technical advances have enabled multidetector CT to become the non-invasive modality of choice for coronary imaging. Recent clinical literature has supported the power of CCTA using 64-slice multidetector CT scanners in the detection and ruling out of significant (> 50%) coronary artery disease, with an average negative predictive value of 98% on a per-patient basis [6-8]. With the capability of acquiring 3D data volumes (thus providing an infinite number of viewing angles) along with its tomographic nature, it shares many of the advantages of IVUS and thus has the potential to enhance the practice of percutaneous coronary intervention in the catheterization laboratory by providing data which was difficult to obtain by invasive coronary angiography [9, 10].

The following sections demonstrate some unique applications of CCTA in percutaneous coronary intervention (PCI), while at the same time avoiding the pitfalls of ICA. Specific clinical scenarios, such as left main and ostial disease and detection of diffuse narrowing, are presented. In addition, the examples demonstrate the power of pre-acquired CCTA data in facilitating and guiding successful intervention for chronic total occlusions.

All CCTA scans were performed on a Brilliance 64 Multidetector CT scanner (Philips Healthcare, Cleveland, Ohio, USA), employing advanced cardiac gating algorithms [11], adaptive cardiac reconstruction techniques [12] and dose-saving technologies (DoseRight Cardiac, Philips Healthcare, Cleveland Ohio, USA) to reduce radiation.

All CCTA images were generated by advanced post-processing applications (Comprehensive Cardiac Analysis and CT TrueView) on a dedicated CT workstation (Brilliance Workspace, Philips Healthcare, Cleveland, Ohio, USA).
Figure 1 demonstrates the important role played by coronary CTA in the detection of left main artery stenosis. A 62 year old male with atypical chest pain underwent retrospectively-gated helical CCTA. By using ECG-triggered dose modulation (DoseRight Cardiac, Philips Healthcare, Cleveland), radiation dose savings of 42% were achieved, resulting in an effective radiation dose of 8 mSv.

The exam revealed significant distal left main artery stenosis in the curved multi-planar reformatting (MPR) view (Figure 1a). A straightened lumen view (Figure 1b) was used to generate a cross-sectional view (Figure 1c) providing valuable quantitative information (minimum lumen area of 5 mm²). Two-dimensional cardiac angiography failed to demonstrate any significant disease (Figure 1d). However, a significant stenosis was detected on IVUS (Figure 1e) with a minimum lumen area of 5.4 mm², confirming the findings in CCTA. A retrospective analysis of the cardiac angiography images revealed a linear ridge of calcified plaque (Figure 1d, white arrows) corresponding to the true outer border of the vessel. The CCTA data was crucial to the correct diagnosis and surgery was recommended.

Ostial disease and the route to the stenosis
Ostial and proximal disease, particularly the bifurcation of the left main artery into left anterior descending (LAD) artery and the left circumflex artery, present unique problems. The presence of a stenosis in this region could be obscured by the overlap of the vessels. Using the standard viewing angles in the ICA, this area is sometimes poorly visualized and requires additional angiographic views for further examination. Passage of percutaneous intervention hardware through diseased left main artery areas en route to the lesion may create significant lesions where none previously existed.

CCTA not only has the ability to provide unlimited 360° of data to examine this area, but can also clearly delineate the path to the lesion, thereby guiding the treatment plan. For instance, CCTA can provide knowledge of any distal left main artery disease present in the path proximal to the stenosis that could be missed on interventional coronary angiography. Any calcification present in the left main artery is easily detected on CTA, potentially altering the treatment plan if found to be extensive.

Clinical applications

Left main artery disease
Significant left main artery disease is defined as a stenosis of over 50% in diameter with a minimum lumen area of less than 6.0 mm². Left main artery lesions are difficult to assess using the standard limited projections of invasive coronary angiography. Since a clearly normal reference area may not be readily identifiable and the minimum lumen area cannot generally be measured without IVUS, the findings can be misleading. Additionally, vessel foreshortening and overlap with the left circumflex and left anterior descending (LAD) artery also contribute to this problem [13, 14].

While IVUS is the preferred modality for assessing the severity of left main artery lesions [1, 15], recent work has shown the usefulness of non-invasive coronary CTA in the assessment of left main artery lesions [16].
increase of the maximum lumen area from 2.8 to 8.3 mm² (Figure 2d).

The operator was aware of the moderate distal left main artery disease noted on the CCTA prior to the procedure (Figure 2g, left) and confirmed by IVUS, but the small caliber distal vessel suggested percutaneous intervention rather than coronary artery bypass graft surgery. Symptoms disappeared following percutaneous intervention but returned after four months;
documented a decrease of the left main artery MLA from 6.7 to 2.6 mm², and patency of the ostial stent (Figure 2g). Trauma from the percutaneous intervention undoubtedly caused the subsequent left main artery disease; similar insult to the ostial LAD during the first stent implantation was the likely etiology of the ostial disease, which was angiographically inapparent.

**Diffuse disease**
The diffuse nature of coronary artery disease poses problems in interventional coronary angiography, causing it to underestimate the degree of stenosis when there is no nearby “normal” reference segment. Under these conditions, segments with diffuse disease could appear on invasive coronary angiography as a normal artery of a small caliber.

In contrast, IVUS and CCTA are immune from this problem; they depict the vessel wall as well as the lumen and provide measures of maximum lumen area. Accurately assessing the degrees of positive and negative remodeling may be crucial in choosing the ideal strategy and appropriate size of the device.

Figure 3 is an example of a symptomatic 64-year-old male with a prior LAD stent. The MPR (Figure 3a) revealed significant diffuse narrowing from the LAD ostium to the stent, with only mild narrowing evident on the corresponding invasive angiogram (Figure 3b). The straightened MPR (Figure 3c) along with its cross-sectional analysis (Figure 3d) demonstrated a significantly reduced maximum lumen area of 2.9 mm² (Figure 3d, left), confirmed by IVUS (Figure 3d, center), and followed by percutaneous intervention.

**Procedure planning using CTA**
Having prior knowledge of the complexity of the vascular system, e.g. the course, tortuosity, size and the length of the vessels, can be of enormous benefit to a diagnostic and therapeutic procedure. Modeling techniques have recently been developed that extract information from 2D Invasive coronary angiography projections to generate a 3D arterial model [17, 18]. From the model, optimal viewing angles for a coronary artery segment of interest can be visually displayed to the user in the form of a color map. The availability of this information has positive implications for interventional procedures, making them safer and more efficient.

CCTA, with its IVUS-like advantages, is an obvious fit for the above model [19]. As before, a CT-based 3D tree can provide identical information. If a pre-procedural CCTA has

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**Figure 3. Diffuse disease in the left anterior descending artery in a 64-year-old male.**

Figure 3a. CMPR from CCTA showing disease from the ostium to the stent.

Figure 3b. Invasive coronary angiography showing only a mild narrowing.

Figure 3c. Straightened MPR of the CCTA data.

Figure 3d. Cross-sectional CCTA images (left and right) showing reduced minimum luminal area, confirmed by IVUS (center).
already been performed, valuable information like the appropriate choice of guide wire, catheter, balloon and stent could be made available even before the patient enters the interventional laboratory.

From the information provided by the segmented coronary artery tree from the CTA scan, the model generates a four-quadrant color map showing areas of minimum and maximum foreshortening for a lesion of interest, with each quadrant representing the standard C-arm orientations (LAO-cranial, LAO-caudal, RAO-cranial, RAO-caudal). This CT optimal-view map (CT TrueView) also provides the operator with optimum C-arm orientations that result in minimum foreshortening for the given lesion. This information is extremely useful, not
only for a single lesion percutaneous intervention, but also for complex, multi-vessel, multi-lesion interventional procedures.

Figure 4 shows CT TrueView displays, with a model of the coronary artery tree in the main viewport. The segment of interest corresponding to the lesion in the right coronary artery (RCA) in this example is shown in yellow. The optimal view map (shown on the left of both figures) represents areas with various degrees of foreshortening, with areas in red indicating increased foreshortening and the green areas representing reduced foreshortening.

Figure 4a shows the orientation of the tree corresponding to a significant foreshortening for the segment of interest (with the location on the color map represented by a small white square in the red area). In contrast, Figure 4b shows the corresponding orientation of the tree with significantly reduced foreshortening (with the white square now located in the green area). In addition, the corresponding C-arm orientations are shown at the bottom. Thus advances in technology such as segmentation and dynamic modeling of the coronary arteries from a CCTA scan provides valuable information, paving the way to a more efficient interventional procedure even in challenging situations, such as stent placement for complex lesions, even in the presence of vessel overlap and bifurcations.

Taking this one step further, a proof-of-concept of an integrated approach linking the already-acquired CCTA data to the C-arm via registration has also been investigated [19]. This approach can provide the operator with a close look at the working view of the anatomy even before the acquisition is made. This integration has important clinical implications in the guidance of percutaneous interventions.

Successful intervention to treat a chronic total occlusion is predicated on the ability to:

• identify the route and course of the totally occluded arterial segment, along with the visualization of the distal vessel beyond the occlusion
• measure its length and diameter
• detect any tortuosity of the vessel proximal to the lesion, and
• identify the nature of plaque within the occlusion, which, if heavily calcified, may be a contraindication to the procedure.

In general, shorter, less calcified chronic total occlusions are easier to open [20]. CCTA is ideally suited to provide all the requisite data. The segments of the artery distal to the occluded area are always visible from CCTA (which is not always the case with interventional coronary angiography) because of the presence of collateral flow, thus providing a more accurate measurement of the length of the occluded segment with minimal foreshortening, no overlap, and a clear course of the vessel. This provides the operator with a good starting point for the procedure, thereby optimizing the success rate while also enabling contrast optimization and reduction of fluoroscopy time and radiation exposure. Lastly, the capability to analyze the types of plaque present makes it possible to decide on the optimum therapeutic interventional strategy.

Figure 5 demonstrates a successful interventional procedure based on a pre-operative CCTA scan. Selective invasive coronary angiography on a symptomatic 65-year-old woman with anterior ischemia showed flush occlusion of the LAD with partial collateral filling from the RCA (Figure 5a). After six months of persistent symptoms, CCTA guided intervention was planned. Curved multi-planar reformatting (CMPR) of the CCTA data clearly visualized the occluded LAD segment (Figure 5b, right).

CT TrueView of the left coronary artery and all its branches (Figure 5c) was imported to the catheterization laboratory monitor and electronically linked to the C-arm. The C-arm was rotated, with accompanying automatic update of the CT TrueView map, to the angle predetermined by the CCTA to best demonstrate the origin and course of the occlusion without overlapping branches. Simultaneous injection of the right and left coronary arteries (Figure 5b, left) was performed. With CT TrueView guidance, the guidewire was introduced to the precise origin of the flush occlusion, followed by successful recanalization (Figure 5d), and further stenting of the distal vessel six weeks later. Flush occlusions present a particularly difficult problem; without CCTA guidance, the operator can only guess at the origin of the occlusion, with a subsequent prolonged, often unsuccessful outcome.

Figure 6 is another example of a successful CCTA-guided intervention for treatment of a chronic total occlusion. Selective invasive coronary angiography in a symptomatic 55-year-old man with inferior ischemia showed proximal occlusion of the RCA with a very poorly visualized distal vessel (Figure 6a). A CMPR from the CCTA data showed the occluded segment, with a clear visualization of the distal vessel (Figure 6b), measuring 16.6 mm on the straightened MPR (Figure 6c), with minimal calcified plaque in the mid-portion. CT TrueView
Figure 5. A successful interventional procedure in a 65-year-old woman, based on a pre-operative CCTA scan showing occlusion of the LAD.

Figure 5a. Invasive coronary angiography with simultaneous injection of the left and right coronary arteries.

Figure 5b. CMPR from CCTA shows the occluded segment (right).

Figure 5c. CT TrueView and the optimal view map. The optimum viewing angle was predetermined by CCTA.

Figure 5d. Based on CCTA’s guidance, recanalization was performed successfully.

Figure 6. Proximal chronic total occlusion of the right coronary artery in a 55-year-old male, with successful treatment guided by CCTA.

Figure 6a. Invasive coronary angiography.

Figure 6b. Corresponding CMPR from CCTA showing the occlusion and also enhancement of the vessel distal to the CTO via collaterals.

Figure 6c. Straightened MPR from CCTA. The occlusion length measured 16.6 mm.

Figure 6d. The optimal view map of the CT TrueView determined the angle of least foreshortening.

Figure 6e. Corresponding view of the RCA.

Figure 6f. The CTO was successfully treated and stented.
of the RCA was generated (Figure 6d) and imported to the catheterization laboratory monitor. The C-arm was rotated to the CT TrueView determined angle of least foreshortening, thereby showing a good working view of the RCA (Figure 6e). The occlusion was easily opened and stented (Figure 6f). The information about the length of the occlusion, knowledge about the plaque content (minimal calcification) and the course of the distal vessel from the CCTA (missing from the ICA) predicted a successful outcome.

Thus, there is enormous potential for CCTA to enhance diagnostic and therapeutic strategy. Based on our experience, we have developed a CTA-guided percutaneous intervention paradigm at our institution, in which the patient selection for intervention is based on CCTA rather than stress testing [9, 10], with CTA derived measurements helping triage the patients to interventional or medical management. An extension of the integrated approach has also been investigated, wherein an active overlay of CCTA data is “merged” and shown in the background of a fluoroscopic image [19], thereby facilitating safer and more efficient interventional procedures.

Lastly, radiation dose concerns for CCTA are being addressed with the introduction of low-dose prospective acquisition techniques, resulting in radiation dose reductions of more than 80% [21] with image quality comparable to traditional techniques. These low-dose techniques have also been implemented in a newer generation of faster and wide-coverage multidetector CT scanners [22-24]. With these advances, the routine use of CCTA before percutaneous intervention, and consequently a CTA-guided percutaneous intervention paradigm, would direct treatment. Prospective validation studies of the CTA-based percutaneous intervention strategy are currently under way, investigating the safety, efficiency and success of interventional procedures.

**Conclusion**

The profound impact of CCTA on percutaneous interventions, while still greatly underappreciated, is inevitable. While the role of CCTA in treating chronic total occlusions is well recognized, it is only a matter of time before interventionalists acknowledge the limitations of relying on invasive lumenography in general, and take routine advantage of the plaque delineation and maximum lumen area measurement offered by CCTA. With the greatly decreasing radiation doses associated with prospectively-gated CCTA acquisitions, the routine use of CCTA before percutaneous coronary intervention becomes more attractive and feasible.

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**References:**


Clinical applications

MRI assessment of cardiac function in the newborn

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While a number of research tools for assessing circulatory status in preterm infants have been investigated, none have so far proven reliable in assessing cardiac function or cardiac output. While important advances in understanding of physiology have been made using echocardiography, the technique has poor repeatability [3], and is unable to accurately determine how well the heart muscle is contracting.

Cardiac magnetic resonance (CMR) techniques have significantly advanced understanding of cardiovascular physiology and pathophysiology in adults. These non-invasive assessments of cardiac health are now being gained faster, in more detail and with greater sophistication than ever before [4]. Techniques currently available in adults can accurately and reliably assess both contractility of the heart muscle and volume of blood ejected by the heart. In addition, tagging of distinct areas of heart tissue has permitted the complex contractile and rotational movement of the heart to be interrogated. However, until now, technical challenges have prevented the use of CMR in vulnerable preterm infants.

Scanning facilities

In 1996 an MR scanner was installed in the Neonatal Intensive Care Unit at Queen Charlotte’s and Chelsea Hospital. This enabled the safe study of brain development and injury in thousands of even the smallest, sickest preterm infants. In 2006 the system was upgraded to a Philips Achieva 3.0T MR scanner with full cardiac capacity.

Full intensive care facilities are available within the scanning suite, enabling us to safely perform MR scans on infants requiring ventilatory and inotropic support. Since its installation our group has been developing functional CMR techniques for study of the preterm transitional circulation.

Neonatal cardiac imaging

While the overall care provided to sick newborn infants has improved dramatically in recent decades, the most prematurely born infants remain at high risk of death and neurodevelopmental impairment. There is considerable evidence that circulatory factors play a central role in the pathophysiology of patterns of brain injury that result in poor long-term outcome in preterm infants. However, despite the importance of circulatory factors in determining outcome following premature birth, currently available clinical methods for assessing circulatory adequacy in preterm infants are inadequate, due to the complex nature of the unique circulation present during the transition from fetal to extrauterine life. Blood pressure remains the most commonly monitored indicator in neonatal units, despite its uncertain correlation with volume of blood flow [1]. Other clinical assessments such as capillary refill time, volume of urine output, etc. are of limited value in indicating circulatory health [2].

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Figure 1. Doll illustrating oxygen saturation, heart rate and temperature monitoring for MR scanning.
field strengths and can degrade imaging performance. However, while this is a particular problem over larger structures such as the adult thorax, the smaller size of the neonatal chest appears to produce less inhomogeneity, and excellent image resolution at 3T [5].

