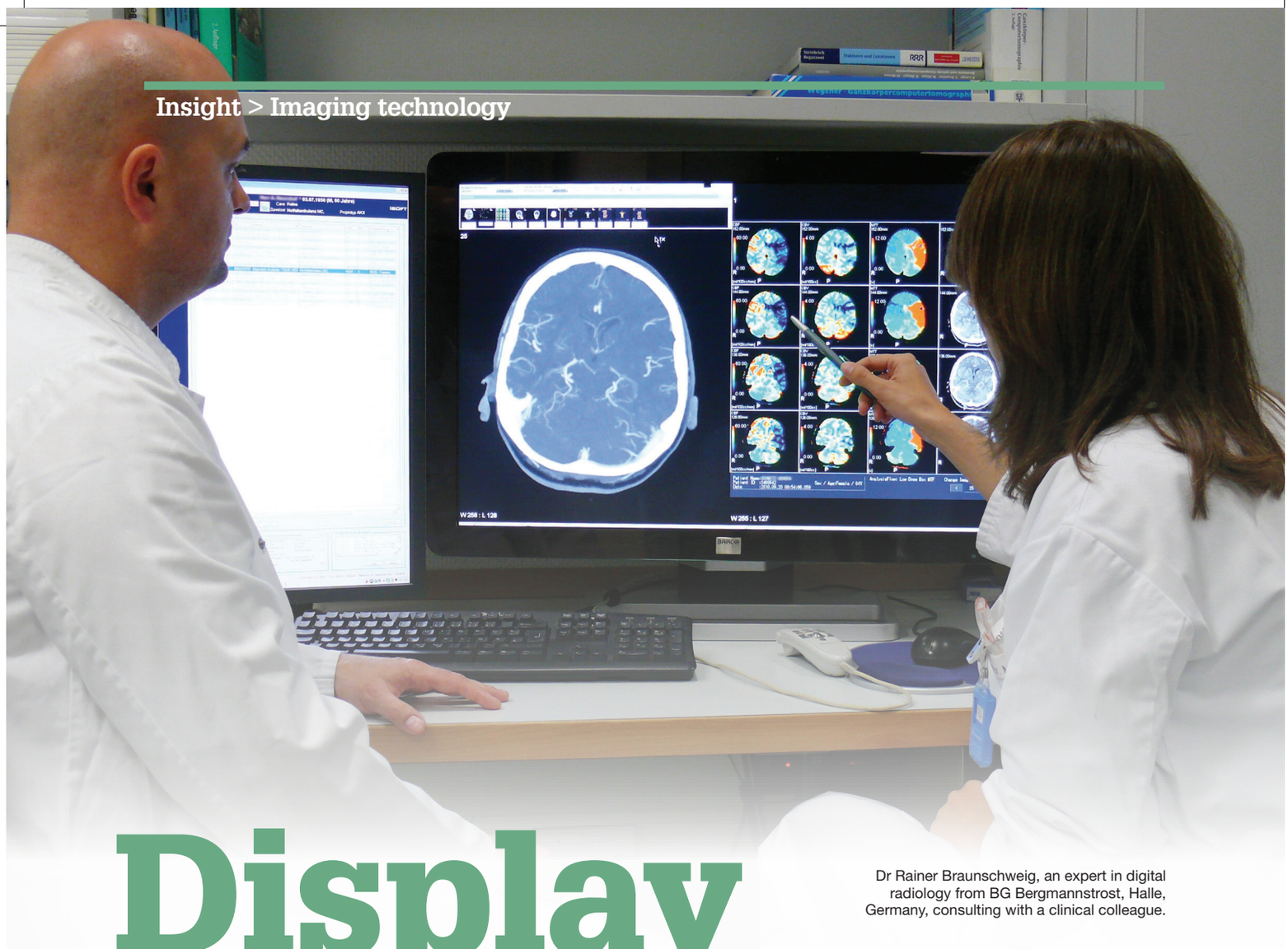


Dr Rainer Braunschweig, an expert in digital radiology from BG Bergmannstrost, Halle, Germany, consulting with a clinical colleague.

Display purposes only

Knowing which monitor to select for diagnostic imaging has long been an issue for imaging departments. As technology advances, these decisions risk becoming outdated within a short time frame. When committing, decision-makers are acutely aware that, at a time of strained financial resources, it is a choice they and their teams could have to live with for some time. Andrew Tunnicliffe talks to **Geert Carrein** about the issues involved and how to overcome them.

Andrew Tunnicliffe: Can you give us a brief history of digital imaging displays?

