Digital imaging is a rapidly developing field in radiology. The UK government committed £60 million in 2004, through the then National Programme for IT, to provide picture archiving and communication systems (PACS) throughout the UK. At the time of writing, the implementation of this programme is still in progress.

In a film-based system, the film is used for both the acquisition and the display of the image data. In a digital system, this physical link no longer exists and, consequently, diagnostic images can now be viewed anywhere, particularly when Internet interfaces are used.

This has recently raised issues about the display requirements for viewing images, particularly outside radiology. Although there are regulations and guidelines relating to soft copy display devices (display) [1–5], some practical issues of implementation are not fully explored. This paper aims to address some of the practical issues for hospital-wide soft copy viewing, including equipment selection, environment considerations, quality assurance and legislation.

Equipment selection

Cathode ray tube vs thin film transistor

One of the first issues with respect to a potential purchase is whether the display should be a cathode ray tube (CRT) device or a flat panel liquid crystal thin film transistor (TFT) device. There have been several recent publications comparing the technical and diagnostic performance of CRT and TFT displays [6–9]. Samei [8] gives a good tutorial on the differences between the competing display technologies and emphasizes the need to consider these differences and human factors to achieve optimal display. Krupinski et al [9] reported that TFT displays may be suitable for soft copy reporting and may even be better than CRTs on account of lower veiling glare and isotropic modulation transfer function. This is dependent, however, on ensuring on-axis viewing of the images. If these concerns are considered, there does not appear to be any major technological reasons for not using a TFT display for all display requirements. Other factors may affect the choice of display such as size, weight, heat output and magnetic field considerations. It is also important to note that a comparable specification CRT will produce a more “film-like” image than its TFT counterpart because of its analogue nature, and that TFT displays must be driven at their native resolution.

Specification

There has been a huge investment worldwide in display technology, driven by the consumer market, resulting in a dynamic and large product range. There is also a wide range of medical applications requiring the soft copy display of images, although currently only two classifications of display, either reporting (primary or diagnostic) or review (secondary or non-diagnostic), seem to be considered. This makes matching the wide technology range and display selection difficult.

It is proposed that this limited classification range be expanded to more closely match the full range of applications. One approach to this would be to use equipment banding, as used by some equipment suppliers for private finance initiatives. This places the available product range into bands based on applications which have a minimum technical specification. A banding scheme suggested by the author is shown in Table 1. It is important to note that, where a single display is used for multiple applications, the highest applicable band is specified. Therefore, in many PACS environments, only Band A or Band C displays will be required.
A minimum specification is also required for this banding scheme. Analysis of the current display product ranges, by the author, allows a minimum specification to be proposed for each band (Table 2).

Another consideration for display specification is whether it needs to be a medical device. This has significant implications for a Trust rolling out PACS where the difference in cost between high quality consumer displays and CE marked medical devices can vary by as much as a factor of four.

Medical devices

Currently, the only published UK advice on soft copy display devices, specifically for the UK, is from the Medical and Healthcare products Regulatory Agency (MHRA) [3]. This document does not give specific recommendations but does imply that the MHRA considers a diagnostic display as being a medical device. The document states that ‘The MHRA is aware that visual displays of inappropriate quality are being used for diagnostic purposes. There is also concern that the viewing environment and the maintenance of all types of electronic visual displays are given insufficient attention’. This introduces the risk that a display that is used for diagnostic purposes, but is not a CE marked medical device, would be at the user’s/Trust’s own liability. A medical device is classified as:

Any instrument, apparatus, appliance, material or other article, whether used alone or in combination, intended by the manufacturer to be used for human beings for the purposes of: diagnosis, prevention, monitoring, treatment or alleviation of disease diagnosis, monitoring, treatment or alleviation of or compensation for any injury or handicap investigation, replacement or modification of the anatomy or of a physiological process control of conception and which does not achieve its principal intended action in or on the human body by pharmacological, immunological or metabolic means, but which may be assisted in its function by such means. [10]

It is clear from this definition that a soft copy display used for reporting, monitoring or patient treatment is a medical device; this is consistent with the Band A and B applications in Table 1. But what about the Band C displays? The Royal College of Radiologists (RCR) guidelines [11] state that the report is the legal record; therefore, a review image is illustrative only and, as such, is not used for a diagnosis or for monitoring or treatment. Therefore, displays intended to be used solely for review purposes do not need to be medical devices, although it is expected that a suitably high quality and specification consumer display is used to meet performance prerequisites. It is important to note that electrical safety regulations will apply to any device positioned within the patient vicinity, i.e. within 1.5 m of the patient [12, 13].

