Workflow in diagnostics and intervention – the quiet revolution

Richard Lyons

Introduction

What started many years ago as simple ergonomic changes in imaging system design to reflect and improve customer usage, have culminated in systems that are more influenced by the clinical use and the benefit provided than the technology employed. Technology for technology's sake often came with a price tag, an unnecessary complexity and a lack of user consideration.
Sense and economics prevailed as manufacturers adopted industry standard solutions, such as Windows™ based systems, and saw the potential beyond user-friendliness. Evaluation of the customer's desired outcome and how they achieved it led, through the appropriate application of innovative technology integrated with optimised processes, to improved workflow and outcomes. The term workflow, like solutions, once greeted with patronising smiles in clinical imaging departments in the United Kingdom (UK), is now used universally.
Why the change in attitude? The simple reason is that workflow improvements that are being achieved daily due to, for example, process change, the design of modalities and their integration with radiology information systems (RIS). Picture archiving and communication systems (PACS) and cardiac data management systems, even at a departmental level, are clearly differentiating the service provision of whole hospitals. Efficient core diagnostic services, including the diagnostic service provided by imaging departments, are essential to meeting government targets and to remaining competitive and viable, so are to be ignored only at peril. Some departments may consider that all they have to do is to wait for their

'free' PACS or RIS to achieve the levels of efficiency needed. However, it is not the distribution of images that provides the benefit but the transfer of clinically relevant information to provide guidance on patient management, and this latter requires much more thought if it is to be achieved.

Workflow and department design

Many institutions, to achieve the more significant changes that will improve quality of healthcare and drive costs down, are investing in departmental designs that suit patient workflows. For example, at Southampton General Hospital (SGH) the approach has been to bring together what they see as the key components to deliver an enhanced cardiovascular service, namely catheter laboratories, cardiac magnetic resonance imaging (CMR), computed tomography (CT) and operating theatres. CMR at Southampton is now in the frontline for the management of ischaemic heart disease whereas, previously, it was used mainly for congenital and functional cardiac disorders. The patient presenting at casualty with chest pain has a prompt clinical assessment, an electrocardiogram (ECG) and an enzyme level check and, if appropriate, is sent directly to the catheter laboratory. A team is on standby to ensure the 'door to intervention time' is minimised and, overall, kept below the 90 minute guideline[1].

Should the preliminary investigation show that multiple vessel disease is present, the patient may be sent to have a stress cardiovascular magnetic resonance (CMR) scan to assess the viability of the myocardium and so help determine whether revascularization therapy would improve chest pain and the function of the heart. The stress CMR scan can also provide guidance on which artery to stent. An examination technique of measuring blood flow to the heart as well as late gadolinium enhancement (LGE), which takes approximately 30 – 40 minutes, identifies both ischaemia and non-ischaemia related cardiomyopathies, and necrosis caused by myocardial infarction 2. This diagnostic process ensures that costly interventional procedures and stents are only carried out where they are able to enhance the clinical outcome. Due to the close proximity between the CMR unit and the catheter laboratories, three to four acutely ill patients per week are now undergoing this additional stress MR examination.

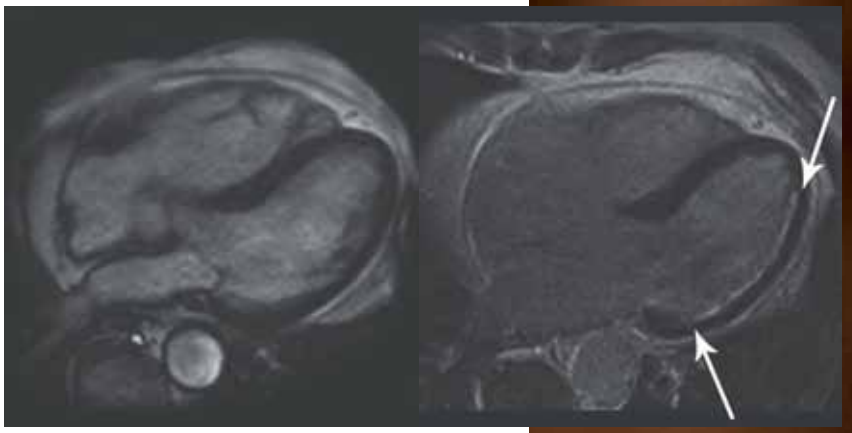

Figure 1. Cardiac MR examination: function (left image) shows wall motion abnormalities which correspond to the area of sub-endocardial infarct appearing bright in the delayed enhancement image (right image, and arrowed).

