The General Infirmary at Leeds (Figure 1), part of the Leeds Teaching Hospitals Trust and home of the Yorkshire Heart Centre, has a long tradition of pioneering new techniques for diagnosis and treatment.

The Yorkshire Heart Centre serves a population of 3.2 million people, representing 5% of the total U.K. population, and treats over 35,000 adults and children per year. The center has six cath labs, five of which are Philips’ systems.

The main workload of the Yorkshire Heart Centre comprises percutaneous coronary interventions, the full spectrum of electrophysiology studies, and pediatric diagnostics and interventions. The center has seven Leeds-based interventionalists, and about eleven visiting interventionalists from the district units, enabling it to deal with a large patient cohort while maintaining acceptable waiting times.

Patients with acute coronary symptoms who are admitted to the hospitals in the district are transferred to the Leeds General Infirmary for angioplasty. In this respect, organization plays an important role in minimizing transfer times which would otherwise result in a significant
underutilization of resources. Leeds General Infirmary can complete the transfer procedure in less than two to three days. This is due to the availability of interventionalists throughout the day, and due to the organization of cath lab schedules being led by the nurses. Leeds General Infirmary pioneered this approach, which has now been adopted by other centers.

Interventional patients fall into three distinct categories:

• elective
• acute
• primary (emergency).

**Elective**

Patients admitted for elective angioplasty come direct from home. It is evident that the waiting times for these patients are leveling out in the U.K. as a whole, and like elsewhere, at Leeds General Infirmary they are kept to a minimum.

**Acute**

The number of patients with acute coronary syndromes treated by intervention has risen sharply over the last decade and is continuing to rise. This trend is partly due to improved life expectancy among an aging population.

**Primary (emergency)**

At present, emergency patients with “heart attacks” in the U.K. tend to be treated by thrombolysis, with angioplasty being used only as a last resort. In the U.S.A. and Continental Europe these patients are referred for immediate emergency angioplasty. It is our view that this approach should also be implemented in the U.K. Unfortunately, 80-90% of patients present to hospitals which do not provide an angioplasty service.

It is evident from the literature that studies of thrombolysis compared with angioplasty in hospitals indicate that the latter offers clear advantages, even if there is significant delay in the initiation of treatment [1]. Studies indicate that there is lower mortality and reduced in-hospital stay (the patients are sent home in 2 - 3 days rather than after 6 - 7 days). These findings have influenced the National Health Service Forum on Arrhythmia and Sudden Cardiac Death, which now recommends that heart attacks should be treated by immediate angioplasty.

A “pilot” program was started in the Leeds General Infirmary from April 1st, 2005. This has now been extended to the neighboring unit at the Bradford Royal Infirmary and is expected to cover the whole of the West Yorkshire region within the year.

We have been performing 250 primary angioplasties per annum. If the recommendations of the National Service Forum are implemented, this figure would increase by about 1000 for the West Yorkshire region as a whole. However, this additional workload is an overestimate, as some 60-70% of the emergency patients would have had angioplasty in any case, albeit after thrombolysis. The beneficial effect is also seen by a total reduction in the duration of in-hospital stay. Consequently, any reduction in the length of hospital stay would represent a significant financial saving.

The present group of 250 emergency angioplasties per year forms a part of a total of 3000 angioplasties carried out per year. This figure is expected to increase to 4500 by 2009. As the number of interventions increase, the reduction in total radiation dose to patients and staff is even more important than it has been in the past.

**The cath labs**

The Yorkshire Heart Centre has six cath lab installations:

1. Philips Integris BH 3000 biplane unit (soon to be replaced)
2. Philips Integris H 3000
3. Philips Integris H 5000
4. GE Innova 2000
5. Philips Allura FD10 with flat-panel detector.

The cath labs serve the West Yorkshire Cardiac Network of 11 hospitals, and are used for the whole spectrum of cardiac applications, including diagnostic angiography, coronary angioplasty, pediatric angiography, and electrophysiology.

The Yorkshire Heart Centre is a tertiary referral center, and hence many of the procedures tend to be complex, as most routine angiographic procedures are performed in the district units. The complex interventional procedures include high-risk interventions in patients who are unsuitable for surgery, as well as multi-vessel interventions.