Environmental considerations

Cleaning and infection control

All displays need to be cleaned regularly to remove dust and fingerprints [3, 14]. If the display is not in a clinical area, this is relatively straightforward and can be achieved with appropriate consumer cleaning materials. If the display is within a clinical environment, consideration needs to be given to the potential severity of infection and how this can be removed. CRT displays are made of glass and are relatively easy to clean, although anti-reflective coatings may need special cleaning. TFT displays are usually supplied with a polymer screen, but may optionally have a glass screen fitted, which is more resilient than polymer faces but will

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**Table 1.** Banding scheme for soft copy displays used in hospital applications

<table>
<thead>
<tr>
<th>Band</th>
<th>Description</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>A+</td>
<td>Highest end reporting for demanding applications</td>
<td>Mammography</td>
</tr>
<tr>
<td>A</td>
<td>High quality reporting monitor</td>
<td>Radiology conventional reporting</td>
</tr>
<tr>
<td>B</td>
<td>Reporting monitor for lower contrast or resolution modalities or highly supportive review applications, i.e. immediate feedback to clinical activity</td>
<td>MRI, PET, CT, ultrasound, cardiology</td>
</tr>
<tr>
<td>C</td>
<td>Review monitor not to be used for diagnosis but images viewed only in conjunction with the report</td>
<td>Ward, clinic</td>
</tr>
<tr>
<td>D</td>
<td>Do not use to view clinical images</td>
<td>IT applications only</td>
</tr>
</tbody>
</table>

PET, positron emission tomography.

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**Table 2.** Minimum technical specifications suggested for use with the scheme for soft copy displays used in hospital applications (it is important to note that these specifications need to be reviewed regularly, i.e. annually)

<table>
<thead>
<tr>
<th>Band</th>
<th>Type</th>
<th>Physical size (inches)</th>
<th>Bit depth</th>
<th>Resolution (mp)</th>
<th>Dot pitch (mm)</th>
<th>Max lum (cd m&lt;sup&gt;2&lt;/sup&gt;)</th>
<th>Contrast ratio</th>
<th>CE medical device</th>
</tr>
</thead>
<tbody>
<tr>
<td>A+</td>
<td>Mono CRT/TFT</td>
<td>21</td>
<td>10</td>
<td>5</td>
<td>0.16</td>
<td>&gt; 700</td>
<td>&gt; 700:1</td>
<td>Yes</td>
</tr>
<tr>
<td>A</td>
<td>Mono CRT/TFT</td>
<td>21</td>
<td>10</td>
<td>3</td>
<td>0.2</td>
<td>&gt; 500</td>
<td>&gt; 500:1</td>
<td>Yes</td>
</tr>
<tr>
<td>B</td>
<td>Colour TFT</td>
<td>20–21</td>
<td>8</td>
<td>2</td>
<td>0.25–0.27</td>
<td>250–300</td>
<td>&gt; 400:1</td>
<td>Yes</td>
</tr>
<tr>
<td>C&lt;sup&gt;+&lt;/sup&gt;</td>
<td>Colour TFT</td>
<td>17+</td>
<td>8</td>
<td>1–2</td>
<td>0.27–0.29</td>
<td>200–250</td>
<td>&gt; 400:1</td>
<td>No</td>
</tr>
</tbody>
</table>

CRT, cathode ray tube; mp, megapixel; TFT, thin film transistor.

<sup>*</sup>Will also depend on other factors, e.g. ambient lighting, distance from viewer and compliance with IEC 60601.
have a higher reflectivity and increased cost. There are many different cleaning products readily available in a hospital environment, and it is possible that some of these may damage a polymer or anti-reflective surface. It is suggested that any display may be positioned in clinical areas where there is a low infection risk, but that a statement of cleaning product, based on the manufacturer’s recommendations, is placed on the display casing. For areas where there is an infection risk, conformance is required to the IP65 [15] level, which provides protection to the level that dust cannot enter at all and water jets directed at the enclosure from any direction must not have any harmful effect. If the display is sited in the patient environment, International Electrochemical Commission (IEC) 60601 [12] will also apply. Ultimately, the local infection control team should be consulted if there is any uncertainty as to the suitability of a display for its environment.

**Ambient lighting and reflections**

Careful siting of displays is important to minimize strong ambient light sources, which are a significant factor in image degradation [16–18]. Positioning the displays facing windows or other strong light sources should be avoided. It is suggested that, in areas of high ambient light/reflections, monitor hoods should be considered, as frequently used on graphics displays. These also have the advantage of increased privacy for viewing images in more public areas such as wards, and may also assist in complying with the Health and Safety (Display Screen Equipment) Regulations 1992 [5], which require the screen to be free of reflective glare and reflections liable to cause discomfort to the user. Use of software contrast and brightness controls may compensate for loss of contrast [16], although this may not be practicable in some environments such as theatres. Hardware brightness and contrast controls must not be used as these may compromise any Digital Imaging and Communications in Medicine (DICOM) calibration. A useful indicator of the potential impact of ambient light and reflections on a display is the coefficient of reflectivity. The lower the coefficient, the fewer the reflections from the monitor face; published figures [19] show coefficients for film to be in the order of 0.013–0.039 depending on optical density, CRT displays from 0.0034 to 0.042 depending on anti-reflective coatings and TFT from 0.0019 to 0.012. In general, TFT displays have the lowest coefficient of reflectivity. This may be a factor where manufacturers use glass/panels sourced from different suppliers, even within the same product range. This can result in inconsistency between displays and needs consideration, particularly if displays are used in pairs. The American Association of Physicists in Medicine (AAPM) report TG18 [20] presents a method for determining the maximum ambient light level for a specific display based on the luminance range of the display and the coefficient of reflectivity. This relatively complex method makes it difficult to specify absolute levels for ambient light for different environments; however, the Institute of Physics and Engineering in Medicine (IPEM) report 91 [14] does set a remedial luminance level (> 15 lux) for reporting environments.