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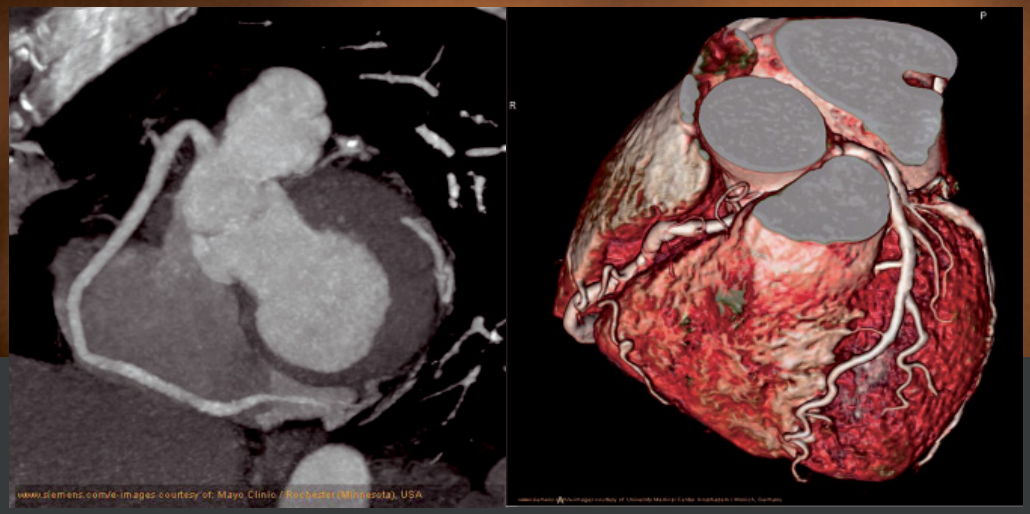

Figure 2. High spatial and temporal images acquired without beta blockers on a DSCT system

Cardiac magnetic resonance imaging has been cultivated at SGH more than at many other UK sites, but not to the exclusion of cardiac computed tomography (CT) and CT angiography (CTA). These examinations provide a valuable service, for example, to those needing clarification on the extent of disease, or for patients prior to valve surgery to exclude coronary disease. A particular SGH protocol which both reduces cost and improves service quality is provided for young women who have a non-invasive CTA to exclude heart disease, benefiting from the lower dose compared to catheterisation and the high, 99% negative predictive value of CTA[3]. The broader application of CTA to screen the 'at risk population' (because of family history, for example), will become less controversial as more sophisticated dose modulation techniques deliver much lower radiation doses, and are complemented by software which provides a discernible result quickly. Techniques such as ECG pulsing can now allow the user the discretion to reduce the period of full exposure during the diastolic phase, and to set how low should be the exposure to be delivered during the systolic phase. Of the other limiting factors for CTA, namely temporal and spatial resolution, the limitation on temporal resolution in Cardiac CT has a more significant impact on patient care currently. All CTA scans on conventional multi-slice scanners require beta blockers to be administered to endeavour to reduce heart rate to a level that the systems can image; an important drawback for patient management is that it takes an hour for the beta blockers to take effect. The impact of such medication goes beyond the clinical and financial, affecting patients' abilities to transport themselves.

Papworth Hospital, another site centralising a significant part of its cardiac diagnostic capabilities, expects to overcome the beta blocker requirement and other limitations with a Dual Source CT (DSCT) scanner. DSCT provide consistent results with variable heart rates, atrial fibrillation, and asthma. DSCT can also cope with paediatric cases with heart rates as high as 144 beats per minute. Overall, the introduction of DSCT will make the total examination period shorter and provide an improved capability to deal with the full range of patients, including acute cases.

As cardiac CT and MR seem to be more and more capable of coronary and heart function diagnosis, does this mean the end of the line for other traditional modalities in cardiovascular diagnostic imaging? At present, no one is advocating this seriously and catheter laboratories still provide the most appropriate and economic procedure for patients with a high likelihood of disease[4].

