# The Royal College of Radiologists

# Guidelines for Image Viewing and Reporting Systems, Diagnostic Displays and Human Interface Devices

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## 1. Key Recommendations

- Image review on a primary diagnostic workstation should be undertaken with a reliable display with at least three megapixels (MP) resolution, a luminance range of at least 1–350 candelas per square meter (cd/m2) which is hardware calibrated at least annually such that it remains within 10% of the digital imaging and communications in medicine (DICOM) grayscale standard display function (GSDF).
- Mammography is regarded as a specialist imaging situation requiring a higher resolution and brighter display unit than for standard diagnostic reporting.
- Clinical review displays and mobile displays used for clinical review or point-of-care ultrasound (POCUS) should be at least 2 MP resolution with a luminance range 0.8–250cd/m2 and should be calibrated at least once a year to remain within 20% of the DICOM GSDF. Either hardware or perceptual calibration (using the Task Group 18 [TG18] test patterns) may be used.
- The viewing environment should be strictly controlled in the primary diagnostic setting with light levels maintained at between 25-75 lux (similar to “evening living room” illumination levels) and avoidance of direct light sources. For clinical review, the environment should be controlled as best achievable.
- Appropriate voice recognition software deployment with good quality microphones, human interface devices and environmental design are recommended to promote comfort and productivity.

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## 2. Introduction

Radiology as a medical speciality consists of the interpretation of images acquired by various modalities and the production of a legally binding radiology report. During the process, images are transferred from the acquisition device to a Picture Archiving and Communication System (PACS), then displayed on a monitor at a workstation either at the Organisation at which the image has been acquired, remotely from other institutions or remote locations such as the Reporter's home. Reports are usually generated with the assistance of voice recognition (VR) software. Images are also viewed by radiologists and other clinicians in a variety of other locations and settings such as Multidisciplinary Team Meetings, emergency departments, ward rounds, for tertiary second opinions and on mobile devices. As such, it is increasingly important that the devices and software that form the sum of the parts of this adhere to an appropriate quality standard in order to ensure accurate radiological assessment, data security and process efficiency.

The purpose of this document is to set standards and give advice around:

- Radiology display devices, their calibration and fleet management
- Viewing and reading environments, ergonomics, human interface devices and voice recognition
- Mobile image review including POCUS devices
- Image viewing and radiology information systems with focus on deployment for both primary site and remote reporting, cross site operability, MDT and teaching.

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## 3. Display Devices

### *3.1 Purpose Based Display Specification*

This document will make a distinction between the specifications of devices used for generating a primary radiology report (a legally binding document which requires an optimised viewing environment) and general clinical review, on which medical decisions may be based but which may be suboptimal for a comprehensive radiological assessment.

Medical grade diagnostic medical displays (DMDs) are display devices focused on whole life stability and maintenance of display characteristics throughout product life with a variety of features to facilitate calibration and audit (covered below) such as inbuilt ambient light detection, self-calibration and quality control as well as inbuilt Look up tables and software for maintaining the greyscale GSDF.

Cheaper and readily available consumer off-the-shelf (COTS) monitors can offer similar paper specifications and have been shown to be equivalent to DMDs for primary review when used under controlled conditions.

The exact displays purchased for a particular workplace may depend on factors such as cost and availability but must adhere to the same criteria:

Most, if not all displays used in healthcare settings are variants of flat panel liquid crystal displays (LCDs) which have long-ago supplanted cathode ray tube devices due to their superior specifications, low cost, small footprint and relative energy efficiency. LCDs come in two general types, depending on the source of the liquid crystal backlight. LED lit LCDs (compared to the older fluorescent lamp lit LCDs) tend to offer better contrast ratios, colour accuracy, power efficiency and longer lamp life (with more stable luminosity). LED backlit LCDs are often built using in plane switching (IPS) technology which allows wider viewing angles in multiple planes which are beneficial where users may be stationed in different positions distant from the display (eg. In theatres or MDT rooms) or when larger displays are used so that the corners are just as readable as the centre. Many modern LCDs are edge lit so care must be taken to ensure that the monitor is capable of good uniformity across the image plane. This is often achieved by uniformity corrections added to the monitor at the factory although some cheaper LED LCD displays may have uneven luminosity across the panel rendering it unsuitable for consistent image display. There are also problems with newer OLED (organic LED) displays in terms of their calibration and display artifacts and these are not currently recommended.

For primary review of medical images, the most important specifications for a display are:

**Resolution and pixel pitch**: The resolution of the monitor should equal or exceed the resolution of the visualised image (5 MP for mammography, 3 MP for plain radiographs and 2 MP for other cross sectional imaging). The pixel pitch (pixel spacing) is based on the maximum spatial frequency on average perceivable by human vision (2.5 cycles/mm) and therefore should be no higher than 0.21mm for plain radiographs.