Geert Carrein: Digital imaging displays have been in existence for more than a decade. Since their introduction, they have continuously gained momentum in the diagnostic imaging field. Progress has been focused on:

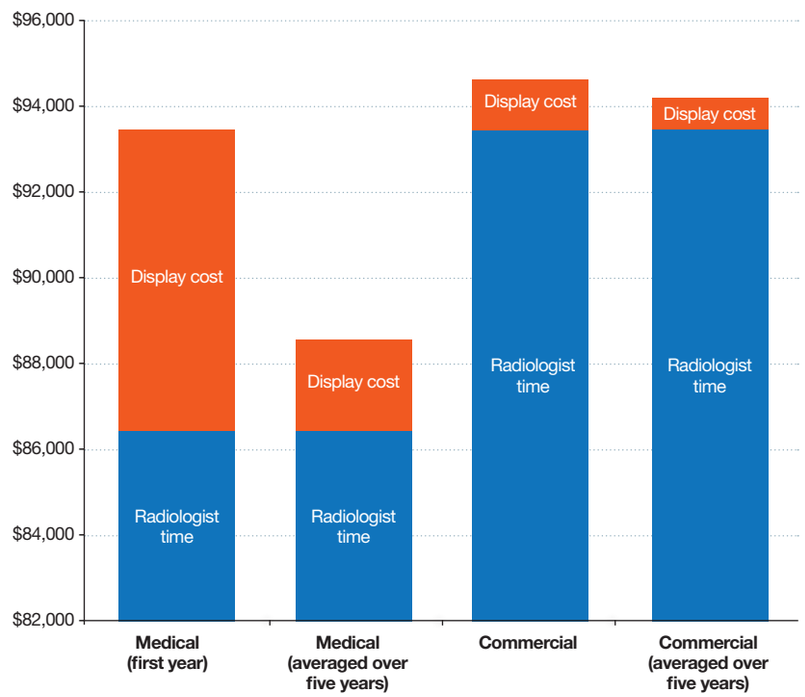
- improving image quality
- increasing display real estate (dual/triple/quad heads)
- productivity of the imaging system
- improving the regulatory aspects
- multimodality viewing and the trend from greyscale to colour
- form factor improvements
- improved ergonomics
- recent trends for cloud imaging.

Geert Carrein
Geert Carrein is vice-president – strategic marketing diagnostic imaging at Barco, a global technology company that designs and develops enterprise visualisation solutions for a variety of markets including healthcare. Previously, he was director PACS and product group manager at Barco.

What have been the biggest advances in display technology in recent years?

There has been a clear shift from greyscale to colour medical displays over the last couple of years. Colour displays have now become a standard part of the diagnostic displays system portfolio. Colour has many benefits, as it can act as a marker in distinguishing important structural and functional elements within an image, supporting more accurate diagnosis.

Combined cost of equipment and cost of radiologist time



Source: 'Image Quality Performance of Liquid Crystal Display Systems: Influence of display resolution, magnification and window settings on contrast-detail detection' by K Bacher, P Smeets, A De Hauwere, T Vote, P Duyck, K Verstraete and H Thierens, European Journal of Radiology, volume 58, issue 3 (2003)

Image quality plays a crucial role in the choice of medical displays. Radiologists pay particular attention to the quality of contrast provided through different medical displays. This has a direct impact on their confidence in terms of what they read from the displays. A combination of brighter screens and good contrast ratios is what radiologists continue to demand.

The demand for a 30in multimodality diagnostic workspace within a single screen has steadily increased. This provides the ability to use the screen as two separate screens or one single one. Radiologists have the flexibility to read colour, greyscale, moving or static images from one study or multiple studies side by side.

A further boost has been provided by technological advancement in LCDs [liquid crystal displays]. Such advancements have allowed for important ergonomic improvements such as brighter displays, which allow radiologists to work in brighter environments, thus reducing fatigue.

Improvement of IPS (in-plane switching) LCD technology has substantially improved contrast and viewing angles; improvements in backlight technology have also been significant.

The selection process for a monitor involves a lot of technical decisions. What are these and can you explain why they matter?

The main questions asked are typically around productivity, workflow, image quality and quality control. These key components will help determine the level of success. While definitions of success will vary among imaging departments, it can be defined by increasing patient throughput, better detection and accurate diagnosis, leading to better patient treatment and care.

Careful evaluation of medical displays is just as important as assessing the imaging modality itself. All manufacturers' medical displays are somewhat different, and therefore diagnostic imaging departments should really examine the impact of each manufacturer's medical displays on their productivity, workflow, functionality and accuracy of the image rendering, and quality assurance.

It is also important for larger healthcare facilities to have an automatic means to calibrate and control the image quality of their installed display fleet in diagnostic imaging and across the hospital.

When selecting a batch of monitors, what other forces come into play (for example, other hardware in the department, type of use and so on)? How important is an audit?

It is exceptionally important that the department conducts an audit so that it knows exactly what type of medical displays are required and within which clinical settings. Hardware and software in combination with the medical display have a vitally important impact on reader performance and productivity. Even a small impact on the overall reader performance can have a large impact on cost or revenue.

