Radiology Display Technology: Progress Over Time and the Role of Standards Today

Frank Mosler[1*Orcid] and Gerd Nöldge[2Orcid]

[1]Department of Diagnostic, Interventional and Pediatric Radiology (DIPR), Inselspital, Bern University Hospital, University of Bern, Switzerland
[2]Institut für Diagnostische und Interventionelle Radiologie, Katholisches Marienkrankenhaus gGmbH, Alfredstraße 9 in D-22087 Hamburg, Germany

Swiss Journal of Radiology and Nuclear Medicine - SJORANM GmbH - Rosenweg 3 - CH-6340 Baar - Switzerland

Abstract

Radiographic images were traditionally recorded on film. Once processed, film offered limited scope for image manipulation compared with digital systems. The introduction of a digital image chain from detector to display separated acquisition, processing, storage, and presentation and substantially expanded the options for post-processing.

Digital radiology distributes images through PACS (Picture Archiving and Communication System) within radiology departments and across emergency rooms, operating rooms, wards, and outpatient clinics. Patient and referrer portals extend access beyond the hospital, while desktops, tablets, smartphones, and other displays support a wide range of viewing tasks.

Display requirements should reflect the intended clinical use. Primary diagnostic interpretation, clinical image review, education, and patient access involve different demands. This narrative review examines the development of display technologies and the evidence concerning their use in radiology.

We argue that quality-control procedures should be proportionate to the clinical task, the display's validated performance, and the viewing environment. Modern displays and integrated calibration tools may reduce manual testing effort. However, comparisons of selected displays do not establish that ongoing quality assurance is unnecessary. Resource-efficient programmes should retain appropriate acceptance testing, validated automated monitoring, and periodic verification in accordance with applicable requirements.

Keywords: *digital image information chain, PACS (Picture Archiving and Communication System), electronic devices with suitable displays, projectors, beamers, computer screens, tablets, televisions, smartphones, diagnostic significance, digital revolution from 1987 to 2025.*

*Corresponding author: Frank Mosler - received: 25.06.2025 - published: 31.07.2025

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Introduction

In 1987, Seeley et al. anticipated an evolving future for radiology, including new display technologies and greater computing capabilities. Their flow diagram envisaged an expert system combining automated feature extraction with information from hospital and radiology information systems to support the radiologist's diagnostic assessment (42). Figure 1 reproduces this historical vision. Many elements of that vision have since entered clinical practice, although diagnostic support systems still require validation for their intended use.

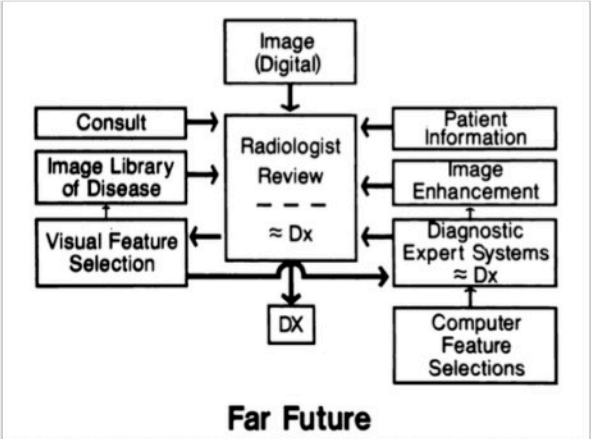


Figure 1: Historical vision of an expert system supporting radiological review through image features and patient information. Starting point: 1987 (42).

Many elements of the 1987 vision are now familiar in digital radiology. The following sections review display technologies and their development, while distinguishing historical expectations from validated contemporary applications.

Display Technologies

CRT - Cathode Ray Tube

A cathode ray tube (CRT) is a vacuum tube that was once the cornerstone of display technology in televisions, oscilloscopes, and early computer monitors. Its operation is based on the controlled manipulation of an electron beam (36, 35).
At the heart of a CRT is an electron gun, located at the narrow end of the tube, which emits a focused stream of electrons. These electrons are accelerated through a vacuum and steered using electromagnetic deflection coils (in most CRTs) or electrostatic plates (in oscilloscopes). The beam is directed toward a phosphorescent screen at the wide end of the tube. When the electron beam strikes the screen, it excites the phosphor coating, causing it to emit visible light (41).