**Luminance response:** The minimum luminance (Lmin) should be high enough not to

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stimulate the mesopic vision response which greatly reduces the human perception of differences in luminance – This results in a minimum recommended value of 1 cd/m2 for most applications and 1.2cd/m2 for mammography but depends on ambient room conditions (covered below).

The maximum luminance (Lmax) and luminance ratio (LR=Lmax/Lmin) should reflect the human visual system's inherent limitations of perceiving different luminosity values. An Lmax of 350 has usually been used to mimic the luminance of traditional light boxes and the LR of 350 corresponds to a radiographic optical density range of 0.20 to 2.75 which is more than sufficient for most applications except for mammography in which a higher LR of 400 is recommended.

**Display size:** When seated at the optimum viewing distance of 60cm from the screen, the screen should be of an appropriate size for the eye to be able to take in the majority of the image without excessive eye or head movement and this corresponds to a screen size of 53cm (21 inches) which corresponds to the screen size of a 3MP monitor at 0.21mm pixel pitch or 5MP monitor at 0.16mm pixel pitch.

"Dual display" monitors are available from a number of manufacturers incorporating the screen footprint of two portrait monitors into one larger, widescreen landscape monitor and are preferable from the display point of view allowing two images to be compared side to side without bezel interruption.

**Interface:** Digital interfaces such as HDMI, DisplayPort (including over USB-C) and DVI-D are recommended to avoid analog to digital conversion during image display and potential image degradation. Similarly, adaptors to convert between DisplayPort/HDMI and DVI-D are also discouraged.

### *3.2 COTS displays and Clinical Review displays*

There has been much debate about the potential use of Consumer off-the-shelf (COTS) displays as primary review displays in Radiology departments given research showing their equivalence to DMDs in controlled settings.

COTS displays are devices not specifically built for the rigorous requirements of continuous display of medical images and although some high end monitors have ambient light detectors, none have inbuilt display calibration. COTS display luminance also degrades unpredictably with time and these displays probably also have a shorter overall usable lifespan than DMDs (although this has yet to be accurately tested). Almost all of these shortcomings can be overcome by an appropriate regular quality assurance and calibration programme, requiring extra manual work and discipline.

The advantages of COTS displays are that they are lighter, more widely available and significantly cheaper. However, the RCR strongly recommends DMDs for use in radiology departments due to their superior stability and ease of set up and calibration across their lifespan.

If COTS are used in any part of a healthcare imaging set up, they should be planned and

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chosen by a specialist who has an in-depth knowledge of display specifications and is able to match these with the intended use-case, and implement a fleet management strategy to assure adequate performance across the intended lifespan. Regular audit and manual calibration of these monitors is compulsory and further discussion of this can be found below.

Clinical review work monitors cover the monitors used throughout various healthcare settings including offices, MDT rooms, operating theatres and emergency departments often used for a wide variety of administration tasks including image review. These are almost invariably COTS displays. As most of this work does not for the most part rely on the detection of subtle findings and for reasons such as cost and practicality, lower specifications may be acceptable for these monitors. Resolutions down to 2MP and luminosities of 250cd/m2 may be acceptable in clinical displays depending on the demands of the setting (for example, theatre screens in areas of high ambient light levels may need higher luminosity screens or other measures to limit incident light such as matte front panels and screen shades).

Given their lower specifications, ongoing quality assurance and calibration are just as important for these displays to track degradation of performance and inform life cycling. Most such displays lack integral calibration and therefore require stand-alone photospectrometer devices or perceptual calibration using the TG18/TG270 test patterns. A number of COTS devices now exist which already incorporate a hardware level DICOM GSDF colour profile, meaning that only critical performance drift needs monitoring.

**Tables with recommended “lower limit” specifications of DMDs and Clinical review monitors - this is the same as for the previous version of this document**

**Table 1: Recommendations for display standards in primary diagnostic work**

| Feature | Plain film x-ray | CT scan | MRI scan | Ultrasound scan | Fluoroscopy | Nuclear Medicine |
|---|---|---|---|---|---|---|
| **Minimum Resolution (Megapixels)** | 2048 x 1536 (3Mp) | 1600 x 1200 (2Mp) | 1600 x 1200 (2Mp) | 1600 x 1200 (2Mp) | 1600 x 1200 (2Mp) | 1600 x 1200 (2Mp) |
| **Megapixel resolution** | 3MP | 2MP | 2MP | 2MP | 2MP | 2MP |
| **Maximum pixel pitch** | 0.21mm | 0.21mm | 0.21mm | 0.25mm | 0.25mm | 0.25mm |
| **Orientation** | Portrait format | Portrait / Landscape | Portrait / Landscape | Portrait / Landscape | Portrait / Landscape | Portrait / Landscape |
| **Calibration** | DICOM GSDF ≤ 10% | DICOM GSDF ≤ 10% | DICOM GSDF ≤ 10% | DICOM GSDF or sRGB ≤ 20% | DICOM GSDF or sRGB ≤ 20% | DICOM GSDF or sRGB ≤ 20% |
| **Luminance (min/max)** | 1 / 350 cd/m$^2$ | 1 / 350 cd/m$^2$ | 1 / 350 cd/m$^2$ | 0.8 / 250 cd/m$^2$ | 0.8 / 250 cd/m$^2$ | 0.8 / 250 cd/m$^2$ |