The General Infirmary and the University of Leeds have a history of 30 years of cooperation with Philips Medical Systems in the development and evaluation of new imaging technologies. Much of the development of the Philips Allura FD system with integrated flat-panel detector was carried out in Leeds and, as the result of this cooperation, the first Allura FD 10 systems has been in routine clinical use in the Yorkshire Heart Centre since November 2003.
system and its clinical applications were described in a previous issue of Medicamundi [2].

**The upgrade path**

The Philips Integris H5000 and Allura systems, including image-intensifier systems, share a “future safe” design platform allowing them to be upgraded with the latest hardware and software. This made it possible to completely revise the Allura FD10 system in Cath Lab 5 (Figure 2), creating a state-of-the-art cath lab with a whole spectrum of advanced imaging facilities.

We are particularly impressed by the way in which the Philips systems can “evolve” to take account of new technological advances and software developments. The present Allura FD10 system was based on an earlier Integris H5000 image intensifier system, and has now been upgraded to a new platform with completely new software, monitors, new control panel, rotational angiography with 3D reconstruction, StentBoost with subtraction, and advanced Xres image processing in fluoroscopy as well as in acquisition.

The physicians are delighted with the improved image quality, and the technologists are fully at ease with the systems’ intuitive operation.

**Improved efficiency**

The aging of the patient population is accompanied by an increase in the complexity of the procedures. There are three main complicating factors to take into account in this group of patients:

- more complex anatomies
- older patients with co-morbidities
- calcified vessels

These make it imperative to provide the best possible image quality together with easy, intuitive operation and review, in order to achieve maximum efficiency and a successful outcome.

High image quality is the first and foremost requirement. During a recent review of all available cath lab systems we carried out when selecting a new system for our sixth cath lab, we found that the upgraded Allura Xper FD10 system provided the best image quality. One of the advantages of the new upgrade is the extra computer processing power. For example, a new image processing algorithm is available that allows the image presentation to be tailored to the patient. This real-time image manipulation is interactive and easy to use.

Another important consideration is fast and efficient backup from the manufacturer to ensure that the system provides peak performance. Philips have always provided “reference-site” technical service and application support whenever required, as well as access to remote servicing.
Figure 3. Xres provides sharp and high-contrast vessel reproduction even at low radiation doses and with low concentrations of contrast medium.

Figure 3a. Unprocessed image.

Figure 3b. Image with Xres.

The flat-panel detector
The Allura Xper FD10 uses an advanced 25 x 25 cm (10 x 10 in.) flat panel cardiac X-ray image detector. The pixel size is 184 microns square. This flat panel has been described in detail in several previous publications [2,3,4,5]. Its advantages are that it is compact and highly maneuverable, allowing steep imaging angles, and yet the "panel" is kept close to the patient.

The detector layer is highly sensitive, with negligible lateral light scatter, providing high-quality images at a relatively low patient dose. Each pixel is addressed individually via an integral data-transfer structure, allowing the images to be acquired and read out in real-time. There is no geometrical distortion or field non-uniformity, and negligible contrast loss. Optimum spatial resolution is maintained throughout the field even at the corners.

The output signal is digital, with no loss of information at the analog/digital conversion stage. Any residual image is eliminated after each frame using a "refresh light." This eliminates ghosting artifacts and lag, allowing fast frame...

Figure 4. 3D coronary angiography during angioplasty of a circumflex lesion.

Figure 4a. Rotational angiography run.

Figure 4b. Color map for automatic selection of optimal non-foreshortened views.

Figure 4c.Three-dimensional reconstruction.

Figure 5. 3D coronary angiography of a segment of the artery following intervention. The color map allows automatic selection of optimal non-foreshortened views, necessary for accurate evaluation of stent deployment and for the use of post-processing tools.

Figure 5a. Rotational angiography run.

Figure 5b. Color map.

Figure 5c.Three-dimensional reconstruction.
rates required for cardiac imaging. The wide
dynamic range ensures images of excellent quality
in patients of all sizes and for all projections.

**Advanced image processing**
Xres is a real-time noise reduction algorithm,
specifically designed for cardiovascular imaging.
It provides sharp and high contrast vessel
reproduction in both acquisition and fluoroscopy,
even at low radiation doses and with low
concentrations of contrast agent (Figure 3). The
sophisticated image processing available on the
Xper system is central to maintaining adequate
clinical image quality under the very low dose
operating mode available on this system.