Early difficulties with susceptibility artifacts have been minimized with appropriate shimming. Shorter TR sequences have reduced artifacts produced by through-plane blood flow, and the associated temporal resolution of around 10 milliseconds has allowed us to acquire 32 phases of imaging despite neonatal heart rates of around 180 beats per minute.

CMR is highly sensitive to movement artifacts, such that in adult and pediatric cardiac imaging most techniques require image acquisition to occur either during episodes of breath-holding, or by use of a navigator bar to coordinate image acquisition with diaphragmatic movement. Both such techniques have a significant impact on the time required for image acquisition. A somewhat surprising advantage of neonatal cardiac imaging has been that high-quality images have been obtained without the need for such measures [5]. This improves the applicability of scanning in the neonatal population (by avoiding the need for intubation and ventilation) and reduces image acquisition time.

**Image sequences and optimization**

To give an idea of the challenges involved in obtaining satisfactory images of cardiac function in the extremely preterm neonate, Figure 2 shows same-scale images of a four-chamber cardiac view from an adult, and from a neonate weighing 590 grams at the time of scan.

Imaging at 3T provides a potential doubling of intrinsic signal-to-noise ratio (SNR) compared with conventional 1.5T platforms. This added signal confers a substantial benefit for imaging small neonates. This is certainly the case for neurological examinations, but there are challenges in realizing this potential for cardiac MR, as field inhomogeneities increase at higher

**Scanning process/stability**

Infants are scanned with oxygen saturation, heart rate and continuous temperature monitoring (Figure 1), with a pediatrician or trained neonatal nurse in attendance throughout each scan. Scans can be performed free-breathing, with the provision of nasal continuous positive airway pressure (NCPAP) or low-flow oxygen as clinically indicated.

In all cases cardiac MR images are obtained after infants have been allowed to fall into a natural sleep after a feed, with careful swaddling. Sedative medication has not been required. Protection from acoustic noise is achieved by applying moldable dental putty to the ears and covering them with neonatal ear muffs (Natus minimuffs, Natus Medical Inc., San Carlos, CA, USA). To date we have performed cardiac MR imaging in over 100 newborn infants without any adverse events.

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imaging parameters used for bFFE sequences are TR 4 ms, TE 2 ms, flip angle 45°, FOV 220 mm, matrix 144, in-plane resolution 1.5 mm, slice thickness 3-5 mm, temporal resolution approx. 10 milliseconds, 32 phases/cycle.

Four-chamber view
The four-chamber view demonstrates the left and right atria and ventricles, and is similar to an echocardiographic apical four-chamber view (Figure 3). The view is used predominantly to allow tracking of atrioventricular valves through the cardiac cycle to eliminate inaccuracy from the through-plane motion of the base of the heart. This base-to-apex shortening may also potentially be quantified using myocardial tagging techniques.

Short axis view
The short axis view demonstrates the left and right ventricles, and is similar to an echocardiographic parasternal short axis view (Figure 4). This is a key view when examining cardiac function. Views taken at a single level allow analysis of wall thickness and thickening through the cardiac cycle. The position of this single slice can be determined from the previously acquired four-chamber view, allowing for constant positioning at the mid-ventricular level. This permits enhanced accuracy of CMR over traditionally echocardiographic assessments, where small variations in transducer positioning may lead to significant variations in quantitative measures in the tiny preterm heart.

However, a “stack” of adjacent slices may also be acquired to allow assessment of global cardiac function. Short axis stacks therefore allow assessment of total left and right ventricular volumes at end-diastole and end-systole by tracing the endocardial border in each slice. Cardiac MR therefore provides enhanced accuracy over echocardiography as the two-dimensional nature of echocardiography means that assumptions, which are often inaccurate, have to be made about the shape of the ventricular cavities.

Assessments of global left and right ventricular function can be made either using Philips own Viewforum software, or with a number of commercially available packages. We are currently comparing quantitative data obtained from Viewforum analysis with that obtained from CMR Tools (Cardiovascular Imaging Solutions Limited, London) which allows modeling of a mesh of the endocardial or epicardial borders (Figure 5) and as mentioned above allows simultaneous tracking of the level of the atrioventricular valves, reducing inaccuracy from through-plane motion of the base of the heart.
Phase contrast imaging

Phase contrast imaging techniques allow quantification of volume of flow in any large blood vessel. The approximate imaging parameters used for bFFE sequences are TR 5 ms, TE 3 ms, flip angle 10°, FOV 250 mm, matrix 208, in-plane resolution 0.98 mm, slice thickness 4 mm, 20 phases per cardiac cycle.

Phase contrast measures of cardiac output at the level of the aortic and pulmonary valves allow internal validation of cardiac output (by comparing measurements taken by bFFE and phase contrast techniques). However, their particular value in the neonate lies in quantifying flow at multiple points in the circulation. The persistence of fetal shunt pathways in the preterm neonate means that neither left nor right ventricular output can necessarily be taken to represent true systemic or pulmonary perfusion. Cardiac MR allows quantification of flow in the superior vena cava (SVC) and descending aorta (DAo), both of which are considered to be markers of true systemic perfusion in the preterm neonate [3]. In Figure 6, static tissues are shown as mid-gray, flow in the head-foot direction is dark, flow in the foot-head direction is light.

By estimating velocity in each pixel covering the vessel throughout the cardiac cycle, a velocity-time graph is produced, with the area under the curve representing total volume of flow (Figure 7). Our initial data suggests that repeatability of phase contrast quantification of blood flow volume may be significantly improved when compared to echocardiography in neonates. Provisional data also suggests that measures of left ventricular output by bFFE and phase contrast techniques are closely related, so providing valuable internal validation of both techniques.

Comparison of CMR and echocardiography

While echocardiography has clear utility at the cotside, the technique is far from ideal. In particular, the relatively poor repeatability of echo flow measurements limits its use as an end-point in clinical trials of intervention.

Cardiac MR techniques have a number of advantages over echocardiography:
- Cardiac MR is less operator-dependent, enhancing repeatability
- Direct visualization of function in all areas of the heart obviates the need for assumptions of cardiac geometry, which are often overly simplistic
- Assessment of shortening in radial and axial planes (see below), along with assessment of rotational motion, provides multiple markers of contractility
- Multiple techniques allow internal validation of flow measurements
- Improved repeatability allows decreased subject numbers while maintaining the power of interventional studies
- Multiple assessments of intracardiac volumes, wall motion and blood flow will provide an enhanced appreciation of how clinical interventions impact on the three principal components of cardiac function – preload, contractility and afterload.

Placement of radial and axial plane slices

Placement of the radial and axial plane slices can be determined from orthogonal views, reducing error in quantitative measures from variability in image plane. This may be of particular value in assessment of velocity of circumferential fiber shortening, an afterload-correctable measure of “true” contractility taken from the short axis view. Afterload correction of functional measures is of particular significance in neonates, given the prominent role of peripheral vascular resistance in governing blood pressure in this population.

Future directions

Continuing rapid developments in MR technology mean that newborn infants will benefit from further advances in image quality, complexity and post-processing.

CMR-guided insights into neonatal circulatory function may in future be linked with the IUPS Physiome project [6] by registering neonatal
CMR images to computational models, potentially greatly advancing understanding of newborn circulatory physiology. We may also be able to investigate the importance of common genetic polymorphisms on newborn circulatory function [7] and response to therapeutic interventions.

The key ultimate goals of the project are to use CMR biomarkers to improve understanding of neonatal cardiovascular function in health and disease, employ biomarkers as endpoints in clinical trials of existing and emerging therapies, and allow standardization of bedside echocardiographic techniques to apply improvements in patient care to the largest number of sick newborn infants. In the long term we hope that improved ability to monitor and support heart function in premature babies will help infants to survive, and survive free from disability.

References


Improved clinical performance of myocardial perfusion SPECT imaging using Astonish iterative reconstruction

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Myocardial perfusion SPECT imaging is a useful tool to help diagnose patients suspected of having coronary artery disease or to assess patients with known disease. There has been significant growth in the number of these procedures, with about 8.9 million performed in 2007. The laboratories performing these procedures are under pressure to reduce costs, improve image acquisition efficiency, reduce absorbed radiation dose and improve diagnostic accuracy. Additionally, the recent shortages of 99mTc have further increased the call for more efficient use of 99mTc-labeled radiopharmaceuticals.

To address these needs, Philips has developed an improved reconstruction method termed "Astonish". Astonish improves reconstruction accuracy and makes more efficient use of acquired counts by incorporating internal modeling of the imaging physics in the reconstruction process. Astonish also provides for scatter and attenuation correction, which can mitigate artifacts in the imaging process that can reduce lesion contrast or mimic perfusion defects.

This paper provides a brief explanation of the reconstruction methods and presents clinical results of a recent multi-center trial designed to test performance of the Astonish algorithm for myocardial perfusion SPECT imaging. The clinical performance of Astonish was tested on both full-count and half-count stress-rest data, both with and without attenuation and scatter corrections [1]. Clinical performance of a stress-only imaging approach that can further improve laboratory efficiency was also tested on full-count and half-count data with scatter and attenuation corrections [2].

The half-count data gives the nuclear physician the option of improving efficiency by reducing the acquisition time using conventional dosing protocols, or reducing the radiation dose and, potentially, radiopharmaceutical costs by injecting less radioactivity while using more conventional acquisition times. The improved diagnostic accuracy of attenuation-corrected data enabled stress-only interpretations. Elimination of the resting portion of the exam further reduces radiation exposures and improves laboratory efficiency.

Reconstruction methods

Iterative reconstruction methods are well suited to improve image quality and clinical performance. This is done by incorporating internal modeling of the imaging physics in SPECT reconstructions to correct for the major factors affecting image quality. These factors include degradation of spatial resolution with increasing distance of the source from the collimator, Compton scatter and photon attenuation.

The degradation of spatial resolution with distance from the collimator reduces the overall spatial resolution in the images and can produce non-uniformity artifacts in the heart. Scattered photons detected in the energy window reduce image contrast and interfere with the ability to efficiently perform attenuation correction. Non-uniform photon attenuation may produce artifacts that can mimic perfusion defects if not corrected. Attenuation correction also plays an important role in differentiating artifacts from true defects with stress-only imaging. Astonish is an OSEM (Ordered Subsets Expectation Maximization) iterative method that incorporates statistical noise reduction [3] and depth-dependent resolution recovery through internal modeling of the imaging physics. When an attenuation map is present, Astonish can additionally perform Compton scatter correction and attenuation correction.

Figure 1 provides a diagram of the OSEM iterative process using three ordered subsets as

Myocardial perfusion SPECT imaging is a useful tool for diagnosis and assessment of coronary artery disease.

Astonish improves reconstruction accuracy.
In the iterative process, a new estimated image is calculated by multiplying the previous image by a modifier matrix to produce the subsequent image. In other words, the next image \((n + 1)\) is produced by multiplying the previous image \((n)\) by a modifier matrix \((n)\).

The modifier matrix is developed using subsets of the projection data as described below. The “ordered subsets” are a limited number of the total projections. For example, two ordered subsets of 64 total projections are the 32 odd projections \((1, 3, 5 \ldots 63)\) and the 32 even projections \((2, 4, 6 \ldots 64)\).

A key to understanding iterative reconstruction methods is the understanding of how the modifier matrix is calculated and applied throughout the process. Figure 2 depicts conceptually how the modifier matrix (shown in green) is produced in a three-step process. Note that the process is shown only for one projection angle, so these steps must be repeated for all of the angles in a subset to produce the modifier matrix for that subset.

In the first step, the values in the image matrix (shown in blue) are forward-projected to produce an estimated projection, \(E_\theta\). As shown, Astonish uses a constant value as the initial image estimate.

In the second step, the estimated projection is compared with the measured projection, \(P_\theta\), to produce an error estimate by taking the ratio \(\frac{P_\theta}{E_\theta}\). In this step to minimize the image noise, Astonish uses a matched filtering procedure. In the matched filtering step, both the estimated projection and the measured projection are filtered by smoothing the quantity \(\frac{P_\theta}{E_\theta}\).

Performing the smoothing within the iterative process preserves spatial resolution and improves uniformity of the myocardium (by minimizing the impact of image noise). By comparison, smoothing after completing the iterative process would reduce spatial resolution in the final resulting images.

Figure 1. Depiction of the OSEM iterative reconstruction process showing the relationship between the image estimates at each step and the modifier matrix. As the image estimate becomes “closer” to the image of the true object, the amount of change in the modifier matrix becomes smaller.

Figure 2. The modifier matrix is calculated in a three-step process. The first step is the forward projection (from reconstruction plane to projection plane) of an image consisting of pixels all having the same count values in the image matrix to produce an estimated projection (which is a constant value for the initial image estimate).

The next step is to compare the measured and estimated projection values including smoothing (filtering) of the result using the matched filter. The third step is to back-project (from projection plane to reconstruction plane) the error estimate into the modifier matrix. This three-step process is then repeated for all of the projection angles in the subset (not shown in the Figure).
In the third step, the smoothed error estimate, $P_{\Theta}/E_{\Theta}$, is back-projected into the modifier matrix. This is repeated until all the angles in a single subset are utilized. Once all of the subsets have been utilized, a single iteration has been completed. Note that while Figure 2 shows only a single representative projection angle, the process is repeated for each of the angles in a subset. This means that the modifier matrix is updated for all of the projection angles in a single subset. A single iteration is then completed when all of the subsets have been used to update the modifier matrix and all of the measured projection angles are used.

The spatial resolution of the collimator degrades with increasing distance from the surface of the collimator. Compensating for this effect can improve image quality. The Astonish algorithm performs depth-dependent resolution recovery as shown in Figure 3. The change of spatial resolution with distance from the collimator is calibrated in the software. During the acquisition of patient data, the distance from the collimator to the center of rotation is recorded for each projection angle. During the reconstruction process, the changes in spatial resolution with distance are calculated in both the forward-projection in the image matrix and in the back-projection in the modifier matrix as shown in Figure 3. The counts are spread over multiple pixels during both the forward- and back-projection steps and the degree of broadening is determined by the distance between the pixel and collimator using the collimator resolution response function.

Non-uniform attenuation can produce attenuation artifacts in the perfusion images that mimic perfusion defects. These defects may be reduced by performing both scatter and attenuation correction. When an attenuation map is present, the Astonish algorithm can perform scatter and attenuation correction in addition to resolution recovery.

Scatter correction is performed using the ESSE method (Effective Source Scatter Estimation) [4]. This method uses the concept of defining an effective source distribution of scatter, calculating the expected scatter projection data from this effective source of scatter photons, and adding this calculated scatter projection data to the projection of the estimated image to produce the total estimated projection $E_{\Theta}$. The estimate of the scatter is calculated from the image estimate and density map by convolving the image estimate with a three-dimensional scatter convolution kernel. This convolution kernel is pre-calculated and is dependent upon the photon energy.

The attenuation correction method is illustrated in Figure 4. Attenuation is modeled only during the forward-projection process using both the image matrix and the attenuation map to calculate the estimated projection, $E_{\Theta}$. A tissue transmission density image is acquired with a radionuclide scanning line source or a CT scanner, either simultaneously or sequentially with the emission scan. Since the emission and transmission images typically involve different photon energies, the transmission density images are scaled to the appropriate photon energy using the mass attenuation coefficient to
produce a matrix of linear attenuation values known as the “attenuation map”. The attenuation map is used to calculate the amount of attenuation from each point in the object through the body in the image matrix. Figure 4 shows the path along which the counts in the image matrix are attenuated. This calculation is performed during forward projection to produce attenuated estimated projections, $E_\theta$, at each projection angle.

Clinical testing methods

The clinical imaging performance of Astonish, and Astonish with scatter and attenuation correction, was evaluated recently in a multi-center trial. Image quality, diagnostic confidence and diagnostic accuracy for detection of coronary artery disease were evaluated on data from 187 consecutive patients undergoing clinically indicated myocardial perfusion SPECT studies. The patients underwent subsequent cardiac catheterization (132 patients) or had a low likelihood of coronary artery disease (55 patients).

All studies were acquired on Philips CardioMD small field of view gamma cameras with Vantage™ Gadolinium-153 scanning line sources. The line sources were used to acquire the transmission data. The data were acquired according to ASNC imaging guidelines [5]: LEHR collimator, 64 projections at 20 seconds/projection for the stress and 30 seconds for the rest images. An 180° RAO-LPO orbit was acquired beginning at 15 – 45 minutes after injection of 30-35 mCi of a $^{99m}$Tc agent for the stress studies and 10 mCi for the resting studies. Tc-99m-sestamibi was used in 176 patients and Tc-99m-tetrofosmin in 14 patients. The energy windows were set at 140 keV +/- 10% for the emission and 100 keV +/- 10% for the Gd-153 line source transmission data and 118 keV, +/- 6% for down scatter correction. The half-count study was derived from the full-count study by stripping out “every other” projection from the original 64 projection data set. The processed images were interpreted in a blinded fashion without knowledge of the number of projections used in the reconstructions and without knowing if attenuation correction was or was not applied.
The images were reconstructed using three different methods: conventional filtered back-projection, Astonish, and Astonish with attenuation correction.