**Table 2: Clinical and Mobile Review Display Standards**

| Feature | All modalities |
|---|---|
| **Minimum Resolution (Megapixels)** | 1600 x 1200 (2Mp) |
| **Megapixel resolution** | 2MP |
| **Maximum pixel pitch** | 0.25mm |
| **Colour / Monochrome** | Colour |
| **Orientation** | Landscape or portrait format |
| **Calibration** | DICOM GSDF ≤ 20% *or* using TG18 test pattern |
| **Luminance (min/max)** | 1 / 250 cd/m$^2$ |

**Breast radiology**

| Feature | All modalities |
|---|---|
| **Minimum Resolution (Megapixels)** | 2560 x 2048 (5Mp) |
| **Megapixel resolution** | 5MP |
| **Maximum pixel pitch** | 0.17mm |
| **Colour / Monochrome** | Colour or Monochrome |
| **Orientation** | Portrait format |
| **Calibration** | DICOM GSDF ≤ 10% strictly maintained |
| **Luminance (min/max)** | 1 / 400 cd/m$^2$ |

### *3.3 Mobile image review*

In the last decade, mobile review of clinical images both by radiologists and other clinicians has become more common as to warrant specific discussion as mobile devices are of varied specification and present a wide range of challenges. It has become common for medical images to be reviewed in a range of situations including on hospital tablet computers during ward rounds, on phone screens as instant messaging videos and even integrated vehicle displays.

Mobile displays have variable specifications, but resolution, luminosity and pixel pitch can often equal or exceed our minimum recommendations. Several tablet devices meet recommended standards for clinical or mobile review, and use of DICOM viewing software can apply look-up tables to normalise greyscales to the DICOM standard GSDF.

Several studies have looked at the Apple iPad as a possible device for reviewing medical

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images and found it non-inferior for some indications including stroke on head CT. However, due to the small screen size and high pixel pitch, image zooming is required to enlarge the image to reach spatial frequencies at which human vision has greatest contrast sensitivity (around 0.5 cycles/mm) allowing only small portions of the image to be appropriately interrogated at one time. This limits the sensitivity of mobile devices to smaller and low contrast abnormalities.

Clinical review of medical images on smartphones can also be achieved with DICOM viewing applications but suffers from even more acute problems with screen size and pixel density (although resolution and brightness of screens is often adequate). Images viewed on phones and other devices outside of DICOM viewing software are frequently compressed with lossy algorithms which have the potential to introduce artefacts rendering them less suitable for clinical review.

Overall, current evidence on mobile image review is scarce, but points towards mobile devices being adequate for clinical review in certain compromised circumstances where better options are not achievable, and an urgent medical decision is required. Device screen size should be as large as possible, and clinicians must acknowledge and take responsibility for the limitations of the devices in detecting subtle pathology when making clinical decisions. It is good practice to take note and carry out a secondary review of the same images when better equipment becomes available, so that the mobile device is not the only mode of interpretation used for key decision making.

### *3.4 POCUS devices*

Point-of-care ultrasound has become very widely adopted across a variety of diverse healthcare settings due to the low cost, ease of use and lack of ionising radiation. In hospitals, such devices are frequently used in emergency departments, intensive care units and clinic situations. Devices are also prevalent in the community, including in smaller, private clinics who often lack a good image backup and storage strategy. POCUS devices are used for both diagnostic and interventional cases and application of guidance may therefore vary, with a more rigorous standard being required where key clinical diagnostic decisions are made.

In previous decades, point of care ultrasound devices included an inbuilt screen and proprietary quality assurance software to maintain screen response. However, more recently, point of care devices that use external displays such as tablet computers or mobile phones as output devices have emerged where live ultrasound images are transmitted either by cable or wireless signals to the display.

Although the convenience of such devices is undeniable, clinicians that utilise these devices should be aware that:

- It is assumed that the proprietary applications used to display these ultrasound images apply LUTs to normalise greyscale values, but this may not be the case in some devices and as such, grey levels of images may differ across different display devices.
- All display devices used for POCUS image display should be periodically assessed as for all mobile image review devices (as below) and the responsibility to arrange quality

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assurance (typically with medical physics professionals) lies with the department in possession of the scanner.

- The limitations of human vision in assessing images on small high-resolution screens should be considered as image zooming during ultrasound is often not possible or awkward to perform therefore larger output displays are favoured to offset this.
- POCUS is not equivalent and should not be used in lieu of scanning under correctly controlled conditions in the radiology department with formally qualified staff.