**Rotational Angiography and 3D-CA**
Rotational Angiography (RA) is a technique in
which a coronary artery is imaged while the X-ray
imaging assembly rotates around the patient [7].
This allows views of the artery to be acquired
from multiple view points in an efficient manner.
Acquisition of all the required views in one or at
most two rotations represents a significant saving
in both radiation dose and the quantity of contrast
agent required. Previously, several different
acquisitions would have been required. Now, it
is possible for nearly all post-angioplasty imaging
to be done with a single run. This results in a
faster examination procedure and reduced
discomfort for the patient.

Three-Dimensional Coronary Angiography
(3D-CA) is a virtual imaging technique in which
a 3D model of part of the arterial tree is created
from suitable images in the RA run. The 3D
model can be processed and rotated through
any angle, giving a clear impression of the
morphology of complex structures. This offers a
totally different way of looking at the vascular
tree, providing views of the lesions from any
required angle (Figures 4, 5, 6). An advantage of
the updated software is that it allows the optimal
non-foreshortened automated views to be obtained. The Xper upgrade integrates 3D-CA
with cath lab itself. In a similar way to the
StentBoost system, images are transferred to the
3D-CA workstation automatically over the
ultra-high speed link, and 3D-CA models can be
displayed on the monitors in the cath labs.
Additionally, if the 3D-CA model is used to
derive an optimal view of a lesion, the Xper system
can automatically position the X-ray imaging
assembly to achieve this view. The displayed 3D
model can also be automatically rotated as the
X-ray imaging assembly is moved by the user,
keeping the view of the model consistent with
the current imaging projections.

**Work in progress**

**3D venous angiography**
At Leeds, 3D angiography has been extended to the imaging of cardiac veins. This has tremendous potential for electrophysiology. The technique is undergoing clinical evaluation, but is expected to become routine technique for electrophysiology in the near future.

3D venous angiography can be an important aid in positioning of the leads in biventricular pacemaker implantation (Figure 7). For the first time it is possible to see the outline of the veins in three dimensions. This makes it much easier to access the origin of the veins and to position the leads appropriately in biventricular pacing. The clear depiction of the spatial location of the veins allows the position of the leads to be accurately linked to the viability maps.

**StentBoost**
The Yorkshire Heart Centre was one of the first sites to be equipped with StentBoost. This innovative interventional tool produces a highly enhanced image of a stent in the coronary arteries while the catheter is still in place, allowing the user to make an evaluation of stent expansion without the need for further acquisition (Figure 8). A study comparing StentBoost with
intravascular ultrasound (IVUS) in assessing stent deployment found very good agreement in stent shape between IVUS and StentBoost [6].

The Xper upgrade facilitated a number of major improvements in the StentBoost system. Firstly, “Live StentBoost” automatically transfers cine acquisition runs intended for analysis with StentBoost to the StentBoost workstation over an ultra-high speed data link. In effect the images are available on the StentBoost workstation immediately following their acquisition. Secondly, using the MultiVision Xper interface, the results of the StentBoost processing can be displayed on the main cath lab monitors. Live StentBoost with the Xper makes the StentBoost images available to the clinical operators with minimum delay, easily...
allowing the StentBoost to be integrated with the clinical work flow.

Direct visualization of the relationship between the stent and the vessel wall may be possible using a future development of StentBoost, pioneered in the Yorkshire Heart Centre, in which StentBoost is combined with subtraction. This provides extremely clear images of the stent (Figure 9) and may allow the size and shape of the stent to be compared with the vessel lumen, showing the relationship of the stent to the vessel wall, as well as allowing the assessment of quantitative parameters.

Minimum X-ray dose

X-ray dose reduction is an important consideration in cardiac procedures, particularly in electrophysiology. This has been the subject of an intensive joint

Figure 9. StentBoost in combination with subtraction (right) clearly shows the struts of the stent, which could not be distinguished on the conventional angiogram (left) despite the presence of significant calcification.