How important are productivity and workflow? There has been criticism that both can be hit by the introduction of digital reading. What should facilities' heads consider when making their choices?

These factors are vitally important to today's diagnostic imaging centre. Preliminary results published by researchers from Montefiore Medical Center in the US have found that a single 30in widescreen 6MP medical display provides increased productivity and reduces eye strain compared with two 3MP displays used in dual-head mode. They conclude that the single 6MP can increase productivity by up to 19% compared with two 3MP dual-head displays, while the 6MP display caused less eye strain for long reading sessions compared with the 3MP display. The average time per CR case was 148 seconds on the 6MP display, compared with 183 seconds on the dual 3MP displays. The study is ongoing.

Factors that affect productivity and workflow include how large-image studies are loaded and can be manipulated. The power and optimisation of the graphics controller

packaged with the diagnostic display system become exceptionally important. Instantaneous loading of image studies and image manipulation is vital, and has a direct impact on the radiologist's reading efficiency. In breast screening, for instance, this can have a significant impact.

Also, the medical imaging and PACS companies have a significant part to play in terms of productivity and workflow. A graphical user interface with limited numbers of clicks, fast image rendering, automated toolsets and real-time pan-and-zoom tools, along with screens optimised for specific clinical workflows, are all critical to workflow and how fast an image study can be read.

Calculating the savings from the faster radiologist and balancing this against the cost of the money used to buy the equipment gives a very positive net present value and a good return on investment:

- **COTS [commercial, off-the-shelf] display investment**: $1,200
- **medical display investment**: $7,000
- **radiology yearly cost reduction if medical displays are bought**: $6,933
- **reduction for whole period**: $34,663
- **NPV**: $23,009
- **ROI**: 4.98.

What are the benefits of medical displays?

It is well documented that patient safety and radiologists' productivity can be adversely affected by use of consumer-grade displays on diagnostic reading. The ability to see radiographic abnormalities can be directly linked to the diagnostic display's ability to show subtle details such as pulmonary nodules and pneumothoraces, in addition to producing a uniformly high, bright DICOM image; an adequate range of shades of grey; and the ability to manage colour shift at off-angle viewing, which affects image interpretation.

Studies such as Bacher in 2003 and Krupinski in 2008 show that radiologists come to the correct interpretation more quickly with medical displays. Both the Bacher and Krupinski studies indicate that there is more certainty with the better displays, as is demonstrated by the lower number of false positives and less time spent on viewing them. Here is an example calculation of the financial impact:

- **Number of new displays to purchase (COTS or medical display)**: One
- **Number of studies per year**: 15,000
- **Period**: Five years
- **Cost of radiologist per hour**: $295
- **COTS display cost**: $1,200
- **Medical display cost**: $7,000
- **Time to read image on medical display**: 35.17 minutes
- **Time to read image on commercial display**: 37.99 minutes
- **Faster reading of image on medical display compared with a COTS display**: 2.82 minutes
- **Faster reading of study on medical display compared with a COTS display**: 5.64 minutes.

In addition, there are various well-controlled studies demonstrating that differences in certain parameters such as resolution and luminance certainly do affect radiologist performance (Bacher 2003, Krupinski 2007). The recent, well-controlled study by Krupinski (2008) compared detection of pulmonary nodules by radiologists using a 3MP Barco colour medical-grade display with the same commercial display that Dr David Hirschorn used in his study. In this study, challenging cases were presented with subtle nodules that would be hard to see if conditions weren't right. The overall accuracy was expressed as the area under the receiver operator characteristic curve, which addresses inaccuracy resulting both from missed cancers and false positives. The study showed that every radiologist observer found the medical displays to give more accurate results. The results confirmed the common-sense notion that with better displays, radiologists perform better.

How comparable are costs with traditional methods of analysis?

This question was raised when the first wave of PACS (picture-archiving and communications systems) hit the market about a decade ago. In the early days, people questioned whether the higher cost of the new digital systems outweighed their benefits. Since then, costs have come down substantially with each generation and the traditional technology has nearly been completely replaced. The massive breakthrough of the technology was only possible because of its benefits and continuously reduced costs.

How have regulators addressed the growing number of medical-grade displays and what are the requirements for manufacturers?

Regulations and guidelines for diagnostic displays in key markets have been in place for nearly a decade now, but we are seeing the strengthening or extension of existing regulations and guidelines in some countries. Medical device regulations vary, but all have the fundamental principle of ensuring that medical devices are effective and safe to use.

In addition to medical device regulations, medical displays are subject to practical guidelines and standards that are usually the domain of the local radiology society. In the US, for example, the American College of Radiology (ACR) provides practical guidelines and standards.