### *3.5 Multidisciplinary team meeting and virtual image review including teaching*

Multidisciplinary Team Meetings often involve review of radiology and pathology digital images and increasingly images captured by other specialists (e.g. endoscopy or arthroscopy images). Since the COVID pandemic, these meetings have often continued in a hybrid format with images being shared over streamed videoconferencing applications and within MDT conference rooms simultaneously.

MDT room displays are usually conference room solutions consisting of one or two large format flat panel TV type displays or projectors. Displays such as this are not considered clinical review displays as they are predominantly for demonstration of findings and not suitable for diagnosis. However, as the attending radiologist may be asked to provide rapid clinical assessment on unprepared cases during a meeting, they should be equipped with a primary review capable workstation in a suitable viewing environment.

Videoconferencing applications invariably use lossy compression to deliver streaming video at low latency to prevent “stuttering”. Clinical review is emphatically not recommended over this type of connection. However, such setups often involve a radiologist using primary review grade equipment reviewing and streaming their findings, a situation which is adequate for decision making by remote meeting attendees in their audience.

Radiology teaching is provided in a similar way to MDT discussions – often in hybrid format, although distance teaching should not entirely replace the other benefits of face-to-face teaching interactions. In this case, the teaching radiologist should be aware of the limitations of the videoconferencing format and tailor teaching so as not to hinge on subtle findings that may be hidden by compression artefact or lost to temporal latency (scrolling large CT scans).

### *3.6 Calibration and fleet management*

**Calibration**

Medical displays chosen for image review should allow adjustment of colour and grayscale representations so that they can be tested against and calibrated towards recognised reference standards such as the DICOM GSDF for greyscale images. Calibration of displays towards the DICOM GSDF allows standardisation of the brightness of different grey levels or contrast response across different monitor types. The white point of displays is also important to normalise the presentation of both greyscale and colour images and is recommended set to Daylight standard (CIE Standard Illuminant D65/ Correlated Colour Temperature 6500K).

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Displays should be evaluated for performance by a qualified medical physicist or equivalent at time of deployment and after any major workstation upgrades or repairs (eg. graphics card replacement). After initial testing, regular testing (at least annually but may need to be more frequent depending on use case) against the DICOM GSDF contrast response curve is recommended - either by inbuilt calibration equipment or external photometer devices. Display performance data for a healthcare institution should be centrally collated and regularly reviewed.

For primary diagnostic displays, the response curve should be within 10% of the GSDF across the full range. Perceptual calibration using the TG18-QC or similar test patterns is not recommended as formal testing.

For other clinical review displays, a response within 20% of the GSDF is sufficient. In the absence of trained staff, perceptual calibration using the TG18 test patterns can be undertaken as a substitute, but it is not possible to accurately assess a display with the test pattern alone and as such a minimum of occasional formal calibration with a stand-alone photometer is recommended in these circumstances.

DMDs with inbuilt photometers and backlight sensors will often perform more frequent automated testing and calibration to ensure that they stay within the expected parameters. However, it should be noted that the internal calibration devices themselves also require periodic calibration every 10,000 backlight hours (as mandated by AAPM 270).

The day-to-day practicalities of testing a fleet of diagnostic displays is determined by fleet size and proximity – e.g. a large fleet or one with a large proportion of remote workstations may be best audited remotely with centralised dashboard control highlighting problem displays requiring attention whereas smaller, more localised fleets may be managed manually. The practicalities of routine testing of all of the clinical review displays in a healthcare setting are daunting and resource intensive, but regular testing is desirable. Therefore, it may be most appropriate to concentrate resources to prioritise high use areas (eg. Doctor’s offices, Emergency departments, outpatient clinics and theatres).

Mobile devices for the most part cannot be calibrated in the same way as larger displays without custom code and root access. They should be tested periodically for suitability using the TG18 test patterns.

Colour displays are now default across most radiology departments with monochrome only displays being life cycled or phased out for the most part. Colour images within the imaging department are used extensively within nuclear medicine and within ultrasound and now increasingly introduced into image packets by AI algorithm overlays. As PACS in some settings are now starting to include a wider range of medical images, in some settings clinical photographs and other medical images can also be present in-patient image packets.

Most colour radiology images requiring assessment of colour levels are “pseudocolourised” based on lookup tables – i.e. numerical data overlaid onto a greyscale image as a colour mask produced by the image display software (eg. SUVmax in PET-CT). As colour scales can be adjusted and changed according to clinician preference, the exact colour representation is not as important as greyscale representation. Nevertheless, uniformity of

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colour representation across devices is desirable so that users do not have to recalibrate colour scales on using new devices.

Although there are a number of options for colour standardisation, the sRGB standard created in 1996 is recommended in DICOM and enjoys wide interoperability with most medical applications utilising this standard when establishing colour scales. Although the gamut is relatively narrow and other options have better linear response at the extremes of luminosity, given the current low demands of colour display in medical imaging it is currently considered the most universal option.