Figure 10. Low Dose Image. Two selected frames from an interventional procedure in the circumflex artery. The frame on the left, using the low dose acquisition program, was taken during the early part of the procedure. The frame on the right, using standard dose, was taken during the latter parts of the same procedure. Both frames show the coronary arteries and interventional wires with diagnostic quality.

Figure 11. Selected fluoroscopy frames from a pediatric electrophysiological study in an 11 year old girl. Fluoroscopy was performed with an 80% skin-dose reduction as compared with standard fluoroscopy skin-dose rates, using novel dose-reduction techniques and algorithms pioneered in Leeds.
The flicker-free flat-screen monitors are easy and uniriting to view, and the telescopic ceiling suspension allows them to be set at the optimal viewing height for every user.

Research effort between Philips, Leeds General Infirmary and The University of Leeds [8]. The high performance of the flat detector, in combination with the advanced image processing, has already made it possible to reduce patient skin dose in fluoroscopy by as much as 80%, while maintaining diagnostic image quality (Figure 10). The ability to image at very low dose is of particular importance in pediatric procedures and, especially, in pediatric electrophysiology (Figure 11). Many such patients have a long history of surgery and repeated X-ray examinations.

Dose reduction is also important for the staff, and becomes increasingly so as the workload rises. Here again, there is close cooperation between Leeds General Infirmary, the LXI department at the University of Leeds and Philips Medical Systems, aimed at reducing the X-ray dose within the cath labs. The object is to provide the best possible environment for all at the lowest possible dose (ALARA).

New developments in flat panel technology are likely to achieve even greater dose savings in the foreseeable future. The goal of the Leeds X-ray Imaging Research Group is to reduce dose in electrophysiology by an order of magnitude (10 x).

From the Medical Physics standpoint, the system upgrade gives an opportunity to explore the possibilities of even further dose reduction. From the electrophysiologist’s point of view it makes it possible to exploit the higher sensitivity and better image quality of the flat detector. Thus, reduction by an order of magnitude is a realistic goal in electrophysiology.

A similar approach is being implemented for coronary intervention and diagnostics, (which is particularly important for pediatric applications). The greatest proportion of X-ray dose in diagnostics occurs during acquisition, which accounts for approximately 75% of the delivered dose, as compared with 25% for fluoroscopy. Clearly reducing the dose accrued due to acquisitions would result in substantial savings.

In intervention the proportion of procedural dose due to acquisition compared to fluoroscopy is typically 50:50. The goal here is to reduce dose without compromising image quality. It should be possible to maximize image quality as and when needed, using a lower dose with a correspondingly lower image quality for orientation. At present this type of hierarchy is being evaluated.

Easy, intuitive operation

The ergonomics of the new system are excellent. The new telescopic height adjustment of the monitors is a significant benefit, as different procedures require different viewing heights (Figure 12). Thus, the height adjustment helps to make the Allura Xper FD10 very acceptable as a multi-specialty system.
The new control desk at the foot end of the patient table (Figure 13) provides all functions on a single touch panel. This is seen as a major improvement, with easy, intuitive operation. However, the new remote control required some familiarization.

**Optimum Access**

The compact flat panel detector allows optimum access to the patient, and the revised patient table is designed for access from either side. This is an important advantage for the cardiologist, in particular for left-sided access for pacemaker implantation.

**Full technical support**

The complete platform conversion from the existing Allura FD10 installation to the new system took place at the end of November 2005, and was accomplished with minimal disruption of the work of the department. In this first upgrade the whole procedure took less than ten days, but future conversions are expected to be even faster.

The hospital particularly appreciates the willingness of Philips staff to listen to proposals for system improvement, and their enthusiastic technical support in implementing them.

**Efficiency and affordability**

An important consideration for any new technology in an NHS hospital is whether it can provide benefits in an affordable manner in a healthcare service funded by public money. It has to meet the strict criteria of efficiency and affordability. The Allura Xper FD10 upgrade met both of these. The ability to create a state-of-the-art cath lab by upgrading an existing system platform represented a significant cost saving, while the increased efficiency results in greater throughput, allowing the department to cope with increased demand and, at the same time, to cut waiting times. The intuitive user-friendly interface makes the system very popular with the staff, while the low dose gives greater confidence and safety in lengthy procedures. The positive experience with this system has led the department to select a similar system for the sixth cath lab.

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**References**