> "The ability to see radiographic abnormalities can be directly linked to the diagnostic display's ability to show subtle details such as pulmonary nodules and pneumothoraces."

Practice guidelines describe recommended conduct in specific areas of clinical practice. They are based on analysis of current literature, expert opinion, open forum commentary and informal consensus. Guidelines are not intended to be legal standards of care or conduct and may be modified according to individual circumstances and available resources.

Technical standards describe technical parameters that are quantitative or measurable. They often include specific recommendations for patient management, or equipment specifications or settings. Technical standards are based on analysis of current literature, expert opinion, open forum commentary and informal consensus. Technical standards are intended to set a minimum level of acceptable technical parameters and equipment performance and may be modified according to individual circumstances and available resources.

With regard to equipment specifications, the ACR states that "compliance with the current National Electrical Manufacturers Association (NEMA) Digital Imaging and Communications in Medicine (DICOM) standard is strongly recommended for all new equipment acquisitions".

This statement is important when planning an acquisition of new radiology reading stations. The current trend within the AAPM (American Association of Physicists in Medicine) and IEC is to develop a global standard for monitor calibration and quality standards for radiology.

The ACR standard outlines the display device guidelines that give recommendations for the acquisition and display of small and large matrix studies.

Small matrix studies are recommended to be acquired and viewed using a display capable of interpreting 1,024 shades of grey or 10-bit greyscale data. Commercial displays have a difficult time rendering 10-bit greyscale data consistently.

Large matrix studies (plain film) are recommended to be acquired and viewed using a minimum standard of 10-bit greyscale data and 2.5lp/mm (line pairs per mm), which is roughly equal to 3MP. This is the reason that 3MP diagnostic monitors have become the standard in radiology.

Compliance with the DICOM GSDF (greyscale standard display function) is mentioned throughout the practice guidelines to ensure that displays being used for the primary interpretation of radiographic images have the ability to be calibrated to the DICOM standard, but also that there are tools available to prove conformance to the standard, and that there is a quality control system built into the monitors.

The ACR standard also recommends that displays used for primary image interpretation are matched for colour temperature, brightness and contrast.

Displays designed to be used in diagnostic radiology applications typically use stabilisation systems (backlight or front of screen) that ensure that the light output, and therefore screen contrast, remain fixed throughout the useful life of the displays.

Pairing displays for brightness and contrast is accomplished by calibrating displays to the DICOM GSDF standard. Pairing displays to account for native colour temperature is handled by the display manufacturer and cannot be done in the field with any accuracy.

Commercial display manufacturers rarely build these systems into their monitors due to cost and lack of application in normal desktop use.

Is future-proofing an issue and how can it be factored in when making a choice?

Diagnostic imaging departments should have a good idea of where their practice is going in the future in terms of modalities, advanced applications and also volume. When deploying new modalities, PACS or medical displays, each manufacturer should be able to provide the right guidance to ensure the best-possible product selection based on the diagnostic imaging department's current and future requirements.

What are the dangers of making the wrong choice?

Possible failure to perceive a radiographic abnormality, which can impact patient safety and raise the risk of liability. These are often referred to as 'misses' or 'missed diagnoses'. According to the ACR, mammographs and chest radiographs expose radiologists to the greatest risk in this regard. The most commonly missed diagnoses are breast cancer, lung cancer and fracture of the spine.

What more can we expect from technological developments in the mid to long term and how will these aid medical care?

We believe that hospitals will dedicate themselves to earlier diagnosis, reduced medical errors, reduced costs and patient safety at all levels.

In the mid term, we will see LCD displays with increased resolution and LED backlights gain momentum, given their advantages in terms of image quality and OPEX.

In the longer term, we see OLED (organic light-emitting diode) technology moving into professional applications. Advances on yield, quality and price are still required before this technology will be adapted in the medical field.

We also expect:

- increased broadband implementation (wired and wireless), increased accessibility and a greater number of products and applications across the hospital enterprise
- implementation of the electronic medical record, providing patient data and medical images on a platform that can be accessed via desktop computers, mobile devices and online
- conversion of the remaining key clinical setting from analogue to digital, for example cardiology, pathology, ophthalmology and so on
- increased medical device connectivity solving the inherent problems created by a multivendor environment
- increased medical device instrumentation and appliances that bring healthcare delivery closer to the patient
- advanced virtualisation networks capable of reducing the IT burden.

Can you give five tips for selecting the right monitor?

1. Overall image quality (brightness, contrast, viewing angle) is paramount.
2. Image stabilisation sensors are a must.
3. High-precision front of screen photometers must be used to perform quality assurance (QA).
4. Uniformity correction improves diagnostic image accuracy.
5. Automated, centralised quality QA provides many benefits and savings.

Finally, only look at medical displays that meet your imaging study needs. ■