Conventional filtered back-projection (FBP) images were reconstructed using a Butterworth filter for pre-filtering of the projections (order 5 and cutoff frequency of 0.45) for the perfusion images, and ECG-gated images were reconstructed in the same way, except that a cutoff frequency of 0.35 was used.

Astonish and Astonish with attenuation correction used four iterations, eight subsets and a Hanning match filter parameter of 1.0. ECG-gated images used the same number of subsets and iterations, with a Hanning match filter parameter of 0.8.

**Coronary angiography**
The percentage of minimal narrowing was determined visually at each lab and reported. The angiographic reports from each center were submitted to a single laboratory where the location and percentage of luminal stenosis narrowing was extracted from the reports for the left main and the three major coronary arteries and their major branches. The percentage of luminal narrowing was determined visually. Significant disease was defined at a 70% stenosis threshold in one or more major coronary arteries, or 50% stenosis in the left main artery, and this value was used for CAD diagnosis unless otherwise specified.

**Results**

There was a statistically significant improvement in image quality for both full-count and half-count images reconstructed with Astonish in comparison with those reconstructed with filtered back-projection (FBP) (Figure 5).

There was no statistical difference in the interpretive certainty of full-count and half-count images reconstructed with Astonish, $p = 0.18$. This demonstrates the ability of Astonish to achieve good image quality with half the counts (Figure 6).

There was no statistical difference in the diagnostic accuracy of full-time data reconstructed with filtered back-projection or full- or half-count imaging using Astonish (Figure 7).

There was a statistically significant improvement in specificity and normalcy when myocardial perfusion data was corrected for scatter and attenuation. This was true for both full-count and half-count data (Figure 8).

In the stress-only portion of the trial, patient studies were interpreted without using the rest
images of the studies. When the patient studies were interpreted using the stress images reconstructed using Astonish with attenuation correction, a high degree of diagnostic accuracy was obtained as shown in Figure 9.

The stress-only data also provided a high level of diagnostic confidence for both the full- and half-count data. The levels of diagnostic confidence are shown in Figure 10.

Additional comparisons were performed on the full- and half-count stress-only data. There was no statistical difference for summed stress scores, ejection fraction or the need for resting images between the full-count and half-count data. In the population studied, there was a desire for resting data in approximately 20% of the images interpreted with stress-only images. These results are presented in Figure 11.

Finally, a comparison was performed between stress-only half-count Astonish with scatter and attenuation correction and traditional rest/stress FBP SPECT. The same diagnostic accuracy was found despite using only a single image set (stress-only) and with half the counts.

**Conclusions**

When images were reconstructed using Astonish without attenuation correction, this study demonstrated significant improvements in perfusion image quality for both full- and half-count data. Furthermore, there was no loss in diagnostic accuracy using coronary catheterization as the gold standard.

When full- and half-count data were reconstructed using Astonish with scatter and attenuation correction, this study demonstrated
a significant increase in normalcy and specificity with no significant loss in sensitivity.

These data demonstrate that the use of Astonish technology with or without attenuation correction improves image quality and may be applied to reduced acquisition time studies without compromising diagnostic accuracy. The ability to reduce imaging times should lead to reduced patient discomfort, reduced likelihood of patient motion, and improved laboratory throughput and overall efficiency. Alternatively, absorbed radiation doses can be reduced by injecting less activity while imaging for conventional imaging times.

The stress-only results demonstrate that perfusion and gated imaging can be performed on half-count data with high diagnostic accuracy, acceptable image quality, high interpretive certainty, similar defect extent and severity to full-time acquisitions, and a low perceived need for rest imaging. Performing studies using stress-only increases patient acceptance, further reduces radiation doses (compared to stress/rest half dose imaging), and improves laboratory efficiency.

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References


Clinical applications

From recognition to reperfusion in acute myocardial infarction: a call for a comprehensive community approach

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An acute occlusion of a coronary artery is a vascular emergency. Outcomes for non-treatment, or substantial delay in treatment, of the acute occlusion of coronary arteries can result in crippling cardiac insufficiency or death.

Organized, modern healthcare systems place a high degree of focus on prompt evaluation and treatment of patients suffering from acute myocardial infarction (AMI). In spite of these efforts, even in the developed countries, death from cardiovascular disease remains at the top of the list of all causes of mortality.

The magnitude of the advancement in the care of the AMI patient over the last two generations is so vast as to almost deny belief. This author can only reflect with amazement at the increase in treatment modalities available today as compared with the early 1970’s when he trained. Then, a patient with an AMI would receive pain control, oxygen, and a program of bed rest, the injured myocardium setting its own course. The patient experiencing increased shortness of breath with a chest X-ray suggesting pulmonary congestion would typically receive digoxin and a diuretic. As many as a third of AMI patients would succumb to their disease, and if the AMI was associated with acute congestive heart failure the figure would be significantly higher.

It is useful to reflect upon the advances in medical care for the AMI patient that have led to the present era and the astounding advances that have been made. Aspirin became understood as beneficial to these patients. Sophisticated monitoring devices for emergency personnel, such as easy-to-use monitor/defibrillators (Figure 1), have become more widely available.

The 1980’s brought the advent of thrombolysis, and shortly afterwards came the ability to dilate a plaque in a coronary artery via catheterization. Today, we have the astounding capability of precisely locating the offending clot and fractured plaque in the involved artery, the penultimate step in a complex series of events leading from the patient’s bedside at home to the percutaneous coronary intervention (PCI) laboratory at a nearby hospital, where cath labs have proliferated in sophistication, safety, and success.

A bit of gray hair brings remarkable appreciation of this transition and advancement. Those who have only recently entered medical practice might consider our ability to intervene in AMI in such a definitive manner – indeed directly resolving on an emergent basis the acute vascular occlusion and restoring blood flow, leaving behind a stent to prevent restenosis – in an almost casual manner. However, the astounding success of modern programs for rapid intervention in AMI is the result of the increasing sophistication of all elements in the complete cycle of cardiac care. The care cycle has been described in detail by J. van den Hurk and A. Mukherjee in a recent issue of Medicamundi [1]. The success of the AMI programs also allows us to see even more clearly where the problems still lie today in the identification and management of patients with AMI.

Figure 1. An easy-to-use monitor/defibrillator: the Philips HeartStart MRx.
Identification and management

A critical, and arguably principal, factor in the spectrum of the impact of cardiac disease is patient denial. This denial occurs in two ways, both of which directly affect the issues of revascularization on both an acute and chronic basis.

The first way that denial affects patient care is in the chronic circumstances that produce atherosclerosis. The many elements which affect the presence and progression of atherosclerosis, from heredity, to hypertension, to sedentary lifestyle, to elevated and/or suboptimal blood lipids, etc., can be significantly altered with respect to their ability to induce cardiovascular morbidity and mortality. It is in denial, either overtly or covertly, that patients place themselves at an increasing medical risk over time. Very significant progress has been made through public education, such as attitudes to smoking, which have clearly had a positive influence on the outcome of cardiovascular disease, and have generally improved the public health overall.

The second area of denial is with the onset of symptoms. Patients experiencing acute chest pain, with or without related symptoms such as nausea, diaphoresis, shortness of breath, fatigue, etc., will distinctly benefit from the activation of a well-trained and appropriately-equipped emergency medical services (EMS) agency to attend, treat, and provide prompt transport to an appropriate facility. Yet, even today, many patients deny the onset of symptoms for hours or even longer, often with disabling or even lethal results.

A modern EMS system with trained EMS personnel can usually identify the presence of an AMI, occasionally confounded by variables such as left bundle branch block and left ventricular hypertrophy, and provide prompt treatment, including transport to a hospital facility which stands ready on a 24 hour per day basis to promptly activate the PCI lab and initiate care.

Many patients and/or their families either persist in the denial of symptoms, and/or transport themselves to a hospital by private means. Such private transport of someone suffering from an AMI is unsafe for the patient, not to mention the potential risks from a patient or family member possibly driving at high speed. Patients transported privately may not get aspirin, pain control, oxygen, and ECG monitoring, and the risk of sudden death occurring while en route is substantial. In spite of these risks, or unaware of them, as many as 60 – 80% of patients with AMI present to hospitals by private vehicle [2].

Patients presenting by private vehicles to an area emergency receiving facility may also significantly prolong the period of time until reperfusion is accomplished. Moreover, patients with AMI transported by private vehicle have a significant chance of presenting to a hospital that is not equipped to manage the clinical problem, including possibly not having a PCI lab available for prompt activation. Not all hospitals have active PCI labs. At the time of the writing, for example, 17 of the 21 acute care hospitals in the Dallas County, Texas area have PCI laboratories available at all times [3]. Thus, at any given moment an AMI patient being transported by private means within the breadth of Dallas County has roughly a 1 in 5 chance of arriving at a hospital without PCI capability.

Variations in electronic equipment create confounding problems for EMS system managers. The present era finds at least three manufacturers of electrocardiographic monitors for EMS agencies providing capability of transmitting 12-lead electrocardiograms (ECG’s) from the field to the hospital in the setting of patients having chest pain. Urban centers utilizing a single type of monitor throughout that system generally can achieve ECG transmission to the receiving PCI facility promptly and with a high degree of reliability. For example, MedStar Ambulance Service, in Fort Worth, Texas, utilizes Philips HeartStart MRx monitors and achieves reliable, internet-capable ECG transmission to area hospitals. This allows the receiving staff, including the cardiologist who will be treating the patient, to have the field ECG available virtually immediately and to initiate the activation of the PCI lab (Figure 2).
Recently, the ECG and Arrhythmia Committee of the American Heart Association (AHA), the American College of Cardiology (ACC) and the Heart Rhythm Society (HRS) published a series of recommendations for the standardization and interpretation of the ECG. One of these (Part VI) is specifically concerned with acute ischemia/infarct [5]. The recommendations take into account new developments in technology, new imaging modalities, and new insights into the electrical activity of the heart. The consequences for automatic electrocardiographs with interpretative algorithms, such as the Philips DXL diagnostic algorithm, are discussed elsewhere in this issue of Medicamundi [6].

A reasonable concern for PCI lab activation based upon paramedic interpretation of ECG’s is in the potential for false activation of the PCI facility. The Dallas area experience suggests that a false activation rate of one in seven cases (or less than one in seven) can be reliably maintained. Area hospitals in the Dallas area will activate hospital PCI labs based upon paramedic interpretation of ECG’s, achieving substantial improvement over cases in which ECG transmission was technically difficult or impossible in “Field ECG acquisition to balloon times”.

**A call to action**

This era in the history of medicine is bringing change at an ever-increasing rate. Indeed, we stand on the verge of a novel achievement, with “prehospital emergency care” now being considered as a budding new medical subspecialty. We in the house of medicine now must embrace, as never before, the full spectrum of community public health involvement. Our challenge now is to utilize our resources to continue to get at core principles that may increase the rate and scope of the improvement of the health of the public.

A realistic approach to assessment of our work in the rapid deployment of emergency cardiac care (ECC) resources requires that we solidify our relationships with those whom we serve. No reasonable appraisal of our ECC system is complete without including in the equation the...
interval from initial onset of symptoms (the moment of “recognition”) until the vascular emergency has been resolved (the moment of “reperfusion”). “Recognition to Reperfusion” must be the essential underpinning of ECC system design. Anything less is deficient and does not fully inform as regards the total ECC system’s impact. “R-to-R” must be the leading energy in our efforts and in our analyses.

Opportunities for improvement are boundless. For example, EMS electronic medical record software now has a common federal data management standard, the National EMS Information System (NEMSIS) [7]. Compliance with NEMSIS data management and reporting standards allows EMS systems managers to manipulate and analyze patient care data as never before.

An example of EMS data management opportunities is to create a report such as, “List (all) Cardiac Arrest Patients (for) Citizen CPR = “No” (and) List “Zipcode” (and) “Address”. The findings of this report may be imported into Geospatial Information System mapping software, indicating locales, companies, and institutions in which experience has shown that citizen CPR is seldom if ever performed and where CPR training could be offered. Through such an effort a pressing public health problem – poor cardiac arrest outcomes – can be addressed utilizing clinical experiences gained through the newly-emerged data reporting standards.

Conclusion

In the final analysis, it may be said quite correctly that we now stand at the threshold of incredible opportunities for service to our citizens and patients. “Recognition-to-Reperfusion” must be the watchword of our STEMI networks, as we continue to implement a comprehensive community approach to myocardial infarction, empowering our citizens to help themselves and to help each other.

“Recognition to Reperfusion” must be the essential underpinning of ECC system design.

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Advances in ECG recognition of acute myocardial ischemia/infarction

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Acute occlusion of a coronary artery leads to the irreversible loss of cardiac muscle and with it, unstable cardiac rhythms, including ventricular fibrillation and sudden death, and impaired contractility resulting in heart failure. The ability to identify and open the occluded vessel and to restore blood flow with thrombolytic drugs, coronary angioplasty or bypass surgery prior to the onset of these irreversible changes will prevent the above-mentioned consequences.

The electrocardiogram (ECG) is the one and only test currently available that can be recorded virtually anywhere an electrocardiograph is present. It provides an immediate result that can be quickly interpreted by trained personnel and/or by an automated, computerized electrocardiograph with interpretive algorithms, provided these automated algorithms are accurate and dependable. The ability to open acutely occluded coronary arteries before myocardial cell necrosis occurs is one of the most dramatic advances in the care of patients with coronary artery disease, but this ability is time-dependent. For this reason, the more rapidly the diagnosis of acute ischemia/infarction is made, the more likely the chance of successful intervention. Similarly, the more able an automated computerized ECG system is able to accurately detect an acute ischemic event and to provide the physician with information that will aid him/her in the choice of diagnostic and therapeutic options, the more useful and potentially life saving it becomes.

Recently, the ECG and Arrhythmia Committee of the American Heart Association (AHA), in concert with the American College of Cardiology (ACC) and the Heart Rhythm Society (HRS) published a series of Scientific Statements concerning recommendations for the standardization and interpretation of the ECG [1-6]. These recommendations recognized and took into consideration the changes in technology, the recently recognized ECG manifestations of both cardiac and non-cardiac diseases that affect the electrical activity of the heart, and the correlative information obtained from newly developed imaging modalities such as echocardiography, magnetic resonance imaging, and a variety of nuclear techniques that have been developed within the last 25 years. These recommendations considered the Technology (Part I), Nomenclature (Part II), Intraventricular Conduction Disturbances (Part III), Repolarization and the QT Interval (Part IV), Chamber Enlargement (Part V) and Acute Ischemia/Infarct (Part VI).

The purpose of this article is to discuss the recent changes in our understanding and interpretation of the electrocardiographic manifestations of acute myocardial ischemia and infarction that are reflected in the recommendations in Part VI of the standards documents, and to relate the new features contained in the Philips DXL diagnostic ECG algorithm [7] to these recommendations. The changes in our appreciation of the electrocardiographic changes of acute ischemia/infarction are important because they impact on our ability to diagnose more promptly and accurately acute myocardial ischemia and infarction, and because they provide clues as to the precise location of the lesion responsible for the ischemic event. As such, they carry with them the opportunity to affect therapeutic decisions that are capable of altering the natural history of this debilitating and potentially lethal disease.

The recommendations contained within the AHA/ACC/HRS Scientific Statement considering acute ischemia/infarction (Part VI) [6] include the following:

1. That labeling specific leads as anterior/inferior/lateral be avoided. Rather leads should be labeled according to their original nomenclature, i.e. I, II, III etc.
2. That the electrocardiograph be equipped with switching systems that allow the limb leads to be displayed in their anatomically contiguous sequence, i.e. aVL, I, aVR, II, aVL, III if so desired by the user/institution.
3. That threshold values for abnormal J-point elevation or depression be adjusted for age and gender
4. That software capable of displaying the ST segment spatial vector in the frontal and transverse planes be employed
5. That algorithms be employed to suggest, whenever possible, the occluded artery and the site of the occlusion within that artery
6. That ECG machines be programmed to suggest recording of the right-sided chest leads V3R and V4R in the appropriate setting; that they be able to label these leads; and that algorithms be developed to describe and interpret abnormalities that may occur in these leads
7. That use of the term “posterior” be retained, at least for the present
8. That algorithms suggesting ischemia/infarction in the presence of left bundle branch block that meet recently described criteria be employed
9. That algorithms capable of determining the “Selvester Score” be made available for optional use by the reader.

We will briefly summarize the rationale for these recommendations which are considered more completely in the original articles [1-6].