**Power management**

Displays are often the largest power drawing component of a workstation, and although LED LCD monitors do not suffer from burn-in artefacts as older CRT monitors did, they do have a finite lamp life and as such active management of screen power saving times is desirable. Power management solutions (auto-sleep etc.), either built into the monitor or utilising the operating system settings can be locked to prevent customisation and applied institution wide. For example, a radiology department with 100 workstations left with one monitor on over a weekend would consume an average of 189kwh of electricity considering the monitor consumption only.

**End-of-life cycling**

Life-cycling of diagnostic monitors is inevitable as although the backlights in LED LCDs have significantly longer lamp life than older CCFL LCDs and indeed CRTs, they will start to dim lower than the recommended 350cd/m2 and this can be uneven which may render the display unsuitable for primary review. Most manufacturers of DMDs guarantee backlight luminosity for 5 years or a certain number of lamp hours (typically 10-20,000).

There are a number of choices for DMDs that have fallen below either the luminance threshold or fall outside the 10% tolerance range for the DICOM GSDF.

- Redeploy these monitors at other clinical review stations in the same institution (e.g. Emergency Departments or clinic rooms). This has the added benefit of automated calibration and centralised tracking allowed by the inbuilt DMD hardware at these sites.
- Donate or sell to other countries for lower specification use cases.
- Recycle – medical display providers are required in some countries to provide a waste stream for recycling of their end-of-life products through third party companies.

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## 4. Imaging related software

The radiology workflow has long since moved past the age of physical film storage for images, handwritten protocols and printed reports. Currently, the roles of these parts of the radiology workflow are taken by software packages known as Picture Archiving and Communication Systems (PACS) and Radiology Information Systems (RIS).

RIS software is predominantly involved in the pre-acquisition[1] and variably also in the post-acquisition parts of the radiology workflow: This includes but is not limited to:

- The generation of a "request" for imaging, from an electronic input (eg. from the Electronic Patient Record or other electronic requesting system) or from scanned paper requests
- Allowing requests to be triaged, justified and protocolled for the imaging to proceed
- Scheduling and appointing with associated communications
- Generation of a radiology report with integration of Voice recognition (VR) software

depending on preferred workflow

PACS software is involved in the post-acquisition workflow allowing the acquired images to be viewed by the reporter. Images acquired in radiology are encapsulated in the Digital Imaging and Communications in Medicine standard (DICOM), which is a technical standard allowing communication of image data between software and hardware components of the medical imaging workflow, especially between different manufacturers.

PACS software may also allow a certain degree of image post-processing (such as 3D reconstruction, volume surface reconstruction, lung nodule tracking) although most specialised postprocessing is currently done in separate advanced imaging software suites. Many PACS allow fully integrated reporting without leaving the environment using inbuilt VR software.

Many PACS providers offer enterprise imaging software packages in which RIS, PACS and sometimes advanced reconstruction functionalities are offered within the same integrated software suite, ideally in a unified, common user interface.

There may be separate viewer environments deployed within a hospital – usually a "fully featured" viewer software for radiology departments containing all requested functionalities and a "light" viewer for non-radiology department use (eg. by ward physicians and in outpatient clinics). These "light" viewers are often web-browser based and allow image processing to be pooled remotely, offering better performance on lower specification workstations, without the need for dedicated GPU or client software installations. Recent advances in server level GPU (largely fuelled by AI) have also sparked a trend in moving *all* imaging processing away from client workstations to either on-site or remote, cloud hosted compute facilities, though network resilience and bandwidth may be limiting factors.

**Teaching files, storage and security**

There are many reasons that particular scans or patient cases are stored for quick retrieval at a later date, including for Multidisciplinary team meeting reviews and for teaching and training purposes. Most PACS software implementations include the means for such cases

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to be saved in file systems within the software and there are often options for adding case notes and basic (often incomplete) anonymisation. However, annotation and other teaching features vary widely between manufacturers.

Advantages of these systems are the convenience of having teaching files available within the same application and integration of teaching file creation within the PACS software. However, the disadvantage is that teaching files are difficult to transfer between institutions and may be lost if PACS systems are updated or changed. There is also limited functionality for tagging, annotating and editing cases and as such large case databases can become unwieldy to search and use. Cases are also often incompletely anonymised and therefore insecure to export.

Other options for teaching file maintenance include subscription-based cloud PACS services which can completely anonymise and annotate cases for easy search access. Cases are also accessible and viewed via a web based PACS application which can be accessed from anywhere. Disadvantages of this solution are ongoing cost and sometimes some difficulties in integrating case export from institutional PACS software. The ideal solution will vary between imaging departments and use cases.

It is important for standardisation purposes that classification of pathology within a teaching file archive is as similar as possible between radiologists and institutions and as such a common lexicon such as SNOMED CT or RadLex is recommended.