Technical specifications of CRTs include the screen size, typically measured diagonally, the resolution, which depends on the fineness of the phosphor dots or stripes, and the refresh rate, commonly between 60 and 100 Hz. Color CRTs use three electron guns (one for each primary color: red, green, and blue) and a shadow mask or aperture grille to ensure precise alignment of beams with corresponding phosphor elements. Other key parameters include deflection angle (e.g., 90° or 110°), aspect ratio (usually 4:3 or 16:9), and dot pitch, which determines the sharpness of the image. CRTs require high voltage, often 20,000 to 30,000 volts, to accelerate the electron beams.

Despite being bulky and power-hungry, CRTs offered excellent color rendering and fast response times, which made them superior for video applications until they were largely replaced by flat-panel technologies.

Flat-Panel Display Technologies

Flat-panel display technologies have fundamentally transformed how we consume information and interact with digital devices. Unlike their bulky cathode ray tube (CRT) predecessors, flat-panel displays are lightweight, energy-efficient, and capable of high-resolution output in compact form factors. They have become the visual core of televisions, smartphones, tablets, laptops, signage, and medical imaging systems.

Over recent decades, flat-panel technologies have evolved through advances in physics, materials science, and electrical engineering. The following overview explains their operating principles and practical differences without treating model-specific specifications as universal performance limits.

Early Flat-Panel Displays

A) Electroluminescent Displays (ELD)

Electroluminescent panels generate light when an electric field excites a phosphor layer. Thin-film designs place the emitting material between electrode and insulating layers. Rugged designs have been used in industrial and other specialist instruments. Resolution, brightness, colour capability, and service life vary with the device; no single numerical range adequately describes the entire class.

B) Liquid Crystal Displays (LCD)

LCDs control light transmission through liquid-crystal layers and polarisers, with illumination supplied by a backlight. Digital addressing and panel design determine resolution and colour capability. Relevant medical-display characteristics include luminance response, uniformity, reflections, and viewing conditions (35, 36, 43).

1. Twisted Nematic (TN) Panels

TN panels change the orientation of liquid-crystal molecules to modulate transmission through crossed polarisers. They have been used in economical, fast-response displays. Off-axis changes in contrast and colour can limit applications that require consistent appearance across viewing positions. Refresh rate, response time, bit depth, and resolution are model-dependent.

2. In-Plane Switching (IPS) Panels

IPS arrangements rotate liquid-crystal molecules largely within the panel plane. They are commonly selected where viewing-angle stability and colour consistency matter. A panel label alone does not establish medical suitability: luminance response, uniformity, calibration, and the intended clinical task still require assessment (35, 36, 43).

3. Vertical Alignment (VA) Panels

VA panels use liquid crystals that are aligned approximately perpendicular to the substrates in the unpowered state. They can offer strong native contrast, while off-axis behaviour and response characteristics depend on the implementation. Comparisons should use measured device performance under stated conditions rather than fixed technology-wide numerical ranges.

C) Plasma Display Panels (PDP)

Plasma panels excite gas cells to produce ultraviolet light, which stimulates red, green, and blue phosphors. They were widely used in large televisions before LCD and OLED alternatives became dominant. Power consumption, image retention, physical size, and ageing are relevant limitations. Their characteristics should not be transferred to modern diagnostic LCD or OLED displays (35, 36).

D) Organic Light Emitting Diode (OLED)

OLED pixels emit light from organic semiconductor layers when current is applied; a separate backlight is unnecessary. Passive-matrix and active-matrix arrangements differ in addressing and achievable device complexity. Per-pixel emission permits very low black levels, but measured contrast depends on ambient conditions. Luminance, colour gamut, lifetime, and image-retention behaviour vary with panel design, image content, and operating settings. OLED technology alone does not guarantee diagnostic suitability (43).

E) Quantum Dot Displays

Quantum dots are semiconductor particles whose optical properties depend on size and composition. In QD-enhanced LCDs, they alter the backlight spectrum; the panel remains an LCD. QD-OLED combines an OLED light source with quantum-dot colour conversion for red and green output (46). These architectures should not be treated as interchangeable. Claims about colour coverage, peak brightness, power use, or lifetime require model-specific measurements.

F) MicroLED Technology

MicroLED uses small inorganic light-emitting elements to generate light directly at the pixel level. Commercial development includes modular large-area displays. Accurate placement, uniformity, integration, and manufacturing cost remain significant engineering considerations (48). Manufacturer claims about longevity or resistance to burn-in should be distinguished from independent evidence of long-term medical performance. A high-quality consumer image does not substitute for clinical validation.