The impact of change for staff

As systems, particularly in the catheter laboratory, have become more automated should there be benefit in terms of staffing levels? Many NHS hospitals are considering merging disciplines to deal with qualified staff shortages and improve financial performance. Different opinions prevail across the centres in the UK as to which role should disappear, with the choice generally between the radiographer and physiologist. The Cardiac Catheter Laboratory Practitioners (CCLP) programme that has provided flexibility in staffing whilst maintaining the specialist expertise of the individual disciplines is not (yet) implemented widely. A primary role of the radiographer in the catheter laboratory is to ensure overall image quality through selection of the correct angulation, collimation and minimisation of dose, often giving advice to the less experienced clinician on catheter type for the prevailing circumstances. Another aspect of the role is the importing of data from other modalities, such as CMR into the electrophysiology (EP) mapping system for atrial fibrillation, as well as data validation, quality control analysis (QCA) and post processing. Southampton has redefined the radiographer's role in a highly effective way, through sharing the specific knowledge of the catheter laboratory radiographer in terms of gating and the cross sectional imaging radiographer in terms of anatomy, to create universal cardiac radiographers with wider skill sets. Is it now time for the NHS to reflect industry organisational trends in process management and workflow by adopting a structure related to the disease rather than the branch of medicine[5]?

Meeting the challenge of increasing patient volumes

In cardiology, modern diagnostic tools are in place mainly due to recent government expenditure, but the linkage between imaging equipment and data management systems needs to be tighter if cardiovascular departments have any hope of keeping up with the ever-growing volume of patients. With more patients undergoing diagnostic care more frequently, conventional data management resources need to be updated to manage the images and information of today's leading technologies. Without an efficient work and data flow in place, it will not be possible to improve the quality of care whilst decreasing the costs for patients and healthcare providers alike. The integration of workflow and information is essential to achieve the efficiencies needed to address the growing demand for cardiology services. Perhaps it is necessary to turn to the United States of America (USA) to see really significant examples of the benefits of a fully integrated approach. The Heart Centre of Indiana (THCI) is such an example and is a totally digital centre, with a history of pioneering new clinical techniques. It carries the accolade of being the first freestanding US Heart hospital, established independently in 2002. The approach taken at the centre from the early design stage was an innovative patient-centric one, using lean process concepts in the design, such as having one room for the whole hospitalisation process with a universal bed – the patient does not move, rather, staff come to the patient.

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THCI understood what technology could do for them and used it effectively where it improved their processes. Their patients have, for years now, booked appointments through the internet and received reminders for medication on their mobile telephones. These applications will sound familiar to those that know the goals of the Connecting for Health (CfH) programme in England. The clinical information system is a workflow engine combined with a computerised physician order entry (CPOE) system and a bar coded/radio frequency identification detection (RFID) pharmacy system; it incorporates PACS, and is universally available on-line within the single fully integrated system. The workflow engine ensures the many adverse events that beset hospitals are minimised. Incorrect medication and methicillin resistant staphylococcus (MRSA) infection are avoided through protocol guidance to nurses and clinicians.

THCI utilises smart health cards for patients and home monitoring to achieve high levels of efficiency. This approach culminated, within a few years of operation, in recognition as one of the top five healthcare institutions in the USA, with, additionally, five star ratings for heart attack, percutaneous coronary intervention (PCI) and valve surgery. Some metrics are shown in figure 3 to illustrate how THCI compares with the benchmark data laid down by the American College of Cardiology (ACC) in the context of percutaneous coronary intervention (PCI).

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Indicator	The Heart Center of Indiana	Benchmark (American College of Cardiology[6])
Average length of Stay	2.0 days	3.0 days
PCI Success Rate	99.4%	91.9%
Abrupt Closure	0.09%	1.3%
Unplanned Return to Lab	0.49%	1.0%
Door to Intervention Time	46.2 mins	90 mins
Mortality	0.58%	1.1%

Figure 3. Data for percutaneous coronary intervention: THCI compared to ACC benchmark data

Changing patient care

Once the diagnosis is established, what then? Interventional procedures, day case surgery and outpatient procedures in general have all contributed to the changing landscape of healthcare in the UK. Innovations in the technology of imaging systems, medical devices and clinical techniques have advanced together to widen the scope and effectiveness of these procedures. Specifically, today's technological advances in interventional angiographic systems are aimed at making both the technique and the workflow easier, in addition to improving the diagnostic information available. Some may consider this is the usual manufacturers' proposition – highlight expensive leading edge technology to improve the position for a limited patient group. This is not so; notable workflow improvements that enhance patient management and save costs can be obtained economically. For example, in the past it was often necessary to move a patient to CT to evaluate and master complications during an angiography-based intervention. Now angiographic CT, soft tissue CT-like,