**Standards for Imaging Integration**

RIS communicates with other hospital software (including Order Comms) using HL7 messaging (v2.x) which is an interoperability protocol allowing transfer of patient and other data between applications. HL7 and NHS England are evolving to use a more modern web service standard, HL7 FHIR (Fast Healthcare Interoperability Resources) which will overcome many of the shortcomings of HL7 v2.x and allow wider interoperability including between legacy healthcare systems and newer software. This is not currently used in UK RISs for day-to-day communications, though some EPR integrations with RIS use FHIR to obtain and display results.

FHIR is a RESTful (REpresentational State Transfer) web service-based set of protocols and promises longevity for future use as it is simpler and more lightweight than older SOAP (Simple Object Access Protocol) based web services. NHS England has a strategic vision for the increased use of HL7 FHIR and the UK specific adoption of FHIR called UK FHIR Core. IHE (Integrating the Healthcare Enterprise, a global initiative focussed on improving healthcare information sharing and interoperability) is increasingly adopting FHIR as the main communication protocol - all new IHE profiles are developed using FHIR and there is a gradual replacement of the older SOAP based protocols. New developments coordinated by NHS England (such as the National Imaging Registry, NIR) will evolve to use FHIR from IHE XCA-I. This convergence of the development of international standards is intentional as IHE and HL7 collaborate more closely.

DICOM as a standard dates back to the late 1980s but is still very strong and relevant today. DICOM has two important aspects: the image object definitions (the description of the pixel data and metadata about the images) and the transport mechanism (how to send

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images over networks). DICOM has its own robust network transfer protocol for internal transfers, DIMSE. This is commonly used inside hospitals to get images from modalities into PACS (or other storage).

DICOM also has a set of web services available for web-based transport which is more easily made secure and more appropriate for wider sharing of images. WADO (Web Access to DICOM Objects) has two flavours; the older -WS, web Service and the more modern -RS, RESTful service. As DICOM evolves to make increasing use of web services, WADO is becoming more common: in pathology imaging it is almost exclusively used and the NIR programme will soon evolve to WADO-RS from WADO-WS in line with the future increasing use of RESTful (FHIR like) services. Internationally, there are also important developments making use of image sharing via web services: a new (X)cross-Community service to exchange between different regions and countries, XC-WADO is in development alongside a formalisation of access to images by non-image aware software (e.g. EHRs) using a PACS vendor's web application called Invoke Image Display (IID). These developments are being carried out collaboratively between HL7, IHE and DICOM, to ensure the use of web services and the location of relevant imaging (through metadata) is consistent across all the interoperability standards.

**Security, Networking and Home Reporting**

Log in authentication to PACS/RIS systems should be governed as by information governance policy and features accessible within these systems restricted by staff role (Role Based Access Control). Single sign-on (SSO) solutions may be used to simplify user access and are often associated with enterprise PACS/RIS solutions. Use of multifactor authentication increases security confidence in identification and may be used in line with the NHS England MFA policy.

Clinicians and radiology department staff may be required to access radiology information systems from other sites either within the Trust or remotely, often from users' home workstations. It is crucial that appropriate security measures be put in place to ensure robust identification of users/devices can be achieved and access to critical systems is restricted but maintaining usability and allowing productivity.

Currently, this is usually achieved through one of two solutions:

1. Virtual Private Network (VPN) - Private tunnelling of user devices into the hospital network after appropriate identification (multifactor authentication is strongly advised in this case). This allows use of a remote workstation as if on site but can be problematic with large numbers of users/devices and does not intrinsically restrict user access to systems once authentication has been achieved therefore has potential security risks.

2. Virtual Desktop Infrastructure (VDI) - A solution in which desktop instances are run on a server within the Trust network and a desktop application or thin client is used to access the desktop. In most instances, only keyboard/mouse data and display data is transmitted to and from the remote client. This may be sufficient for administrative tasks and other non-graphically intense applications but is unsuitable for viewing and primary assessment of radiology images due to the potential screen "lag" due to the requirement for rapid transmission of large packets of image data during scrolling. As yet there has

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been no standard to build to lossless for VDI technology and as such, it may also be liable to image compression artefacts.

Newer remote access solutions such as Zero Trust Network Access (ZTNA) may become more prevalent as these allow further restriction of application access and have more robust device health and identification verification over VPN solutions.

In general, Trusts should ensure imaging systems are kept within support and security patched to address known vulnerabilities.

All suppliers must adhere to local Trust guidance and policies on cyber security.

As an example, under the NHS Supply Chain framework, suppliers are required to follow the UK Government's National Cyber Security Centre (NCSC) guidance (Procurement Policy Note 014) and demonstrate compliance with Cyber Essentials Plus (CE+) or equivalent controls.

Suppliers handling personal or patient data must also complete the Data Security and Protection Toolkit (DSPT) and achieve at least "Standards Met" in line with NHS England requirements to provide assurance that they are practising good data security and that personal information is handled correctly.