The first recommendation recognizes that all leads are actually bipolar (the negative pole of the chest leads being Wilson’s central terminal, comprised of the leads I, II and III) and that the various components of the ECG waveform, i.e. the QRS complex, ST segment, T and U waves, may be negative as well as positive. As such they not only reflect electrical events that are directed towards the positive electrode, which in the case of the chest leads is the recording electrode, but also those occurring 180° away from the positive electrode. For instance, a negative QRS complex in V1 reflects a QRS spatial vector directed away from this lead, i.e. posteriorly and to the left, as anticipated by the greater mass of the left ventricle which is located posteriorly and to the left. Similarly, depression of the ST segment in V1 reflects an ST segment spatial vector that is directed away from this lead as occurs in acute ischemia/infarction of the posterior wall. Thus, the leads provide information from the entire heart and not just from the area under the respective positive lead.

The second recommendation recognizes that the current display of the frontal plane leads in groups of three (I, II, III and aVR, aVL, and aVF) are traditional and does not present the leads in their anatomically contiguous sequence. This is accomplished by the Cabrera format of aVL, I, -aVR, II, aVF, III. This format was recommended in the 2000 European Society of Cardiology/ American College of Cardiology guidelines [8]. It is the current standard and commonly used in Sweden and Spain.

The third recommendation recognizes that the junction of the beginning of the ST segment with the end of the QRS complex, the J point, is normally slightly elevated, particularly in the chest (V) leads, and that the amount of this normal ST elevation is age-, gender- and lead-dependent. In general, the J point is highest in leads V2 and V3 and is greater in men than in women. For these reasons thresholds that vary from 0.05 to 0.2 mV (0.5 to 2 mm at standard calibration), depending on the factors identified above, are recommended for these leads.

Recommendations 4, 5 and 6 are interrelated and are based on the recognition that the coronary artery housing the culprit lesion and the location of the lesion within that vessel (i.e. proximal or distal) can often be predicted from analysis of the leads with ST segment depression as well as ST segment elevation, and that this ability might influence the decisions of those having initial contact with the patient, such as Emergency Medical technicians, Emergency Department nurses and Emergency Department physicians.

Analysis of the leads with depression as well as elevation of the ST segment allows creation of the ST segment spatial vector. This permits identification of the region of the heart affected by the acute ischemia/infarction and, by inference, the site of the culprit lesion. For instance, occlusion of the left anterior descending coronary artery (LAD) causes ischemia and infarction of the anterior/lateral wall of the left ventricle and, depending on the length of the vessel, on the cardiac apex. This results in an injury current that will be directed to the left, towards the positive poles of leads V2-V6, resulting in elevation of the ST segment in some or all of these leads. If the lesion is in the proximal portion of the LAD, the basal portion of the left ventricular wall will also be involved and the spatial vector of the ST segment will also be directed superiorly, towards the positive poles of leads I and aVL and away from the positive poles of leads III and aVF. This will be reflected by elevation of the ST segment in leads aVL and I, and depression of the ST segment in leads III and aVF. If the lesion is in the mid- or distal portion of the LAD, the basal region of the left ventricle will not be affected and the ST segment changes in leads aVL, I and III, and aVF will not occur.

The location of a lesion can often be predicted from ST segment depression as well as elevation.
The new Philips DXL diagnostic ECG algorithm incorporates AHA/ACC/HRS recommendations.

Occlusion of the posterior descending coronary artery, regardless of whether it arises from the right or left circumflex coronary artery, will cause acute ischemia/infarction of the posterior wall of the left ventricle. The injury current and, therefore, the spatial vector of the ST segment will be directed posteriorly, away from the positive poles of leads V1 and V2, which are located anteriorly. This will result in depression of the ST segment in these leads.

Since there are no chest leads routinely placed over the posterior wall of the left ventricle (in the V7, V8, and V9 positions), there will be no ST segment elevation recorded in any of the routinely recorded chest leads. If, as usually occurs, the inferior surface of the left ventricle is also involved, elevation of the ST segment will be present in leads II, III and aVF.

If the culprit lesion is in the proximal portion of the right coronary artery, the right ventricle will also be affected and an injury current will be directed to the right and anteriorly as well as inferiorly, i.e. towards the positive pole of lead III and away from the positive pole of aVL. As a result the ST elevation will be greater in lead III than in lead II and ST depression will be present in aVL. In this situation, recording from leads with the positive pole placed over the right ventricle in positions referred to as V3R, V4R, V5R, V7, V8 and V9 will reveal ST elevation.

If both the right ventricle and posterior wall of the left ventricle are involved, the injury current directed anteriorly and to the right may be cancelled by the injury current that is directed posterior and to the left, with the result that ST depression in leads V1 and 2 may not occur and the ST elevation in leads V4R and V3R will be attenuated. However, the ST segment spatial vector will still be directed inferiorly and to the right; the elevation of the ST segment will still be greater in lead III than in lead II and ST depression will still be present in lead aVL.

Thus, by considering the leads with depression as well as elevation of the ST segment, the spatial vector of the ST segment can be generated and from that, the location of the culprit lesion can be predicted. This is facilitated by the ability to record, label and interpret leads V3R, V4R, V7, V8 and V9 as well as the standard V leads.

Recommendation 7 is included because of recent information obtained from magnetic resonance imaging studies which suggests that the myocardial region referred to as “Posterior” on the basis of autopsy studies is actually lateral, and some have suggested that ECG nomenclature should be changed to recognize this fact [9]. However, it was decided that while this may become the consensus in the near future, the current terminology should be retained for the present.

Recommendation 8 recognizes that criteria for diagnosing infarction in the presence of left bundle branch block have been published [10] and, although there is some controversy regarding the sensitivity and specificity of these criteria, it is recommended that algorithms employing these criteria be developed to suggest the possibility of acute/ischemia in the setting of left bundle branch block.

Recommendation 9 is self-explanatory. The Selvester score is a QRS scoring system used to quantitate infarct size [11]. It correlates well with infarct size measured by other techniques, and although not in widespread clinical use at the present time, is likely to become more popular in the future.

The new Philips DXL diagnostic ECG algorithm contains several features that pertain to the recommendations discussed above [7]. These include the following:

- Appropriate lead labels using original nomenclature
- Availability of anatomically contiguous lead sequence in aVL, I, -aVR, II, aVL, III
- Age-, gender-, and lead-specific differences in thresholds for ST segment elevation
- Capability of recording, labeling and interpreting leads V3R, V4R, V5R, V7, V8 and V9
- When an acute inferior wall infarct is detected and right chest leads are not connected, the algorithm suggests recording of right chest leads to check for right ventricular involvement
- Visualization of ST segment vector “ST-Map”
- Identification of culprit lesion
- Recognition of ECG changes indicative of left-, main- or multi-vessel occlusion.

In addition, a new “Critical Value” feature in the Philips DXL algorithm helps identification of ECG changes associated with life-threatening situations requiring immediate medical attention.

Examples of tracings and the associated automated interpretations produced by the DXL algorithm are shown in Figures 1, 2, and 3. The tracings are from three patients with symptoms suggesting an acute coronary event.

In Figure 1, the changes are those associated with an acute inferior wall infarction with posterior wall involvement, and these are recognized by the DXL algorithm. In this patient, leads V3R,
left and slightly superior orientation of the frontal plane vector suggests that the basal aspect of the left ventricle is also involved. It is this combination of findings that prompts the diagnosis of an occlusion of the left anterior descending coronary artery (LAD) which is included in the computerized reading. Indeed, the involvement of the basal portion of the left ventricle, as indicated by the ST segment changes in leads aVL and III, indicate that the culprit lesion is in the proximal portion of the LAD.

V4R (the leads placed on the right side of the sternum) and leads V8 and V9 (the chest leads positioned on the back, i.e. the posterior leads), in addition to the routine 12 leads, are recorded and considered in the interpretation. Note that the interpretation also identifies the culprit lesion as being in the Right Coronary Artery (RCA). It does this because the magnitude of ST segment elevation is greater in lead III (4 mm) than in lead II (3 mm) and because there is depression of the ST segment in lead aVL. This identifies an injury current directed slightly to the right as well as inferiorly. This spatial orientation of the ST segment is illustrated in the ST-Map derived from the limb leads, i.e. the frontal plane ST vector.

Had the lesion been in the circumflex coronary artery, the changes indicating an infero-posterior infarction would still have been present and the injury current would have still have been directed inferiorly but the ST segment would not have been more elevated in lead III than in lead II (indeed, it may have been greater in lead II than in lead III) and there would not have been ST segment depression in lead aVL.

The diagnosis of the posterior infarction results from the ST segment depression in leads V2 and V3 and the ST segment elevation in lead V9. These ST segment changes identify the posteriorly directed injury current which is shown in the ST-Map that is derived from the V leads, i.e. the horizontal plane ST vector. In this patient, the right ventricle might also have been infarcted as the result of the right coronary artery occlusion, but the characteristic ST elevation in the right-sided chest leads V1, V3R, and V4R indicative of the anteriorly and rightward directed injury current associated with the right ventricular infarction is cancelled by the posteriorly and leftward directed injury current associated with the posterior infarction.

Figure 2 shows the changes associated with an acute infarction of the left ventricular anterior and lateral walls. Note the ST segment elevation in leads I, II and aVL and in leads V2-V4. Note also the ST depression in lead III. In this example the ST segment vectors in the frontal plane (derived from the limb leads) and the horizontal plane (derived from the V leads) are shown. In the frontal plane, the ST vector is oriented to the left and slightly superiorly, reflecting the ST elevation in I and aVL and depression in lead III. In the horizontal plane, it is oriented to the left, anteriorly and laterally. The left and anterior orientation of the vector suggests that the anterior and lateral aspects of the left ventricular wall are involved, while the left and slightly superior orientation of the frontal plane vector suggests that the basal aspect of the left ventricle is also involved. It is this combination of findings that prompts the diagnosis of an occlusion of the left anterior descending coronary artery (LAD) which is included in the computerized reading. Indeed, the involvement of the basal portion of the left ventricle, as indicated by the ST segment changes in leads aVL and III, indicate that the culprit lesion is in the proximal portion of the LAD.
Figure 3 shows marked ST segment depression in leads I, II, aVF and leads V2-V6. There is ST segment elevation only in lead aVR. There is also atrial fibrillation and the possibility of combined ventricular hypertrophy. It is possible that the diffuse ST segment depression could be caused by ventricular hypertrophy and perhaps by digitalis, if the drug was being administered. However, in a patient with symptoms suggesting an acute coronary event, these ST segment changes are highly suggestive of a subtotal occlusion of the left main coronary artery or severe diffuse three-vessel coronary artery disease. The ST segment vector is directed away from all the body surface leads, with the exception of lead aVR, indicating that it is directed inwardly from the epicardium towards the endocardium and the right shoulder. This is a most important electrocardiographic finding because it warns of the presence of a life-threatening event demanding immediate medical attention. The critical value printed on the report “>>> >>> Acute Ischemia <<< <<<” serves this purpose.

These tracings exemplify many of the features of the DXL ECG algorithm and satisfy recommendations 1-7 listed above. The threshold values for J-point elevation and depression of the ST segment that are appropriate for the age and sex of the patients have been applied (Recommendation 3); leads V4R, V3R, V8 and V9 are recorded, labeled and interpreted automatically when appropriate (Recommendation 7); the ST vectors in the frontal and horizontal planes are displayed utilizing information from all leads (Recommendation 4) and this information is then processed to facilitate identification of the culprit lesion (Recommendation 5). The DXL algorithm is available with Philips electrocardiograph PageWriter TC series in 12-lead, 15-lead or 16-lead configurations and other user specific lead configurations, as shown in Figure 4 [12]. The DXL algorithm is also available with Philips defibrillator/monitor HeartStart MRx in 12-lead configuration, as shown in Figure 5 [13].

These tracings and the other advances in the DXL ECG algorithm referred to above also illustrate the dynamic nature of the electrocardiogram, and its ability to meld advances in the understanding of the electrical activity of the heart with the recognition of new diseases having an electrocardiographic
signature such as Arrhythmic Right Ventricular Dysplasia/Cardiomyopathy. They also demonstrate the improved ability to visualize the heart in vivo utilizing new and improved imaging techniques, and the advances in computer technology to provide more comprehensive and accurate diagnostic statements that impact directly on patient care.

It is reasonable to anticipate that, in the future, ECG nomenclature will change as correlations to the newer imaging techniques become more robust and that interpretative statements will evolve to reflect the increased informational content of the electrocardiogram.

References


Managing with obstructive sleep apnea

Obstructive Sleep Apnea (OSA) is a potentially serious breathing disorder that disrupts healthy sleep, leading to excessive day-time sleepiness and possibly contributing to the development of several adverse health conditions. People with OSA frequently complain about feeling tired, and may nod off at work, while doing activities with family or friends, or watching TV. Many people dismiss these symptoms as the consequences of their busy lifestyle. They insist they will be fine if only they could get “a good night’s sleep.” For these unfortunate sufferers, however, a good night’s sleep is elusive due to an untreated disease process.

When a person sleeps, there are two main phases of sleep: REM (Rapid Eye Movement) sleep and non-REM sleep, with non-REM sleep accounting for about 75% of sleep time and REM sleep accounting for the remaining 25%. During non-REM sleep, a person progresses through a series of sleep stages from drowsiness and light sleep (Stage 1) through to deep sleep (Stage 4).

During non-REM, the patient’s respiratory rate will decrease, heart rate will decrease, and blood pressure will fall as the body enters a restorative phase of sleeping. About every 90 minutes, a person will enter REM sleep. During this phase, the heart and respiratory rate may rise compared to NREM sleep. During the night, a person without OSA will be able to maintain oxygenation and ventilation due to normal respiratory drive and function (Figure 1).

In a patient with OSA, the normal restful pattern is disturbed. As the patient enters sleep (both REM and non-REM sleep), the airway becomes unstable and either partially (hypopnea) or completely collapses (apnea) (Figure 2). The collapse of the airway leads to a substantial reduction in airflow to the lungs causing a decrease in ventilation and oxygenation. The brain senses these changes and sends a signal through the nervous system to increase ventilation. When this does not occur due to the obstructed airway, the patient will generally have to awaken in order to take an adequate breath.

Simultaneously, the sympathetic nervous system is activated, stimulating the heart and vasculature. As the patient awakens, he or she restores airway patency and hyperventilates to correct the low oxygen and high carbon dioxide. In addition, heart rate and blood pressure surge. Once the blood gases are corrected, the patient relaxes, and reverts to sleep. Throughout the night, the cycle of airway collapse and sympathetic stimulation will occur repeatedly. In individuals with OSA, these pauses in breathing can be as few as five times per hour or as many as hundreds of times per night.

OSA can affect anyone, but is commonly found in men, post-menopausal women, individuals who are overweight, and individuals with a history of snoring or family history of sleep apnea. In the United States, it is estimated that up to 5-6% of the adult population may have sleep apnea and 1 to 3% of children are affected.

Contributing risk factors in the development of
OSA include gender, race, obesity, aging, and upper airway anatomical structure (that is, the small airway behind the tongue, uvula, and soft palate). In children, sleep apnea is generally associated with large adenoids and tonsils [1].

Dangers of untreated sleep-disordered breathing

Left untreated, OSA can lead to adverse physical as well as cognitive consequences, in addition to the potential for increased automobile accidents. At a minimum, excessive daytime sleepiness can diminish productivity, increase irritability, and lead to mood swings and possibly an increase in cognitive errors that could jeopardize the patient’s employment. At its worst, an OSA sufferer may fall asleep on the job causing a major industrial accident threatening not only themselves but also others [2]. An increase in the risk of cardiac arrhythmias while sleeping is also possible [3].

Far more serious in the long run are the potential adverse cardiovascular consequences associated with untreated OSA. A number of studies suggest that sleep apnea contributes to the development of hypertension, stroke; myocardial infarction, Type II diabetes, congestive heart failure (CHF), and depression [1,4,5,6,7].

Not surprisingly, cardiologists and other healthcare providers treating patients with OSA tend to focus on how the patient presents while awake to determine problems that may be occurring during sleep.

Diagnostic criteria and methods

As 80 – 85% of individuals with OSA remain undiagnosed [3], people with this disorder are more likely to see a healthcare provider for fatigue, or other health-related issues instead of seeing their physician specifically for a sleep complaint. In addition, patients may seek treatment because of prompting from their bed partner. Because individuals suffering from OSA usually find ways to cope with excessive sleepiness during the day, they may not realize how exhaustion affects their activities.

It is important for healthcare professionals to be aware of common signs and symptoms of patients who may have sleep apnea, and to ask patients basic questions about their sleep habits when examining for other common disorders linked with OSA. The common signs and symptoms of sleep apnea are:
- Loud disruptive snoring
- Witnessed apneas or cessation of breathing during sleep
- Choking or gasping
- Morning grogginess or sleepiness
- Dry mouth, or dry or sore throat on waking
- Reduced libido
- Depression, moodiness or irritability.