**Quality assurance**

A medical device (Band A and B) should be supplied with a service and quality assurance (QA) schedule. Additionally, in the UK, there is recent guidance on soft copy QA from the IPEM [14] (IPEM report 91) and, in the US, the AAPM report TG18 [20, 21]. The IPEM report 91 presents a QA programme that ranges from daily/weekly inspection of general display condition to 3 monthly testing of grey scale, measurement calibration and resolution, and 6–12 monthly DICOM calibration, consistency and ambient lighting tests. However, it is worth noting that these protocols primarily relate to Band A and Band B displays; although this does not preclude their use on Band C displays, this would be prohibitive from a time resource perspective; the 6 monthly test can take up to 1 h to complete. The MHRA guidelines [3] also state that “Review displays (Band C) do not require the same level of image quality assurance as diagnostic displays. However, these still need to be cleaned and the image quality maintained”. Although annual QA and weekly cleaning may satisfy these guidelines, it is suggested that more frequent testing may be required for Band C displays as they are more likely to be adjusted by the users and to be of a lower quality than those used for reporting. For Band C displays, Jervis and Brettle [22] indicated that a good consistency can be achieved using just the Society of Motion Pictures and Television Engineers (SMPTE) test pattern [23]. However, even a simple QA test like this would require a large manpower resource to support because of the large numbers of displays. It is therefore suggested that Band C display QA needs to be conducted by the user, preferably each time the display is used. This is particularly important if the on-screen controls cannot be disabled, as these may be reset by users to alter the display contrast and brightness instead of using the equivalent software functions. If they are consequently not returned to the optimal levels, then the display is compromised. As a minimum, the user needs to be aware that the display may be suboptimal. One simple method for this is a software notification screen that prompts the user to the application for which the display is suitable and presents a simple contrast detail test image (see Figure 1).

**Figure 1.** Example screen grab from a Band B display showing a statement of use for the display and three test details at the appropriate contrast levels.
The user can be instructed that they need to see these details before using the software and, if they cannot, to follow a simple set-up/QA process or contact technical support. When a display has been set up, it is highly desirable to lock out the ability of the user to adjust the contrast and brightness to prevent compromising the display by uncontrolled hardware adjustment. However, this is contrary to the Health and Safety (Display Screen Equipment) Regulations 1992 (HS(DSE)R) which require that “The brightness and/or contrast between the characters and the background shall be easily adjustable by the operator, and also be easily adjustable to ambient conditions”.

A more auditable method of conducting soft copy QA for Band C displays has been suggested by Brettle and Bacon [24]. This technique uses verified login software that acts as an interface to the image viewing software. In order to use the software, the user has to pass a challenge response code constructed of low contrast letters across the display range set at a level appropriate to the banding of the display. This is effectively point of use QA and provides a minimum level of clinical governance for potentially all soft copy displays. It can also be used with Band A and B displays, particularly those used in remote areas such as clinics or the home where technical support may be limited. This method is also sensitive to ambient light conditions and, controversially, the visual acuity of the user.

**Current legislation**

In the UK, there are three regulations that will relate to the use of soft copy display devices in radiology: the Ionising Radiations Regulations 1999 (IRR99), the Ionising Radiation (Medical Exposure) Regulations 2000 (IR(ME)R) and the Health and Safety (Display Screen Equipment) Regulations 1992 (HS(DSE)R). Any display function that affects the exposure given to a patient, e.g. fluoroscopy displays, will fall under IRR99, although there may be occasions where IR(ME)R could be applicable as well. Outside the X-ray room, the situation is not so clear. It could be argued that, if a radiologist requested a repeat exposure because of poor display on a reporting workstation, this would fall under IRR99 as the display is linked to the exposure. Alternatively, the poor display may be argued to have caused a failure to comply with IR(ME)R as the viewer requested the additional exposures as a result of not being able to distinguish between an inadequate image and an adequate but poorly displayed one. If a patient receives additional radiation due to a failure of a display, then this would fall under one of the Ionising Radiation Regulations. Clarity from the regulators on this matter would be helpful and would assist in the appropriate reporting of incidents.

This commentary aims to address some practical issues relating to selecting, installing and maintaining soft copy displays for all applications within the hospital environment. It is hoped that this may alleviate some of the inconsistencies and confusion currently existing with respect to soft copy display devices and raise the awareness of soft copy as a major, regulated element in the digital imaging chain. It is also intended to highlight that there is a need for additional resources to maintain soft copy quality over and above that required for film-screen radiography.

**Acknowledgments**

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**References**

4. CAR standards and guidelines for teleradiology. Quebec, Canada: Canadian Association of Radiologists, 1999.
18. Haak R, Wicht MJ, Hellmich M, Nowak G, Noack MJ. Influence of room lighting on grey-scale perception with a...
Commentary: Viewing of soft copy image display