These measures ensure consistent, proportionate protection against cyber risks across the supply chain.

**Artificial Intelligence algorithms**

It is not within the scope of this document to make recommendations on the rapidly developing field of Artificial Intelligence (AI) in radiology. However, it is recognised that AI will come to play an important part in radiology in years to come and its integration into current ICT systems is a relevant and important question.

There are many AI algorithms currently approved for use in healthcare settings. These largely sit between the image acquisition and image viewing parts of the radiology workflow.[1] Raw data from the modality is sent to AI servers for processing and output is sent to PACS or RIS systems. This can be in the form of annotated images or changing of metadata – eg. promoting examinations to Urgent if certain findings are present to the algorithm to facilitate triage.

AI software can be integrated into hospital ICT systems by two methods:

- **Direct** – The AI vendor directly interfaces the servers with hospital systems. This may be physical on-site servers or a cloud-based distribution. This has the advantages of the software being used in its intended form (for example there may be adjustments to the algorithm or output possible through the vendor's software suite). However, this method requires in hospital ICT expenditure for each AI integration and makes it impractical to change an algorithm once implemented or install multiple vendors' software.

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- **Indirect** – AI algorithms are installed on a third-party software platform (sometimes called “orchestrators”) which then communicates with hospital systems. In practice, this means images are sent to the third-party software and AI outputs are added and sent back to PACS/RIS without interfacing between the vendor’s software platform and hospital systems. This has the result that some vendor content may be lost, but that algorithms can be installed and uninstalled without requiring hospital ICT resources facilitating installation and allowing different algorithms to be trialled easily.

It is important to understand the workflow and efficiency savings or patient safety goal for each AI software installation as outputs and decisions made by AI are currently legally responsible to the end user. In addition to algorithm installation, appropriate user training and periodic audit of AI outputs is required to ensure that the behaviour and accuracy of the algorithm remain within expected limits.

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## 5. Viewing environment, reporting and human interface devices

### Viewing environment

The viewing environment for assessment of clinical images is tailored to optimise human visual acuity for small differences in contrast. In addition, the long-term viewing environment for generation of primary radiology reports must also enable ease of viewing of a series of studies and seamless generation of radiology reports minimising reporter discomfort.

### Ambient light

Ambient light levels are important for all radiology interpretation including with mobile devices. Very low ambient light levels are not needed for image viewing as it has been shown that they in fact decrease visual sensitivity. This is due to two effects – first is that human eyes take some time to adjust between looking at a dark room then at a bright screen and second is that low light levels may stimulate the mesopic (twilight) response in the retina to recruit more rods at the expense of high-resolution cones. It is not clear what the optimum ambient light level is for viewing, but no less than 10 and no greater than 100 lux (practically between 25-75 lux is optimal). However, it is not the absolute light value that is important, rather the intensity of light directed onto the diagnostic monitor as this increases screen glare and requires an increase in monitor minimum luminance to compensate.

Some studies also have found that the use of blue indigo light can improve visual acuity of monochrome images although this may be impractical to routinely implement in all reading rooms.

It may be beneficial to audit ambient light levels in reading rooms to ensure that they stay within optimal limits – most DMDs include ambient light sensors (of the light directed at the screen) and their readings can be collated and analysed with proprietary software without the need for stand-alone light meters.

Since glare from direct light on screens is the most disruptive ambient light, in reading rooms light should ideally be indirect (eg. upward directed) and behind the monitor. In mobile and clinical review scenarios, this is not always possible and either relocating to a lower light environment or use of anti-glare screen films and light baffles are other practical solutions. Mobile devices can be turned up to maximum brightness to account for higher ambient brightness.

### Long term viewing environment

For ease of reporting accurately for many hours, other ergonomic factors are important including but not limited to:

- Adequate ventilation and room specific adjustable temperature and humidity control
- Full back support chairs with adjustable height, depth and tilt with lumbar support and armrests

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- Height adjustable workstation desks allowing placement of interface devices optimal to reduce strain.
- Noise from other areas and equipment should be minimised to aid voice recognition accuracy and concentration. Privacy screens between stations can be useful to lower noise levels and also aid information security.

Workstation configuration can vary but usually consists of two portrait DMDs and one COTS for report viewing and other non-PACS applications. Increasingly, large widescreen monitors are seen as a substitute for two smaller portrait monitors allowing bezel-less imaging comparison, but some may prefer the latter configuration due to the ability to individually angle each DMD. Other setups such as one COTS and three daisy-chained portrait screens may be beneficial in some workflows but are considered surplus for most applications.

**Voice recognition software and microphones**

Most radiology reporting setups use voice recognition (VR) software to allow seamless generation of report text while simultaneously appraising radiology images. This has many advantages to typed reports or even voice recorded/typed (eg. Dictaphone) reports.