diagnostic information is available during angiographic or interventional procedures with the introduction of a low cost module. When bleeding occurred during the introduction of coils and stents to repair vascular weak spots, a patient would be transferred to the CT scanner to define the extent and location of the problem. Now the interventionalist can resolve the situation more quickly and avoid transferring the patient (a difficult task with the patient under general anaesthesia) to the CT scanner which is, typically, busy and non-sterile. This process, still the case in most hospitals, takes time and is costly, tying up both the interventional and CT rooms, and their respective staff. Providing angiographic CT imaging in the angiography suite supports the handling of difficult situations during interventional procedures.

Initial applications in neuroradiology imaging included the visualisation of local bleedings, the ventricular system, and tumours. This has expanded to abdominal applications, which include chemo-embolisation, radio frequency (RF) ablation, stent placement and vertebroplasty. Angiographic CT has improved patient management during interventional procedures by enhancing decision making using the additional cross-sectional information it provides. Although highly detailed images of the vascular system could be obtained previously, it is now possible to also visualise the soft tissue that surrounds the vessel (see figure 3), with the benefit of enabling the attending clinician to take fast and appropriate action and improving workflow simultaneously.

Changing benchmarks

The beneficial impact on departmental workflow from the application of technology can be seen clearly, but clinical workflow encompasses so much more. Simply getting the correct patient with the relevant clinical information at the designated time to enable diagnosis, timely treatment and follow up would be a major improvement. This can only be achieved if the information technology (IT) systems available to the healthcare practitioner go beyond the current patient administration systems (PAS) and provide real clinical workflow improvements.

The escalating pace of technological development in healthcare creates problems for researchers when trying to carry out longitudinal studies to assess the comparative clinical benefits of emerging systems and techniques against existing study benchmarks, whether cardiology or general angiography. This pace will continue with the added complication of the expansion of clinical IT systems, hybrid imaging and the introduction of molecular and other cellular techniques, such as stem cell research. The opportunity is there to improve radically clinical care and the efficiency of healthcare delivery in the UK; whether UK healthcare is willing to embrace such change is no longer the question, it is how and when will it do so.

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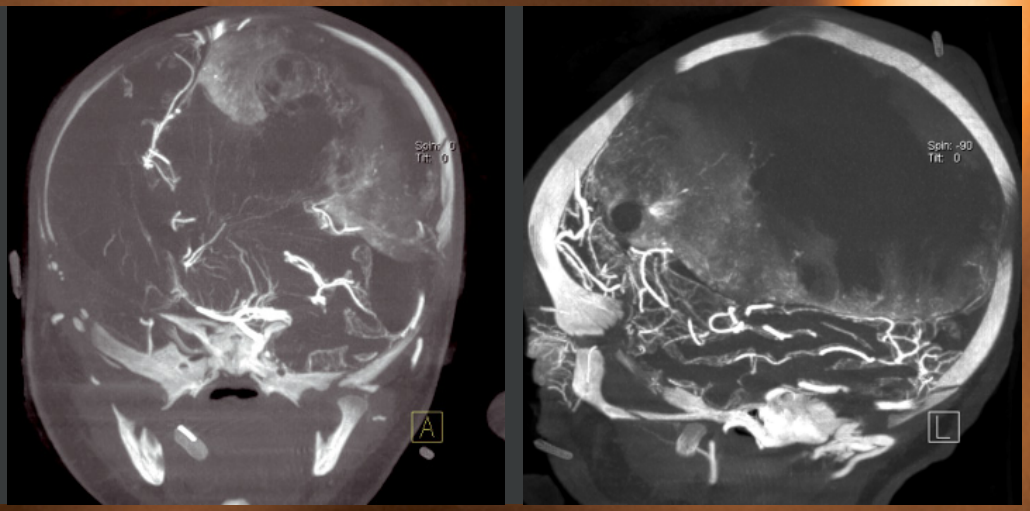

Figure 3. Siemens Angiographic CT (DynaCT) shows the diffuse and irregular enhancing tumour blush in the mass over the cerebral convexity. Furthermore, a cleavage plane between the mass and the underlying cerebral vessels is visible, documenting that the tumour is extra-axial in nature

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Richard Lyons, now retired, was latterly the marketing and communications manager at Siemens Medical Solutions, UK. He was involved in the radiology field with Siemens for more than 40 years.