The questions that should be asked of patients suspected of having the disorder are:
- Do you snore loudly at night?
- Has anyone observed you to gasp or stop breathing during sleep?
- Do you feel refreshed when you wake up in the morning or are you tired during the day?
- Have you ever woken up choking or gasping?
- Do you have a history of hypertension?

If a sleep apnea is suspected, the doctor will usually recommend that the person go to a sleep lab where polysomnography - or sleep study - can be performed. A sleep study is a comprehensive overnight examination during which a number of physiologic variables are monitored while a patient sleeps. Before falling asleep, the individual is outfitted with electrodes and sensors applied to the head, face, chest, finger and legs.

The sensors record brain activity, eye movement, muscle activity, heart rhythm (ECG), breathing, respiratory effort, and oxygenation during sleep. After the study, the signals are scored and the number of apneas (complete cessation of breathing for more than 10 seconds) and hypopneas (decrements in breathing for more than 10 seconds) per hour of sleep can be determined. This is called the apnea-hypopnea index (AHI). These data can delineate the presence and severity of sleep apnea.

Once sleep apnea has been identified, an effective course of treatment needs to be determined. Frequently, patients will have a study where the first half of the night is used to diagnose the sleep apnea while the second half of the night is used to initiate therapy. The patient could then be discharged from the laboratory with a treatment for the disorder in hand. The following are the diagnostic criteria for Obstructive Sleep Apnea based on an Apnea Hypopnea Index obtained from the polysomnogram:
- AHI equal to, or greater than 15 events per hour or
- AHI equal to or greater than 5 but less than 15 events per hour with documented symptoms of excessive daytime sleepiness, impaired cognition, mood disorders, insomnia, hypertension, ischemic heart disease or history of stroke.
- If the patient fits either criteria, they are then eligible for treatment by PAP therapy.

Obstructive Sleep Apnea (OSA) is associated with potential adverse cardiovascular consequences.
Treatment options

In cases of mild sleep apnea, certain lifestyle changes can sometimes achieve positive results. The following are common recommendations for patients with mild sleep apnea:

- Exercise and proper sleep habits: increased physical activity helps reduce body weight and contributes to healthy sleep.
- Weight Loss: Losing weight will usually improve sleep apnea and if the reduction in weight is enough, may lead to a complete cure.
- Oral Appliances: These devices generally advance the mandible during the night thereby pulling the tongue off the posterior pharyngeal wall. The use of oral appliances has been shown to reduce the number of apnic and hypopnic episodes when fitted correctly [8].
- Avoidance of alcohol and sleeping pills: Alcohol and certain sleeping or pain medications can make throat muscles relax more than normal so they cannot keep the airway open effectively at night. Alcohol and medications can also make it harder for the brain to register the oxygen deficiency caused by an apneic episode resulting in longer and more serious pauses in breathing.
- Sleeping on the side of the body: Sleeping on one’s back allows gravity to pull the tongue, soft palate, and uvula into the airway, causing the upper airway to become narrow or collapse completely. Sleeping on the side minimizes these effects.

CPAP delivers a steady, constant pressure during inspiration and exhalation (Figure 4). If patients have difficulty with CPAP, alternative forms of PAP therapy can be offered such as bi-level therapy or Auto CPAP. Bi-level therapy provides two different levels of pressure to the patient while he or she sleeps. With bi-level therapy (Figure 5), the patient receives one level of pressure on inspiration, and a lower level of pressure on expiration. By reducing the pressure on expiration, breathing may be more comfortable for the patient. A second alternative therapy used for patients with OSA is Auto CPAP. Auto CPAP provides PAP with the pressure being constantly adjusted throughout the night based on airway patency. The internal algorithm of the device constantly determines the needed pressure, based primarily on flow patterns, and maintains the pressure at the lowest effective pressure (Figure 6). With Auto CPAP, the prescribed pressures will vary throughout the night but the patient’s airway will be kept patent, generally at a lower average pressure.

To provide PAP therapy to a patient, a mask or interface best fitting the patient’s lifestyle, facial contours, and sleeping requirements needs to be selected. There are a variety of masks available for patients with OSA. Traditional full-face masks cover the nose and mouth and are better for patients who breathe through their mouths while asleep. Nasal masks, which cover only the nose, are the most commonly prescribed interfaces for patients with OSA. A growing number of patients are seeking alternative nasal masks with smaller, lighter configurations that cover the nose or the mouth. The goal of the provider is to work with the patient to determine the best interface that will allow the patient to sleep comfortably through out the night with the mask sealed. Finally, humidification of the air passing through a PAP device has been shown to improve comfort and compliance [9].

Patient education and follow up

Adjusting to life with CPAP therapy can be challenging. While great strides have been made toward increasing patient comfort through modifications of pressure profiles, humidification, and mask comfort, the fact remains that a person with OSA must wear a mask to bed. This adjustment in lifestyle – and comfort – can take some time to get used to, not only for the patient, but also for the patient’s bed partner.

Patients and their partners or caregivers need to work together with their healthcare providers to overcome issues related to their treatment and correct any problems early in the treatment.
surgery is often not effective and there are currently no good methods to determine in which patients these procedures will be curative. However, certain patients prefer this approach to CPAP.

Conclusion

Obstructive sleep apnea remains a common and potentially debilitating disorder that can affect the health and quality of life of the afflicted individual. However, with proper diagnosis, identification of appropriate therapy, and a conscientious effort from healthcare providers, OSA can be overcome and a consistently good night’s sleep attained.

Other therapies for moderate to severe obstructive sleep apnea

If the patient ultimately finds CPAP unacceptable, other therapeutic approaches need to be considered. Second line therapy for most patients would be an oral appliance. As stated above, these devices connect to both the upper and lower teeth and advance the mandible (lower jaw). As the tongue is attached to the mandible, it moves forward as well often leading to improved airway patency during sleep. Although such appliances are often easier to use than CPAP, they are not completely effective in many patients. Thus, a repeat sleep study is often needed with the device in place to assess efficacy.

Third line therapy is generally surgery of the upper airway. Most such surgeries involve removal of the uvula and portions of the soft palate with or without moving the tongue forward. The primary problem with this approach is that the surgery is often not effective and there are currently no good methods to determine in which patients these procedures will be curative. However, certain patients prefer this approach to CPAP.

References


Clinical applications

Vessel Explorer: a tool for quantitative measurements in CT and MR angiography

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High-resolution CT- and MR-Angiography (CT-A and MR-A) have become important in the diagnosis and characterization of vascular pathology. Each of these imaging techniques has its own strengths and weaknesses, and in some aspects they complement each other. Both techniques produce high-resolution image volumes that may take a relatively long time to read without proper tools.

Dedicated advanced packages are available from various sources to help analyze CT-A and MR-A. These applications often aim at providing a combination of several tools for vascular diagnosis, including tools for bone removal, vessel segmentation, path tracking, stent planning, curvilinear and straightened reformats, Maximum Intensity Projections (MIP) and 3D visualizations, and quantitative measurements of vascular lesions. Although each of these tools may provide useful results, this may happen at the cost of requiring considerable user interaction. For straightforward measurements, such as the degree of stenosis, these tools are often considered as cumbersome, complex or requiring too much interaction. This is why routine measurements such as stenosis degree, stenosis length, or vessel diameter are usually done by using “eyeballing”, i.e. assessment with the unaided eye of the expert, even though referring physicians may prefer specific quantitative measurements.

Vessel Explorer

Vessel Explorer is a tool that provides radiologists with robust quantitative measurements of vessels in CT-A and MR-A in a quick, simple, and intuitive way.

Our challenge in developing Vessel Explorer was to build a tool that would be attractive enough for radiologists to move from eyeballing to quantitative measurements in their daily clinical practice. We identified the following requirements:

• measurements of local diameters and degrees of stenosis should be fast and simple (resembling eyeballing) and require very little interaction: clicking near the point(s) of concern should be sufficient to obtain the needed measurements (stenosis, diameter, dilatation, length) and visualizations (cross-sectional, longitudinal, and curvilinear reformats)

• inter-user and intra-user variability should be minimized by robust computations that centers the user’s click into the intended vessel

• the tool should provide a harmonized common interface for CT-A and MR-A.

In order to achieve these requirements, we have used several types of embedded, non-obtrusive automated functions, including local vessel segmentation, robust path tracking, optimal vessel-aligned visualizations and automatic contrast settings. The algorithms have been optimized and validated for CT-A and for several variations of MR-A.

Automation

In conventional tools, user interaction is required in several steps for assessment and quantification of vascular disease, for example optimal Multiplanar Reformatting (MPR) orientation, window width/level adjustments, delineation of vessel centerline and lumen contours. Such manual interaction is time-consuming and introduces inter-user and intra-user variability. Under time pressure, the required manual interactions or the complexity of advanced applications may lead the radiologist to avoid the use of these tools and to perform eyeballing. To make use of quantification tools attractive, we have introduced multiple automation steps
in Vessel Explorer: automatic optimal MPR alignment, automatic window width/level settings, automatic lumen contour delineation and semiautomatic vessel centerline computation.

**Automatic optimal MPR alignment**
A basic step involved in assessment of lumen diameter or stenosis degree is the visualization of cross-sectional and longitudinal reformats of the vessel. It is often cumbersome to determine these reformats manually: it takes several seconds, it is error prone and contributes to variability. Therefore, automatic MPR alignment is very important. In conventional applications, MPR alignment is usually achieved by first tracking a centerline of the vessel under study, and then computing a plane that is orthogonal to the centerline. In those applications, path tracking is a pre-requisite to achieve a cross section reformat.

Our goal was to have a fast one-click approach to generate cross-sectional and longitudinal reformats of the vessel. When the user clicks at a location under study, an algorithm performs a local Principal Component Analysis of the volume gradient in the neighborhood [1]. The result of this analysis is the local direction of the vessel. Longitudinal and cross sections can then be automatically computed, parallel and orthogonal to the main vessel direction respectively.

**Automatic lumen contour delineation: the “ring”**
One of the most attractive automation steps of our application is a one-click lumen contour delineation. From the delineation, local vessel parameters such as vessel minimum and maximum diameter, area, and mean and standard Hounsfield units may be derived.

The cross section automatically computed in the previous step serves as input for another algorithm (the “ring” algorithm) that fits a circle to the lumen edge by minimizing a cost function based on a variation of the Full-Width Half-Maximum criterion (Figure 1).

This algorithm allows the radiologists to skip the tedious task of delineating the lumen contour manually, and it avoids the inter-user variability associated with manual delineation, as has been shown in our validation studies.

**Validation of the ring**
We have performed two validation studies for the ring algorithm: one for MR-A and one for CT-A.

**MR-A validation of the ring**
In the MR-A study, a hydraulic system was built consisting of a computer controlled pump (CompuFlow 1000 MR, Shelley Medical), a phantom of the carotid bifurcation with 50% stenosis in the internal carotid artery (reference diameter 6 mm, stenotic diameter 3 mm, model C50-SSTWV, Shelley Medical), a manually driven syringe to inject gadolinium into the circuit, hoses, and special taps.

The phantom was set into a neck coil, and the coil was placed in the MR scanner (Philips Achieva 1.5T). Two data acquisitions without flow were performed at high resolution (voxel size of $0.25 \times 0.25 \times 0.13$ mm, acquisition time 10 minutes). Three acquisitions (one without flow and two with a flow of 20 cm³/s) were performed with the conventional protocol applied in clinical carotid studies (voxel size of $0.5 \times 0.5 \times 0.5$ mm, acquisition time 40 s).

Four clinical application experts were asked to estimate the stenosis degree manually by drawing...
CT-A validation of the ring

For the CT-A validation study, 20 CT data sets were selected from a collection of data gathered from different sites and scanners. There were 13 abdominal, 3 head/neck, and 4 peripheral cases. A total of 186 positions and orientations were chosen among the 20 data sets. Four clinical application experts were asked to manually delineate the lumen contour at each position and orientation. Then, a gold standard contour was derived from the four manually drawn contours by a repeated averaging technique [2]. Once the gold standard was created, the ring algorithm was applied at each of the 186 positions to determine the lumen contour. The ring contour was compared to the corresponding gold standard contour in the following way. For each point of the ring contour, the distance between the point in the ring and the closest point in the gold standard contour was used as an error measurement. The results summarized in Table 1 show that the error of the ring algorithm is similar to the error of the four application experts.

Manual diameter measurements

If the vessel is locally in close proximity to bone, or in the presence of large calcifications or stents, the automatic lumen contour delineation algorithm may give unsatisfactory results. To solve this problem, there are several options: use of the “measurement probe”, minimum diameter adjustment, and contour editing. The measurement probe is a tool that displays a circle at the mouse position. The mouse wheel is used to adapt the diameter so that the user can fit the circle to the lumen edge. The minimum diameter adjustment allows two points to be dragged with the mouse to fit the lumen diameter. The third option is to manually edit the contour points of the lumen delineation.

Semiautomatic plaque removal

In CT-A cases, our application offers the possibility to set a plaque threshold value in order to exclude the plaque from the ring.

<table>
<thead>
<tr>
<th>User</th>
<th>Mean error (mm)</th>
<th>Std error (mm)</th>
<th>Max error (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ring</td>
<td>0.26</td>
<td>0.14</td>
<td>1.84</td>
</tr>
<tr>
<td>User 1</td>
<td>0.26</td>
<td>0.14</td>
<td>1.66</td>
</tr>
<tr>
<td>User 2</td>
<td>0.21</td>
<td>0.14</td>
<td>2.01</td>
</tr>
<tr>
<td>User 3</td>
<td>0.23</td>
<td>0.14</td>
<td>1.78</td>
</tr>
<tr>
<td>User 4</td>
<td>0.26</td>
<td>0.14</td>
<td>2.12</td>
</tr>
</tbody>
</table>

Table 1. Error measurements for the CT-A validation study.
Figure 5. Semiautomatic plaque removal. Figure 5a. The contour includes plaque. Figure 5b. The plaque is excluded from the contour.

Figure 6. The importance of automatic window width/level computation is illustrated here. On the first image from the left, the window width/level is computed for the aorta. If the same settings are applied in the second image (corresponding to a small peripheral vessel), due to the blurring of the scanner, the vessel is perceived as being smaller than the real size. This can be corrected by re-computing the window width/level automatically (third image). However, the new settings are not valid for the aorta (fourth image).
Accurately as a true centerline through the center of the vessel. When the path is not defined through the center, this can result both in measurement errors and visualization artifacts. Manual delineation of centerlines is a cumbersome task, is prone to error and contributes to variability. Clinical practice therefore requires automated delineation of centerlines.

Our tracking algorithm allows accurate semiautomatic creation of a centerline while using as inputs only a start and an end point and the scale of the vessel of interest. By using these two points, a coarse centerline connecting these points is computed. After the coarse centerline has been found, it is refined and centered to the vessel.

The algorithm has been optimized and validated for CT and MR protocols that generate images where the vessel lumen is brighter than the surrounding tissue, such as bTFE, ToF and SSFP. Figure 8 shows several examples of tracked paths for different types of data. Initial results on validation of the centerline tracking algorithm have been presented in [3].

User interface and task guidance

The most important part of Vessel Explorer is the 3-click tool for measurement of stenotic lesions and the associated easy reporting based on secondary captures. In addition, Vessel Explorer offers other measurements (also based on lumen rings), to measure dilatation, length along a vessel, and angles between vessels. To support manual measurements, Vessel Explorer offers the measurement probe (explained in the section “Manual Diameter Measurements” above) that can be used to measure diameter, area and Hounsfield statistics.
Figure 8. Examples of centerlines computed by the vessel tracking algorithm (top row) together with the resulting curved planar reformats (bottom row).
Left: example of a centerline tracked through the femoral and iliac artery in a CTA dataset.
Middle: example of a centerline tracked through the femoral artery in an MRA dataset.
Right: example of a centerline tracked through the common and internal carotid artery in an inflow MRA dataset.

Figure 9. Vessel Explorer User Interface. The task flow guidance panel is on the left. The inspection window in the middle shows a MIP giving an overview of the case. A single mouse click suffices to compute a lumen delineation and optimally aligned cross-sectional and longitudinal sections as shown in the MPR window on the right.
arrows pointing to the lesion and reference rings, as shown in Figure 10. For the measurement an entry appears in the measurement table at the bottom of the inspect window. This allows navigating back to these measurements, in case multiple measurements are made.

For the occlusion in the left carotid a 3D annotation “occlusion” is created, visualized by a label and arrow like the stenosis measurement, and included in the measurement table. A secondary capture can now be made from the ‘inspect window’ that is stored to PACS and neatly summarizes the measurement and annotation results in one image.

The procedure described above takes longer to read than to perform. The whole procedure can be observed as a movie on the Medicamundi website (www.philips.com/medicamundi). The movie shows how a stenosis can be measured and reported within 60 seconds.