- Allows use of voice commands and macros to automate certain repetitive parts of workflow
- Allows “short code” commands to insert canned text (eg. signatures or templates)
- Significantly faster issue of reports than both typed and voice recorded methods.

Over the last decade, although voice-to-text technology has improved in accuracy, especially with the advent of AI, user experience and volume of VR errors varies significantly within the same institution and even within the same hardware setup. Accuracy of VR transcription is generally determined by these factors:

**1**. **VR application** – this is the most important factor and some algorithms boast better accuracy with a wide range of accents and medical diction than others.

The ability to actively correct errors and train the algorithm/voice profile is an important feature as is seamless integration with RIS/PACS (depending on what application is used for reporting). Desirable features seen in some applications include automatic error correction (eg. left/right errors) and clinical decision support.

Ideally VR software should be installed at an Enterprise license level rather than a per user basis and it may be useful to install at an operating system level allowing use in other applications such as the Electronic Patient Record.

**2**. Data bandwidth – VR applications may either be installed on workstation or require live transcription from a cloud server. The latter often require a certain data bandwidth to server in order to accurately stream voice recording without noticeable latency. 100MBps connection speed minimum is recommended and at least 1.3Mbps per active user.

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**3**. **Background noise** – Low background noise is obviously preferable, but not always achievable in hotdesking offices. Installing sound baffles can help both to reduce crosstalk but also to reduce reverberation in larger offices. Continuous noise sources (fans, air-conditioning, building work) are particularly damaging to the accuracy of voice recognition, unless the software is specifically retrained to accept the baseline noise signature.

**4**. **Microphone type** – The microphone type is only a relatively small part of VR fidelity and the only features that are recommended is a frequency response centred on the human speech range (50Hz to 300Hz – which is within the range of nearly all retail devices) and some form of noise cancelling (either active or passive). Nearly all computer microphones use the same basic (MEMS “microphone on chip”) microphone receiver technology.

Handheld microphones suffer from drawbacks including inconsistent mouth to microphone distance, increased pickup of background noise and the loss of one hand to operate other interface devices while reporting.

These have been supplanted in most contexts by cheaper headset microphones which have boom arms to ensure consistent mouth to microphone distance and have a unidirectional pickup pattern reducing background noise and unwanted cross talk.

Other types to consider are dynamic desk mounted or boom arm mounted microphones that are often used for podcasting. These have a cardioid type pickup pattern which tends to reject side sounds which is desirable for vocal recording. However, these are less suitable to noisy hotdesking environments and may be a good choice for home setups. Similar condenser type microphones are less suitable as they are built for high sensitivity and are thus more liable to record background noise. The shotgun microphone is particularly suitable for radiology use with a narrow cardioid pickup pattern and ergonomics suitable for easy mounting on top of a display, right in front of the reporter.

## Human interface devices

### Pointing devices

Pointing devices control the cursor on screen on standard workstations and laptops. Although most setups use standard optical mice with scrollwheels for radiology purposes, the correct cursor control device for a particular reporter will vary due to personal preference, type of reporting (radiographs vs. cross-sectional) and sometimes disability or musculoskeletal problems.

“Gaming” mice are recommended for some radiology setups due to various features which are convenient for reporting:

- On-the-fly adjustable DPI (sensitivity) allowing to switch between high and low sensitivity for certain cursor tasks
- Improved scroll wheels – some allow “clickless” scrolling which some find helpful for large image stacks
- Multiple customisable buttons allowing RIS/PACS hotkey input from mouse hand.
- Improved ergonomics reducing wrist and joint strain

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Trackballs and pillar mice are amongst some of the ergonomic solutions for users with wrist problems.

Pointing devices which do not easily allow “click-and-drag” motions such as touchpads, touchscreens and Trackpoint type pointing sticks are not appropriate for continuous reporting.

**Text input and other interface devices**

Keyboards in radiology may only be used for VR correction and as such are often overlooked. User preference is most important and a variety of ergonomic keyboards (split keyboard, contoured etc.) are available for those with wrist problems.

Keyboards are also used for hotkey shortcuts for RIS/PACS and VR applications and for this purpose other control surfaces can be used such as hotkey-pads which allow keystrokes and macros to be assigned to custom buttons or dials and certain actions to be automated as mentioned above for voice commands. However, some keypads require third party applications to be installed on the workstation in order to function and as such may not be usable in all ICT configurations.

**Webcams and Videoconferencing microphones**

Most conferencing rooms set up for Multidisciplinary Team use have video and audio equipment suitable for large groups of people and the equipment should be suitable for meetings in which the focus of video and audio can switch quickly and there is a high level of background noise.

Motorised webcams with auto-follow functions that can focus on the current loudest speaker are helpful, or those with a wide field of view to cover the whole meeting area.

Specialised conference microphones which allow omnidirectional input and intelligent boosting of vocal wavelengths which can normalise speech volumes while suppressing background noise are available.

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