Reporting

In Vessel Explorer, reporting is done via secondary capture images. All measurements have 3D labels that can be placed freely so that they do not block the view of the anatomy. The user can create a secondary capture sequence showing all relevant views. To support reporting via the generation of captures Vessel Explorer offers:

- A table with all measurements the user has done: the table serves as a navigation aid to the measurements. When a measurement is selected from the table the system will jump to that measurement and show its first ring in the vessel-aligned views.
Conclusions

In this paper, we have presented a tool that provides radiologists with robust quantitative measurements of vessels in CT-A and MR-A in a quick, simple, and intuitive way. The tool requires minimal interaction while efficiently providing the frequently required measurements and reports. We hope that this will help to make quantification attractive enough for radiologists to replace eyeballing.

The automation algorithms have been validated for CT-A and various kinds of MR-A. In problematic cases where the algorithms fail, simple and quick manual corrections can be performed. We expect that the availability of our easy-to-use application in stand-alone workstations, scanner console, and PACS, combined with a harmonized user interface for CT-A and MR-A, will help to support the daily workflow of the radiology department.

Further research

Although the automation level of Vessel Explorer is relatively mature, further improvement is anticipated for future releases, including automatic vessel scale selection and semiautomatic plaque analysis. In the current version, the user needs to provide a rough estimation of the size of the vessel under study (small, medium, or large). Even though this action requires only a single mouse click, we intend to automate this in a future release. Plaque analysis is becoming more and more important in stroke risk assessment. The current version of our application does not support plaque analysis yet. We intend to change this in a future release.

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References


Investigations and research

Patient-specific heart models for diagnosis and interventions

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Today’s imaging devices such as CT and MR scanners provide a vast amount of high-quality images with high resolution in space and time. A wealth of patient-specific information can be obtained from these images that is both diagnostically and therapeutically relevant. For example, for a patient with ischemia and infarction induced by coronary-artery stenosis, information about the heart function, myocardial perfusion and scar tissue can be derived from imaging studies. With this additional information, the therapy can become more targeted and better adapted to the patient’s individual needs and risks. The provision of the patient-specific information during the actual treatment is also beneficial. This applies in particular to interventions in the cath lab, as even the anatomical details of the heart are hardly visible with conventional X-ray imaging.

Though the images contain a huge amount of information, this information is not readily available and must be extracted from the images. Numerous methods have been developed for this purpose [1]. Time-consuming manual approaches are a serious hurdle in routine clinical practice and the need for an efficient clinical workflow drives the development of automated methods. A suitable method of presenting the information is also needed that allows, for instance, integration of complementary information from different scans as well as the intuitive display of the information during an intervention.

We propose to generate a digital patient-specific heart model and integrate all the required information into this model. While the model represents the relevant aspects of the patient’s anatomy and associated function, it is independent of the actual imaging protocols and modality. To generate the patient-specific heart model, we match a generic heart model to 3D images of the patient [2, 3]. While previous approaches have been tailored to a specific imaging modality or protocol, our framework can be applied to different imaging protocols or modalities. This is achieved by separating knowledge about the organ shape from knowledge about image appearance and algorithmic considerations. In this article, we investigate the generality and portability of our technology by applying it to three different image analysis tasks:

• Adaptation of a whole heart model with attached major vascular structures to contrast-enhanced CT data
• Adaptation of a whole heart model to non-contrast-enhanced MR data
• Adaptation of an accurate model of the aortic valve to contrast-enhanced CT data.

Furthermore, we illustrate the use of our technology for diagnostic and interventional applications. By segmenting time-series of CT images, we can assess the volumes of all four heart chambers over time and provide information about local wall motion. For the guidance of ablation procedures for atrial fibrillation, models of the left atrium and pulmonary veins can be generated from CT, MR and rotational X-ray. Finally, we outline application of the aortic valve model for the guidance of percutaneous aortic valve treatment.

Generation of patient-specific organ models

As mentioned above, we generate patient-specific models by adapting generic models to images of a specific patient. Figure 1 shows the overall architecture of our framework. The central component of this architecture is a generic organ model, to which a wealth of information can be attached. This generic organ model describes the organ shape, its variability and its appearance for an imaging modality or protocol. The framework separates knowledge about the organ shape from knowledge about image
multiple images based on the same mesh topology are available, the mean shape of the organ can be generated. For complex models, meshes may also be generated for individual parts and fused in a second step.

**Generic model shape and variability**

To create the generic model shape, a representative image is selected and the organ of interest is manually annotated, i.e. each voxel of the image is assigned a label corresponding to the anatomical part of the organ. Based on the annotation, a multi-compartment triangular surface mesh is generated. Once annotations of appearance, which facilitates adaptation to new imaging modalities or protocols. In addition, the generic model includes information that controls the sequence and parameters of the steps for model adaptation.

Figure 2 shows the models used in the following sections. The whole heart model comprises the endocardial surfaces of both ventricles and both atria, the epicardial surface of the left ventricular myocardium and the trunks of the great vessels (aorta, pulmonary artery and pulmonary veins). This model has been extended and the major vascular structures (aorta, pulmonary veins,
coronary sinus, inferior vena cava, superior vena cava) have been added. The model of the left atrium and pulmonary veins represents a part of this model. The last model represents the detailed anatomy of the aortic valve.

For model adaptation, a parametric model of shape variability is beneficial. For that purpose, we assign separate linear transformations (e.g., rigid with scaling, affine) to suitable anatomic sub-regions. To ensure smooth connections between the sub-regions, we linearly interpolate the individual transformations in pre-defined transition regions. For the whole-heart model, this description of shape variability turned out to be better than statistical shape models derived from principal component analysis [3]. At the same time, this description can be used to model bending and diameter variations of vascular structures [4].

Appearance model
During model adaptation, the boundaries of the target organ must be detected in the image. Boundary detection is supported by appearance information that is learned from a set of annotated reference images and corresponding meshes. During a training phase, the images and meshes are used in a first step to create a large number (500 – 10,000) of boundary detection function candidates which use gradient information and gray-value information on one or both sides of the mesh. For gray-value calibration, information about global gray-value statistics can also be used [5]. In a second step, “Simulated Search” assigns an optimal boundary detection function to each triangle. The selection process works as follows for each triangle independently:
• The pose of the triangles in the reference meshes is slightly disturbed
• The boundary detection process using the given boundary detection function is performed
• The residual error between the detected point and the reference position is recorded for all tested displacements and all function candidates
• The candidate with the smallest simulated residual error is finally selected.

We create the annotated images and corresponding meshes by the following approach. In the first step the mesh is adapted to very few (1 - 3) manually annotated images. The resulting reference meshes are sufficient to train a first set of boundary detection functions by “Simulated Search”. This initial model is then adapted to a larger set of images and the result is thoroughly refined, e.g., by a clinical expert. With the new reference images and meshes, we then train a second set of boundary detection functions. The process of automatic adaptation, manual refinement, and training of new boundary detection functions is continued until sufficient reference images and meshes are available.

Adaptation control
Automatic adaptation of the generic shape model to an image is typically achieved in several steps [2, 3]. First, we use the generalized Hough transform (GHT) to roughly localize the organ in the image and adapt the size. Secondly, location, orientation and scaling are refined. To this end, boundary detection is performed for each mesh triangle and the parameters of the similarity transformation are modified to minimize the sum of squared distances between the mesh triangles and the detected boundaries. Boundary detection and parameter refinement are iterated until no major changes are observed. Thirdly, the parameters of the combined linear transformations that characterize the shape variability (See above: Generic Model Shape and Variability) are adapted by iterating boundary detection and parameter refinement. Finally, a deformable adaptation is performed. Again boundary detection and mesh refinement are iterated until convergence. In this phase, the locations of all mesh vertices are optimized during mesh refinement until a balance is reached between the geometric constraints defined by the generic shape model and the forces attracting the mesh to the detected boundaries.

The process of model adaptation can be modified in various ways. To speed up model adaptation, the adaptation process described above may be done with a low-resolution mesh model and a final deformable adaptation step with a high-resolution mesh model may be added. Reliable adaptation of vascular structures can, for instance, be achieved by adapting the four heart chambers first and successively activating the tubular segments representing the vascular structures. The information about the adaptation steps that are actually carried out, the mesh resolution or other parameters related to the different steps as well as information about the adaptation order of different model parts is contained in a control file of the generic organ model.

Examples
Generation of a generic organ model for a specific imaging modality or protocol requires experience and time. Once available, adaptation to an image and generation of a patient-specific model is normally fully automatic and requires about 10-15 seconds on a standard state-of-the-art workstation.
We show results for three examples. First, we show results for the whole-heart model with the major attached vascular structures. 35 CTA data sets from 20 patients (reconstructed at various cardiac phases) were used for building the generic model, while 37 additional data sets from 17 patients have been used for testing model adaptation. Secondly, we present results for the whole heart model and adaptation to MR images. Here, we used 42 steady-state free-precession MR end-diastolic breathing compensated “whole-heart” images, acquired to inspect the coronary arteries. Thirdly, we show results for the aortic valve model based on 16 CTA data sets acquired with scanners from different manufacturers.

The accuracy of model adaptation is assessed by measuring the symmetrized mean Euclidean “surface-to-patch” distance, i.e., the mean distance between the triangle centers of the adapted mesh to an anatomically corresponding patch of maximum geodesic radius $r = 10$ mm of the “ground truth” reference mesh and vice versa. This distance is averaged over triangles and test images. For the whole-heart model with major vascular structures, the distal parts of the coronary sinus and inferior vena cava are excluded. These structures are not contrasted in many images and no “ground truth” could be defined. Furthermore, the triangle positions near the artificial cut planes of the truncated vessels in the whole heart models are excluded from the error measurement, since the cut planes do not relate to actual anatomy. For the aortic valve model only the mesh elements representing the aortic bulb, the aortic valve, and the outflow tract have been evaluated.

For whole-heart adaptation to MR images and aortic valve adaptation to CTA images, we used the same data sets for training the generic model and for model adaptation. To avoid a bias we used a cross-validation approach. We divided the MR images into four clusters of 10/11 images, used three clusters for training, one cluster for accuracy measurements, and repeated this process for the four clusters. On the CTA data, we used a leaving-one-out approach, i.e., we trained the model on all images except the one for testing, and repeated this for all images.

Figure 3 shows typical results and allows visual comparison of the contours of the adapted model with the image structures. Numerical accuracies of model adaptation are between 0.5-0.8 mm (see Table 1).

### Exploring diagnostic and interventional applications

On the one hand, we are investigating the use of patient-specific heart models to extract and represent diagnostic information. This is illustrated for the characterization of the heart function from cardiac CTA images. On the other hand, we are investigating the possibility of supporting interventions by generating models for the specific application and visualizing them in combination with X-ray images in the CathLab.

### Heart function from CTA

Once a patient-specific heart model has been derived from an image with sufficient accuracy, volume measurements of the heart chambers are straightforward. Consequently, applying the method to images of different heart phases enables automatic characterization of global heart function (Figure 4). This is confirmed by initial clinical investigations for cardiac CTA [6, 7], where our method has been compared to three manual and semi-automatic tools for the assessment of left ventricular volumes and related measures. A further clinical study [8] evaluates the use of our method for the assessment of four-chamber cardiac function.

With slight modifications [9] that enhance the consistency of heart model adaptation over the...
Specific model of the left atrium can be geometrically aligned with the fluoroscopy images and displayed, for example, as an image overlay [10] (Figure 6).

The patient-specific model may be generated from pre-interventional CTA or MRA images. Recently, we also developed an approach to derive a patient-specific model of the left atrium and pulmonary veins by a rotational X-ray imaging technique during the intervention [11]. Each approach has its advantages and disadvantages. While there may be differences between the pre-interventional anatomy and the patient’s anatomy at the time of the intervention, pre-interventional images have better image quality and may provide important additional information in the future, such as the left atrial wall thickness. To be most flexible and to seamlessly fit into the clinical workflow, it is, therefore, desirable to have all options available as illustrated in Figure 6.

**Percutaneous aortic valve therapy**

Conventional treatment of patients with dysfunctional aortic valves is a highly invasive procedure involving considerable mortality and morbidity risks. To enable treatment of fragile
patients, who currently remain largely untreated, new minimally invasive procedures have been developed that are carried out under X-ray guidance in the cath lab. During such a procedure, a compressed tissue heart valve is inserted through the femoral artery, positioned over the diseased aortic valve, and then unfolded and fixed by inflating a balloon. As in the case of radiofrequency ablation for the treatment of atrial fibrillation, the procedure is complicated by the fact that the heart anatomy itself is hardly visible in the X-ray images.

A patient-specific heart model for this application should accurately model the aortic bulbus, the aortic valve, the outflow tract, the left ventricle and the coronary ostia. In addition, the integration of information about calcifications would be beneficial. Accurate valve placement may then be supported by overlaying the properly aligned vessel model onto X-ray fluoroscopy images (Figure 7).

**Conclusion and future perspectives**

A framework for the automatic extraction and generation of patient-specific organ models from different image modalities has been presented. These models were evaluated with respect to their ability to extract and represent diagnostic information about the heart and its function, to be used for treatment planning, and to support navigation when performing an intervention in the cath lab. In the future, the technology could be extended to further imaging modalities such as ultrasound and complemented by methods for the integration of information from different imaging studies into a single model. The integration of information about scar tissue into a patient-specific heart model illustrates the first step in this direction [12]. Within the EU-funded euHeart project [13], use of the models for biophysical and physiologic simulations that predict the patient’s heart function is also investigated.

**Acknowledgment**

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References


Application of live 3D tools in vascular interventional radiology
A. Gupta and A.G. Radaelli

Accurate morphological assessment of blood vessels and their relationship with interventional devices is essential in the management of vascular lesions. Three-dimensional rotational angiography (3D RA) and flat panel detector technology have contributed to diagnostic accuracy, faster procedures, and improved patient care. There are many reports in the literature on applications in the neck and brain, but little information on the benefits of live 3D tools in (peripheral) vascular interventional radiology. This article provides a showcase of minimally-invasive vascular interventional radiology applications where the availability of 3D tools helped to achieve effective treatment in a busy day-to-day clinical practice.

Evaluation of a recently developed 56” monitor in CV interventions
M.M. Drost

Studies were performed in different clinical situations to assess the possible benefits of a newly developed 56” monitor in the CV interventional lab. The clinical users reported excellent image quality, possibilities for improving the room layout, and improved ergonomics. The flexibility of switching between displays and the ability to significantly enlarge images on the screen were also seen as significant advantages. Finally, the workflow via the touchscreen at the bedside was assessed as intuitive and easy to use. These insights have contributed to optimizing the commercial products FlexVision XL (for cardiovascular procedures) and the EP Cockpit XL (for electrophysiology).

Catheter ablation of persistent AF: integrating advanced imaging and mapping solutions
M. Wright, R. Bullens, M. Häissaguerre, P. Jais, O. Leonard and M. O’Neill

Atrial fibrillation (AF) is the commonest cardiac arrhythmia, and is associated with a long-term increased risk of stroke, heart failure and all-cause mortality. Catheter ablation is recommended for patients who are symptomatic and have failed anti-arrhythmic medications. However, catheter ablation is technically demanding, requiring experienced operators with an intimate knowledge of electrophysiology and the anatomy of the left atrium. Advanced imaging and mapping solutions are being developed to facilitate catheter ablation. The most recent development is the integration of 3D rotational angiography with an EP recording system. These technologies will hopefully allow more patients access to catheter ablation.

Coronary CT angiography in percutaneous coronary intervention
H.S. Hecht

Coronary CT angiography (CCTA) has become the non-invasive modality of choice for coronary imaging. It provides similar information to intravascular ultrasound (IVUS), but is less invasive and has fewer limitations. The availability of a three-dimensional data set allows the physician to assess the significance of a stenosis, thereby improving patient selection for percutaneous coronary intervention, and also impacts other areas such as procedural planning and identification of plaque and high-risk lesions. The three dimensional data set also consistently demonstrates totally occluded segments, facilitating opening of the occlusions with the aid of an advanced application that provides guidance for percutaneous intervention.

Endovascular abdominal aortic aneurysm repair using the Veradius with flat detector
J.A. van Herwaarden

Over the last decade, endovascular aortic aneurysm repair (EVAR) has gained increased application for the treatment of abdominal aortic aneurysms. EVAR is significantly less invasive than open surgery, and the first randomized trials support the use of EVAR in patients. Image quality plays a key role in the procedure, and the Philips Veradius with flat detector offers significant advantages. In the Veradius, a thin, flat detector replaces the conventional image intensifier. Engineered to give excellent quality at low X-ray dose, the flat detector has a wider dynamic range than an image intensifier, providing clearer images, with fewer distortion artifacts.

MRI assessment of cardiac function in the newborn
A.M. Groves and A.D. Edwards

Although the overall care of sick newborn infants has improved dramatically in recent decades, very premature infants remain at high risk of death and neurodevelopmental impairment. Circulatory factors can lead to brain injury, resulting in poor long-term outcome. However, assessment of the complex circulation present during the transition from fetal to extraterine life poses unique problems. The Neonatal Intensive Care Unit at Queen Charlotte’s and Chelsea Hospital has a Philips Achieva 3.0T MR installed in a suite with full intensive care facilities, and is currently developing a range of cardiac MR techniques for study of the preterm transitional circulation.
Improved clinical performance of myocardial perfusion SPECT imaging using Astonish iterative reconstruction

G.V. Heller, T.M. Bateman, S.J. Cullom, H.H. Hines and A.J. Da Silva

Myocardial perfusion SPECT imaging helps diagnose and assess patients with coronary artery disease. There has been significant growth in the number of these procedures in recent years, while the laboratories performing the procedures are under pressure to reduce costs, improve image acquisition efficiency, reduce absorbed radiation dose and improve diagnostic accuracy. The “Astonish” reconstruction method improves reconstruction accuracy and makes more efficient use of acquired counts. Astonish also provides for scatter and attenuation correction, and has the potential to reduce radiation dose and radiopharmaceutical costs, while the improved diagnostic accuracy of attenuation-corrected data enables stress-only interpretations. Elimination of the resting portion of the exam further reduces radiation exposures and improves laboratory efficiency.

From recognition to reperfusion in acute myocardial infarction: a call for a comprehensive community approach

R.L. Fowler

Failure or delay in the treatment of acute myocardial infarction (AMI) can result in crippling cardiac insufficiency or death. In spite of the availability of organized and efficient emergency services, AMI still remains a major cause of death. Patients are often unwilling to adopt a healthy lifestyle and may fail to recognize symptoms. Rapid recognition and treatment substantially increase the chances of a good recovery, and the ability to acquire ECG’s in the ambulance can significantly reduce time from recognition to reperfusion. However, successful identification and management of myocardial infarction depends on public awareness and a comprehensive community approach.

Managing with obstructive sleep apnea

D.P. White and S. Baer

Obstructive Sleep Apnea (OSA) is a common and potentially debilitating disorder that can affect the health and quality of life of the afflicted individual. However, with proper diagnosis, identification of appropriate therapy, and a conscientious effort from healthcare providers, OSA can be overcome and a good night’s sleep attained. In patients with moderate to severe OSA, the most common and effective therapy is Positive Airway Pressure (PAP) therapy, generally in the form of Continuous Positive Airway Pressure (CPAP). If patients have difficulty with CPAP, alternative forms of PAP therapy can be offered such as bi-level therapy or Auto CPAP.

Vessel Explorer: a tool for quantitative measurements in CT and MR angiography

J. Oliván Bescós, J. Sonnemans, R. Habets, J. Peters, S. Higgins and M. Breeuwer

Vessel Explorer is a tool designed to provide radiologists with quick, simple and intuitive quantitative measurements of vessels in CT angiography (CTA) and MR angiography (MRA). It requires minimal interaction while efficiently providing the required measurements and reports. The automation algorithms have been validated for CTA and some MRA applications. The availability of this easy-to-use application in stand-alone workstations, scanner consoles and PACS, combined with a harmonized user interface for CTA and MRA, is expected to support the daily workflow of the radiology department.

Patient-specific heart models for diagnosis and interventions


This article presents a framework for the automatic extraction and generation of patient-specific heart models from different image modalities. These models can be used to extract and represent diagnostic information about the heart and its function. They can also be used for treatment planning, and an overlay of the models onto X-ray fluoroscopy images can support navigation when performing an intervention in the cath lab. The use of the models for biophysical and physiologic simulations that predict the patient’s heart function is also being investigated as part of the EU-funded euHeart project.
Application des outils 3D en temps réel en radiologie interventionnelle vasculaire
A. Gupta et A.G. Radaelli

Une évaluation morphologique précise des vaisseaux sanguins et de leur relation à l’aide d’appareils interventionnels est essentielle pour le traitement des lésions vasculaires.
L’angiographie rotationnelle 3D associée à la technologie à capteur plan a permis d’augmenter la précision diagnostique, d’accélérer les procédures et d’améliorer les soins. De nombreux articles portent sur les différentes applications possibles de cette technique dans des procédures au niveau du cou et du cerveau, mais il existe à ce jour peu d’informations sur les avantages représentés par les outils 3D en temps réel dans le cadre de la radiologie interventionnelle vasculaire (périphérique).
Cet article présente les différentes applications de radiologie interventionnelle vasculaire peu invasives pour lesquelles les outils 3D ont contribué à la mise en place d’un traitement efficace dans le cadre d’examens de routine.

Ablation par cathétérisme d’une fibrillation auriculaire persistante: intégration de solutions d’imagerie et de cartographie avancées
M. Wright, R. Bullens, M. Haïssaguerre, P. Jais, O. Leonard et M. O’Neill


Traitemt d’un anévrisme aortique abdominal endovasculaire à l’aide du système Veradius à capteur plan
J.A. van Herwaarden

Au cours des dix dernières années, le traitement par voie endovasculaire des anévrismes aortiques abdominaux s’est fortement développé. En effet, cette technique est nettement moins invasive que la chirurgie ouverte et les premiers essais randomisés recommandent son utilisation chez les patients.
La qualité d’image joue un rôle essentiel dans cette procédure et le système Philips Veradius à capteur plan offre de nombreux avantages en la matière. Dans ce système, l’intensificateur d’image classique est remplacé par un capteur plan d’une grande finesse. Conçu pour garantir une qualité d’image exceptionnelle, même à faible dose de rayonnement, ce capteur plan offre une gamme dynamique plus large qu’un intensificateur d’image classique, garantissant ainsi des images plus nettes et présentant moins d’artefacts de distorsion.

Évaluation d’un moniteur récemment mis au point de 56” (142 cm) dans le cadre d’interventions cardiovasculaires
M.M. Drost

Des études ont été réalisées dans différentes situations cliniques pour évaluer les avantages représentés par l’utilisation d’un moniteur de 56” (142 cm) dans une salle réservée aux interventions cardiovasculaires. Les cliniciens ont apprécié l’excellente qualité d’image, la possibilité d’améliorer la disposition de la salle, ainsi que l’optimisation du système en termes d’ergonomie. La permutation entre les affichages et la possibilité d’agrandir considérablement les images à l’écran représentent également des avantages significatifs. Enfin, la navigation via l’écran tactile de la console a été jugée aussi intuitive que simple d’utilisation.
Ces commentaires ont permis d’optimiser les produits des gammes FlexVision XL (pour les procédures cardiovasculaires) et EP Cockpit XL (pour les procédures d’électrophysiologie).

L’angiographie coronaire par TDM dans le cadre d’interventions coronaires percutanées
H.S. Hecht

L’angiographie coronaire par TDM est désormais la modalité non invasive de choix dans le domaine de l’imagerie coronaire. Elle permet en effet d’obtenir les mêmes informations qu’une échographie intravasculaire, tout en étant moins invasive et moins limitée. L’accès à des données 3D permet aux médecins d’évaluer la gravité d’une sténose, et par extension d’affiner la sélection des patients susceptibles de subir une intervention coronaire percutanée. Elle permet en outre de hiérarchiser les interventions et d’identifier les lésions à haut risque, ainsi que les plaques.
Les données tridimensionnelles permettent également d’observer les segments totalement obstrués, facilitant ainsi l’ouverture de ces occlusions grâce à une application avancée de guidage au cours des interventions percutanées.

Évaluation par IRM de la fonction cardiaque chez le nouveau-né
A.M. Groves et A.D. Edwards

Bien que les soins prodigués aux nouveau-nés aient beaucoup progressé au cours des dernières décennies, les grands prématurés présentent toujours un risque accru de mortalité et de retard dans leur développement neurologique. Des problèmes circulatoires peuvent être à l’origine de lésions cérébrales dont les conséquences peuvent s’avérer graves à long terme. Cependant, l’évaluation de la circulation au cours de la transition entre la vie foetale et la vie extra-utérine reste extrêmement complexe.
L’unité de soins intensifs en néonatologie de l’hôpital Queen Charlotte’s and Chelsea Hospital de Londres est équipée d’un système IRM Philips Achieva 3.0T intégré à une large gamme d’appareils de soins intensifs. Cet hôpital développe actuellement un ensemble de techniques d’IRM cardiaques permettant d’étudier la circulation transitionnelle chez les prématurés.
Améliorations des performances cliniques de l’imagerie SPECT dans le cadre de la perfusion myocardique à l’aide de la reconstruction itérative Astonish
G.V. Heller, T.M. Bateman, S.J. Cullom, H.H. Hines et A.J. Da Silva

L’utilisation de l’imagerie SPECT dans le cadre de la perfusion myocardique permet de diagnostiquer et d’évaluer les patients présentant une maladie coronarienne. La forte augmentation de ces procédures au cours des dernières années indique que les laboratoires les pratiquant subissent une pression croissante en termes de réduction des coûts, d’efficacité des techniques d’acquisition, de réduction des doses de rayonnement et d’amélioration de la précision diagnostique.

La méthode de reconstruction Astonish permet d’améliorer la précision de la reconstruction et de corriger la diffusion ainsi que l’atténuation. Elle permet également de réduire les doses de rayonnement et les coûts radiopharmaceutiques. De plus, l’amélioration de la précision diagnostique des données après correction de l’atténuation permet d’obtenir des interprétations portant uniquement sur les phases d’effort. La suppression de la phase de repos au cours de l’examen permet de réduire l’exposition au rayonnement et d’améliorer l’efficacité du laboratoire.

L’infarctus aigu du myocarde, de l’identification à la reperfusion: nécessité d’une approche globale et collective
R.L. Fowler

L’absence ou le retard de traitement en cas d’infarctus aigu du myocarde peut être à l’origine d’une insuffisance cardiaque handicapante, voire du décès du patient. Malgré le nombre et l’efficacité des services d’urgence, l’infarctus aigu du myocarde reste une cause majeure de mortalité. Les patients sont souvent réticents à l’idée d’adopter un mode de vie sain et ne sont pas toujours en mesure d’identifier les premiers symptômes d’un infarctus.

Plus l’IDM est diagnostiqué et traité rapidement, plus les chances d’un rétablissement complet sont grandes. La possibilité de procéder à un ECG dans l’ambulance permet de réduire le laps de temps écoulé entre l’identification de l’infarctus du myocarde et la reperfusion.

Toutefois, l’identification des symptômes et la réactivité des patients en cas d’infarctus du myocarde dépendent du niveau de sensibilisation de la population et impliquent donc une approche globale et collective.

Progrès d’identification des ischémies et infarctus aigus du myocarde à partir des ECG
L.S. Gettes et S.H. Zhou

L’identification et le traitement rapides des ischémies et infarctus aigus du myocarde permettent de prévenir tout dommage irréversible du myocarde et tout risque de mort subite.

L’electrocardiogramme (ECG) est un mode de diagnostic utilisable dans pratiquement tous les environnements. Il permet d’obtenir immédiatement des résultats pouvant être interprétés par le personnel qualifié et/ou par un électrocardiographe équipé des algorithmes d’interprétation appropriés.

Cet article présente l’algorithme de diagnostic ECG Philips DXL dans le cadre des recommandations relatives à la standardisation et à l’interprétation des ECG publiées récemment par l’ECG and Arrhythmia Committee de l’American Heart Association, l’American College of Cardiology et la Heart Rhythm Society.

Traitement du syndrome d’apnées obstructives du sommeil
D.P. White et S. Baer

Le syndrome d’apnées obstructives du sommeil (SAOS) est une affection courante présentant des risques pour la santé et pouvant affecter la qualité de vie des personnes concernées. Cependant, il est possible d’éliminer les effets induits par ce syndrome, s’il est diagnostiqué et traité de façon appropriée. La vigilance des professionnels de santé peut ainsi permettre aux patients de retrouver le sommeil.

La pression positive continue (PPC) est le mode de traitement le plus employé et le plus efficace chez les patients atteints d’un SAOS modéré à sévère, administré en général, sous forme de PPC fixe. Toutefois, d’autres options thérapeutiques sont également disponibles, comme le traitement par PPC auto-pilotée ou à deux niveaux de pression.

Vessel Explorer: outil de mesures quantitatives en angiographie TDM et IRM

Vessel Explorer est un outil permettant aux radiologues de réaliser de façon rapide, simple et intuitive des mesures quantitatives des vaisseaux dans des environnements ATDM (angiographie TDM) et ARM (angiographie RM). Il permet d’obtenir efficacement les mesures et les rapports requis, tout en demandant un minimum d’intervention de l’utilisateur.

Les algorithmes informatisés ont été validés pour les applications ATDM et pour certaines applications ARM. Simple d’utilisation, cette application est mise à disposition sur les stations de travail, les consoles d’acquisition et les systèmes PACS via une interface utilisateur harmonisée pour les modalités ATDM et ARM, assurant ainsi la prise en charge de tous les processus de travail utilisés quotidiennement par le service de radiologie.

Génération de modèles cardiaques spécifiques au patient à des fins diagnostiques et interventionnelles

Cet article présente le fonctionnement théorique de l’extraction et de la génération automatisques de modèles cardiaques spécifiques au patient à partir de diverses modalités d’imagerie. Ces modèles permettent d’extraire et d’illustrer des informations diagnostiques relatives au cœur et à la fonction cardiaque et s’avèrent également utiles pour la planification thérapeutique. En outre, les modèles peuvent être superposés avec des images de radioscopie pour faciliter la navigation lors d’une intervention en salle de cathétérisme.

L’utilisation de ces modèles à des fins de simulations biophysiques et physiologiques permettant de prévoir l’évolution de la fonction cardiaque du patient est également à l’étude dans le cadre du projet euHeart financé par l’Union européenne.
**Zusammenfassungen Deutsch**

### Anwendung von Live-3D-Tools in der vaskulären interventionellen Radiologie

**A. Gupta und A.G. Radaelli**

Die genaue morphologische Beurteilung von Blutgefäßen und ihrer Beziehung zu Interventionsinstrumenten ist bei der Behandlung von Gefäßläsionen unverzichtbar.


### Katheterablation bei persistierendem Vorhofflimmern: Einbindung von fortschrittlichen Bildgebungs- und Mapping-Lösungen

**M. Wright, R. Bullens, M. Haisauguere, P. Jais, O. Leonard und M. O'Neill**


### Endovaskuläre Reparatur von Aneurysmen der abdominalen Aorta mit dem Veradius-System mit Flachbilddetektorkonfiguration

**A. Gupta und A. G. Radaelli**

Über die letzten zehn Jahre hat sich die endovaskuläre Reparatur von Aneurysmen der Aorta (EVAR) zu einem immer häufiger angewendeten Verfahren zur Reparatur von Aneurysmen der abdominalen Aorta entwickelt. Die EVAR ist erheblich weniger invasiv als ein offener Eingriff, und die ersten randomisierten Studien belegen die Vorteile der Anwendung der EVAR am Patienten.


### Beurteilung eines kürzlich entwickelten 56''-Monitors (142 cm) bei kardiovaskulären (CV) Eingriffen

**M. M. Droste**


Diese Erkenntnisse konnten zur Optimierung der kommerziellen Produkte FlexVision XL (für kardiovaskuläre Verfahren) und EP Cockpit XL (für Elektrophysiologie) beitragen.

### Koronare CT-Angiographie bei perkutanen Koronarinterventionen

**H.S. Hecht**


### MRT-Beurteilung der Herzfunktion des Neugeborenen

**A.M. Groves und A.D. Edwards**


**Bessere klinische Leistung der SPECT-Bildgebung der Myokardperfusion mit dem iterativen Rekonstruktionsverfahren „Astonish“**

**G.V. Heller, T.M. Bateman, S.J. Cullom, H.H. Hines und A.J. Da Silva**

Die SPECT-Bildgebung der Myokardperfusion hilft bei der Diagnose und Beurteilung von Patienten mit koronarer Herzkrankheit. Der in den letzten Jahren zu verzeichnende erhebliche Anstieg der Anzahl dieser Verfahren bedeutet, dass die durchführenden Labore darauf angewiesen sind, die Kosten zu senken, die Bilderfassung effizienter zu gestalten, die absorbierbare Aktivitätsmenge zu verringern und die Diagnosegenauigkeit zu verbessern.

Der Rekonstruktionsalgorithmus „Astonish“ verbessert die Rekonstruktionsgenauigkeit und ermöglicht eine Streu- und Schwächungskorrektur. Mit dieser Methode können potenziell Strahlenexposition und Kosten für Radiopharmazeutika gesenkt werden, während die verbesserte Diagnosegenauigkeit der schwächungskorrigierten Daten die Möglichkeit eröffnet, nur die Belastungsdaten auszuwerten. Der Verzicht auf eine Ruheuntersuchung sorgt für eine weitere Senkung der Strahlenexposition und verbessert die Effizienz des Labors.

**Von der Erkennung bis zur Reperfusion eines akuten Myokardinfarkts: ein Aufruf zu einem umfassenden gesellschaftlichen Ansatz**

**R.L. Fowler**

Eine ausbleibende oder verzögerte Behandlung eines akuten Myokardinfarkts (AMI) kann zu schwerer Herzinsuffizienz oder zum Tod führen. Obwohl organisierte und effiziente Notfalldienste zur Verfügung stehen, gehört AMI nach wie vor zu den wichtigsten Todesursachen. Die Patienten sind oftmals nicht bereit, einen gesünderen Lebensstil anzunehmen, oder vielleicht nicht in der Lage, die Symptome zu erkennen. Durch schnelle Erkennung und Behandlung können die Chancen für ein gutes Outcome erheblich verbessert werden. Und die Möglichkeit, bereits im Notarztwagen ein EKG zu erfassen, kann die Zeitspanne von Erkennung bis Reperfusion signifikant verkürzen.

Für eine erfolgreiche Erkennung und Behandlung eines Myokardinfarkts sind jedoch eine öffentliche Sensibilisierung und ein umfassender gesellschaftlicher Ansatz erforderlich.

**Fortschritte bei der EKG-Diagnose von akuter Myokardischämie/akutem Myokardinfarkt**

**L.S. Gettes und S.H. Zhou**

Die rasche Erkennung und Behandlung von akuter Myokardischämie/akutem Myokardinfarkt kann irreversible Schäden am Herzmuskel und das Risiko eines plötzlichen Todes verhindern.

Das Elektrokardiogramm (EKG) ist ein Diagnoseverfahren, das praktisch überall angewendet werden kann. Es liefert sofortige Ergebnisse, die von qualifiziertem Personal und/oder von einem EKG-Gerät mit geeigneten Befundungsalgorithmen ausgewertet werden können.

Dieser Artikel stellt den DXL EKG-Diagnosealgorithmus von Philips in Zusammenhang mit der Reihe von Empfehlungen zur Standardisierung und Befundung des EKGs, die kürzlich vom ECG and Arrhythmia Committee der American Heart Association, dem American College of Cardiology und der Heart Rhythm Society herausgegeben wurden.

**Leben mit obstruktiver Schlafapnoe**

**D.P. White und S. Baer**

Die obstruktive Schlafapnoe (OSA) ist eine häufige und potenziell invalidisierende Erkrankung, die sowohl Gesundheit als auch Lebensqualität der betroffenen Person beeinträchtigen kann. Mit einer korrekten Diagnose, der Auswahl einer geeigneten Therapie und gewissenhaften Anstrengungen von ärztlicher Seite lässt sich die OSA jedoch überwinden und die Schlafqualität der betroffenen Person wiederherstellen.

Für Patienten mit mäßiger bis schwerer OSA ist die am häufigsten gewählte und wirksamste Behandlung die positive Atemwegsdrucktherapie (PAP), die in der Regel in Form von kontinuierlichem positivem Atemwegsdruck (CPAP) durchgeführt wird. Wenn Patienten Probleme mit CPAP haben, stehen alternative Formen der PAP-Therapie zur Verfügung, etwa die BiLevel-Therapie oder Auto-CPAP.

**Vessel Explorer: Ein Tool für quantitative Messungen bei CT- und MR-Angiographie**

**J. Olavide Bescós, J. Sonnemann, R. Habets, J. Peters, S. Higgins und M. Breeuwer**

Der Vessel Explorer ist ein Werkzeug, das Radiologen bei der CT-Angiographie (CTA) und der MR-Angiographie (MRA) schnelle, einfache und intuitive quantitative Gefäßmessungen ermöglichen soll. Es erfordert nur minimale Interaktion und stellt gleichzeitig effizient die benötigten Messungen und Berichte zur Verfügung.

Die Automatisierungsalgorithmen wurden für die CTA sowie für einige MRA-Anwendungen validiert. Man geht davon aus, dass der tägliche Arbeitsablauf in der radiologischen Abteilung durch die Einbindung dieser benutzerfreundlichen Anwendung in autonome Arbeitsstationen, Scanner-Konsolen und PACS-Systeme, in Verbindung mit einer vereinheitlichten Benutzeroberfläche für CTA und MRA, deutlich verbessert werden kann.

**Patientenspezifische Herzmodelle für Diagnose und Interventionen**


Aplicación de las herramientas 3D en tiempo real en radiología intervencionista vascular
A. Gupta y A.G. Radaelli

Una valoración exacta de la morfología de los vasos sanguíneos y su relación con los dispositivos intervencionistas es esencial en el tratamiento de las lesiones vasculares. La angiografía rotacional tridimensional (3D RA) y la tecnología del detector de pantalla plana han contribuido a aumentar la precisión de los diagnósticos, la agilización de los procedimientos y la mejora del cuidado al paciente. Se han publicado numerosos informes sobre aplicaciones relacionadas con el cuello y el cerebro, pero existe escasa información acerca de las ventajas de la radiología vascular (periférica) intervencionista con herramientas 3D en tiempo real.

En este artículo se ofrece una exposición de las aplicaciones de radiología vascular intervencionista mínimamente invasiva, en las que la existencia de herramientas 3D ayudó a lograr un tratamiento eficaz en la intensa práctica clínica diaria.

Ablación con catéter de la fibrilación auricular persistente: integración de soluciones de radiografía y cartografía avanzadas
M. Wright, R. Bullens, M. Haisenbauer, P. Jais, O. Leonard y M. O’Neill

La fibrilación auricular (FA) es la arritmia cardíaca más frecuente asociada al riesgo de infarto a largo plazo, la insuficiencia cardíaca y la mortalidad. La ablación con catéter se recomienda en pacientes sintomáticos que no hayan respondido a la medicación antiarrítmica; no obstante, presenta muchas exigencias técnicas, por lo que es necesario que los operadores posean experiencia y un profundo conocimiento de la electrofisiología y la anatomía del ventrículo izquierdo. Se están desarrollando soluciones de radiografía y cartografía avanzadas para facilitar la ablación con catéter, y el avance más reciente ha sido la integración de la angiografía rotacional en 3D con un sistema de registro de EF. Se espera que estas tecnologías permitan la aplicación de la ablación con catéter en un mayor número de pacientes.

Reparación endovascular de aneurisma aórtico abdominal mediante Veradius con detector plano
J.A. van Herwaarden

Durante la pasada década se ha producido un aumento de la reparación endovascular del aneurisma de la aorta abdominal (EVAR) para el tratamiento del aneurisma aórtico abdominal. Esta técnica es considerablemente menos invasiva que la cirugía abierta, y los primeros ensayos aleatorios apoyan el empleo de EVAR en pacientes. La calidad de la imagen desempeña una función esencial en este procedimiento, y el dispositivo Philips Veradius con detector plano ofrece ventajas sustanciales. Veradis incorpora un detector fino y plano que sustituye al intensificador de imágenes convencional. Diseñado para ofrecer una calidad excelente con una dosis baja de rayos X, el detector plano presenta un rango más dinámico que un intensificador de imágenes, lo que permite obtener unas imágenes más claras y nítidas con menos artefactos por distorsión.

Valoración de un monitor de 56” (142 cm) de reciente creación en las intervenciones CV
M.M. Drost

Se han realizado estudios en diferentes situaciones clínicas para evaluar los posibles beneficios de un monitor de 56” (142 cm) de reciente creación en los laboratorios CV intervencionistas. Los usuarios clínicos resaltaron su calidad de imagen, las posibilidades de mejorar su disposición en la habitación y en las soluciones ergonómicas. Además, se observaron otras ventajas importantes, como la flexibilidad del intercambio entre pantallas y la posibilidad de aumentar las imágenes en pantalla de manera significativa. Finalmente, se determinó que el flujo de trabajo a través de la pantalla táctil de la mesa era intuitivo y fácil de utilizar.

Estas opiniones han contribuido a la optimización de los productos comerciales FlexVision XL (para los procedimientos cardiovasculares) y EP Cockpit XL (para electrofisiología).

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**Mejora en el rendimiento clínico de las imágenes SPECT de perfusión miocárdica gracias a la reconstrucción interactiva Astonish**  
G.V. Heller, T.M. Bateman, S.J. Cullom, H.H. Hines y A.J. Da Silva

Las imágenes SPECT de perfusión miocárdica ayudan a diagnosticar y evaluar a los pacientes con coronariopatía. Este tipo de procedimientos ha aumentado en los últimos años de manera significativa, y por ello, los laboratorios que los realizan necesitan reducir costes, mejorar la eficacia de la adquisición de imágenes, reducir la dosis de radiación absorbida y mejorar la precisión del diagnóstico. El uso del método de reconstrucción “Astonish” mejora la precisión de la reconstrucción y ayuda a corregir la atenuación y dispersión. Este método permite realizar interpretaciones basadas únicamente en la prueba de esfuerzo. La supresión del resto de etapas del examen reduce aún más la exposición a las radiaciones y mejora la eficacia del laboratorio.

**Del reconocimiento a la reperfusión en el infarto agudo miocárdico: una llamada para un enfoque social amplio**  
R.L. Fowler

Los fallos o retrasos en el tratamiento del infarto agudo de miocardio (IAM) pueden provocar insuficiencia cardíaca incapacitante o la muerte. A pesar de la existencia de servicios de emergencia organizados y eficaces, el IAM continúa siendo una de las principales causas de fallecimiento. Los pacientes suelen ser reacios a adoptar un estilo de vida saludable y se pueden producir errores en el reconocimiento de los síntomas. La rapidez en el reconocimiento y el tratamiento incrementa de manera significativa las posibilidades de una correcta recuperación; asimismo, la posibilidad de realizar ECG en la ambulancia puede reducir en gran medida el tiempo comprendido entre el reconocimiento y la reperfusión. No obstante, la idoneidad en la identificación y el tratamiento del IAM depende de la concienciación pública y de un enfoque social más amplio.

**Avances en el reconocimiento mediante ECG de la isquemia miocárdica o el infarto de miocardio agudos**  
L.S. Gettes and S.H. Zhou

La rapidez en el reconocimiento y tratamiento de la isquemia miocárdica o el infarto agudo de miocardio puede prevenir daños irreversibles en el miocardio y evitar el riesgo de muerte súbita. El electrocardiograma (ECG) es una prueba diagnóstica que se puede realizar desde cualquier ubicación de manera virtual. Proporciona unos resultados inmediatos que el personal cualificado y/o un electrocardiógrafo pueden interpretar mediante algoritmos interpretativos adecuados. Este artículo relaciona el algoritmo de diagnóstico ECG DXL de Philips con una serie de recomendaciones para la estandarización e interpretación del ECG, publicadas recientemente por el ECG and Arrhythmia Committee de la American Heart Association, el American College of Cardiology y la Heart Rhythm Society.

**Tratamiento con apnea obstructiva del sueño**  
D.P. White y S. Baer

La apnea obstructiva del sueño (AOS) es un trastorno frecuente y potencialmente debilitante que puede afectar a la salud y calidad de vida de la persona afectada. Sin embargo, con un diagnóstico adecuado, la identificación de una terapia correcta y grandes esfuerzos por parte de los facultativos, la AOS se puede superar para poder llegar a tener un sueño nocturno reparador. En pacientes con AOS grave o moderada, la terapia más frecuente y eficaz es la presión positiva en vías aéreas (PAP), que se suele aplicar como presión positiva continua en vías aéreas (CPAP). Si los pacientes presentan dificultades durante la aplicación de CPAP, se puede administrar una terapia de PAP alternativa, como la bi-level o Auto CPAP.

**Vessel Explorer: una nueva herramienta para la medición cuantitativa de la angiografía con TAC y RM**  

Vessel Explorer es una nueva herramienta diseñada para proporcionar a los radiólogos mediciones cuantitativas rápidas, simples e intuitivas de los vasos en angiografía con TAC (ATC) y angiografía con RM (ARM). Requiere una interacción mínima y proporciona las mediciones y los informes necesarios con total eficacia. Se ha evaluado la precisión de los algoritmos de automatización para Angio TC y algunas aplicaciones de Angio RM. Se prevé que la disponibilidad de esta aplicación de uso sencillo en consolas de escáner, PACS y estaciones de trabajo independientes, combinada con una interfaz de usuario armonizada para ATC y ARM, admitirá el flujo de trabajo diario del departamento de radiología.

**Modelos cardiacos específicos del paciente para diagnóstico e intervenciones**  

Este artículo presenta un marco para la extracción y generación automáticas de modelos cardíacos específicos para cada paciente a partir de modalidades de imágenes diferentes. Estos modelos se pueden utilizar para extraer e representar información diagnóstica acerca del corazón y sus funciones. También pueden ayudar en la planificación del tratamiento y, gracias a la superposición de los modelos en las imágenes de fluoroscopia con rayos X, permite la navegación al realizar intervenciones en el laboratorio de cateterismo. El uso de los modelos para las simulaciones biofísicas y psicológicas que prevén la función cardíaca del paciente también se está investigando como parte del proyecto euHeart, financiado por la UE.
New products

Philips Essenta DR Compact: digital for everyone

Philips is committed to making high quality healthcare facilities available for everyone. Our new Essenta DR Compact digital radiography system meets the financial and operational challenges of public and private hospitals, as well as the smaller clinics. It is the ideal choice for facilities going digital, and fits in small rooms with a normal ceiling height.

The Essenta DR Compact is a versatile digital system for environments with a medium patient load. It comes with a fixed floor-mounted stand, which holds the manually adjustable U-arm carrying the X-ray tube assembly and the flat detector unit. Designed for quick and easy positioning, the flexible U-arm gives fast access to the full range of positions required for a wide range of general radiography examinations, including chest X-rays and free exposures.

A choice of mobile patient tables complete the examination room set-up.

Philips’ premium Eleva user interface provides fast and simple operation, so that any staff member can learn to use the system in just 15 minutes. The system gives quick access to the fully processed image, and has automated workflow steps for increased efficiency and faster throughput.

Essenta DR Compact is an economical choice that will continue to save time and money throughout its long, productive working life.

Low-dose gated chest exams on the Brilliance iCT

ECG-synchronized acquisition of the aortic root, thoracic aorta and complete chest is required to eliminate cardiac motion when evaluating thoracic aorta and triple rule-out exams. The large FOV (more than 250 mm) typically used for these types of exams requires increased overlap between steps. This makes it challenging for a 4 cm Z-axis coverage system to complete acquisition within a reasonable breath-hold, limiting the use of low-dose triple rule-out exams.

The Brilliance iCT breakthrough technology has a rotation speed of 0.27 seconds and extended Z-axis coverage of 8 cm. This enables gated chest exams and 30 cm acquisitions at a FOV of 500 mm using the prospective gating Step & Shoot technique.

The Step & Shoot mode on the Brilliance iCT allows for ECG-gated motion-free acquisition of a complete chest or thoracic aorta, with a breath-hold of 8 to 10 seconds and with an extremely low radiation dose of 6 to 8 mSv.
Quantitative vessel analysis at a glance

During case review, immediate multiple measurements can be performed, displayed, adapted and stored. Vessel Explorer performs a full quantitative analysis in the same time it would usually take to just view the MR image data. As a result, the use of Vessel Explorer increases clinical confidence without any time penalty.

Vessel Explorer optimizes your clinical workflow because quantitative results can be obtained on-the-fly, and results can be stored with the patient data for easy sharing and communication with your colleagues.

As part of their Elite Vascular Clinical Solutions, Philips has introduced the new Vessel Explorer as an option for the Extended MR Workspace (EWS).

Vessel Explorer brings a new approach to lesion analysis with MRA imaging data by radically changing the approach towards quantitative vessel analysis with MR.

With its high performance and a highly intuitive user interface, Vessel Explorer will help you to enhance the speed, clinical accuracy and diagnostic capabilities of vascular MR imaging. For more information, please visit the Philips MRI website: [www.philips.com/mri](http://www.philips.com/mri)

Fast, easy cardiac MR image analysis

Cardiac MR data can be analyzed very quickly thanks to the high degree of automation. Complete clinical screen layouts can be selected from a pre-defined list and can even be linked to the MR ExamCard that created the image data.

Cardiac Explorer generates a comprehensive clinical report that contains all relevant clinical information of the Cardiac MR study for the referring physician in a compact, easy-to-read format. For more information, please visit Philips MRI website: [www.philips.com/mri](http://www.philips.com/mri)

As part of their Elite Cardiac Clinical Solutions, Philips has introduced the new Cardiac Explorer as an option for the new Extended MR WorkSpace (EWS).

Cardiac Explorer represents the next important step in fast and convenient assessment of ischemic heart disease by enabling you to determine heart parameters from MR imaging data and present them in a comprehensive clinical report. Thanks to its task-guided approach, Cardiac Explorer leads users step-by-step through the successive tasks required to generate a clinical report. Context-sensitive help texts are available throughout with just one mouse click.

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