G) Mini-LED Backlighting

Mini-LED is an LCD backlighting approach, rather than a self-emissive pixel technology. Local dimming can increase effective contrast, but zone size, control algorithms, viewing conditions, and image content influence the result. Native panel contrast, local-dimming contrast, and peak HDR brightness are different measurements. They should not be combined into a single universal specification.

H) Electrophoretic Displays (E-Ink)

Electrophoretic displays move charged particles under an electric field to form an image. Their reflective, bistable operation can retain a static image without continuous display power; front lighting and device electronics still consume energy (47). They suit reading and static information. Colour capability and update speed depend on the implementation, and suitability for diagnostic image interpretation requires separate evidence.

Interpreting Performance Claims

Luminance must be distinguished from peak HDR brightness; static contrast from dynamic or local-dimming contrast; and panel bit depth from processing or temporal dithering. General technology comparisons provide context but are not acceptance criteria for medical use. Table 1 therefore gives a qualitative overview, with task-specific display assessment addressed by AAPM recommendations (43, 44).

Technology	Emission / light control	Contrast / viewing	Practical limitation
TN LCD	Backlit liquid crystal	Angle-dependent appearance	Assess off-axis performance
IPS LCD	Backlit liquid crystal	Good viewing-angle stability	Measure calibration / uniformity
VA LCD	Backlit liquid crystal	Strong native contrast possible	Response and angles vary
Plasma	Gas discharge / phosphor	Emissive; legacy technology	Ageing / image retention
OLED	Organic pixel emission	Very low black level	Ageing / retention depend on use
QD-LCD	Quantum-dot backlight + LCD	Colour depends on implementation	Still subject to LCD limitations
QD-OLED	OLED + QD colour conversion	Per-pixel emission	No universal lifetime advantage
MicroLED	Inorganic pixel emission	Emissive; modular designs	Cost / assembly / uniformity
Mini-LED LCD	LCD with local dimming	Dynamic contrast is content-dependent	Dimming zones affect appearance
E-Ink	Reflective particle movement	Ambient/front light-dependent	Update speed / colour vary

Table 1: Qualitative comparison of display technologies. General characteristics are not diagnostic acceptance criteria. Model specifications and measurement conditions must be stated; peak brightness is not sustained luminance, and dynamic contrast is not native contrast (35, 36, 43, 46-48).

Ideal for reading and static content but unsuitable for video.

Table 1 provides a comparative overview of current flat-panel display technologies in a structured technical format.

Table 2 provides a comparative overview of the best-fit applications for current flat-panel display technologies, highlighting which technical approaches are most suitable for various consumer and professional product types available on the market today.

Application	Examples of display approaches
Smartphones	OLED / AMOLED; LCD
TVs	LCD, OLED, QD-OLED
Monitors	LCD; OLED
Wearables	Small LCD / OLED
E-readers	Reflective e-paper
Signage	LCD; direct-view LED

Table 2: Illustrative applications; suitability is device- and task-dependent.

Summary of Flat-Panel Technologies

The journey of flat-panel display technology spans nearly a century—from early phosphor-based electroluminescent panels to self-emissive MicroLEDs and hybrid quantum dot systems. Each new technology has tackled previous limitations in brightness, resolution, color fidelity, and form factor.

LCDs remain dominant in cost-sensitive markets, while OLED and QD-OLED are setting benchmarks for visual quality. MicroLED holds enormous potential as it combines the advantages of OLED and inorganic longevity, though it remains prohibitively expensive for most consumers.

Looking ahead, advances in materials (such as perovskites and nanomaterials), flexible substrates, and AI-driven image optimization will likely define the next generation of displays. The goal is not just better visuals, but smarter, more immersive, and energy-efficient display systems that continue to reshape human interaction with the digital world.

Comparison of Color LCD and Medical-grade Monochrome LCD - Displays in Diagnostic Radiology

Digital radiology offers numerous advantages over traditional film-based methods. (38) One key benefit is the separation of functions that were once handled solely by the film. These functions are now divided into four distinct steps: data acquisition, image processing, data storage, and

image display. Each of these stages can—and should—be individually optimized. In the final step, image display, the digital image conveys information to the observer, typically through variations in light and color on a screen. In summary, Geijer et al. found no significant difference in image quality between a medical-grade monochrome LCD display and a color LCD display with equivalent spatial resolution. This held true for both contrast-detail phantom testing and visual grading analysis, provided that the grayscale settings were fully optimized (38).

Widespread Use Cases of Display Technologies

Podcasting
Podcasting is an emerging internet-based broadcasting medium with distinctive features that offer promising applications in radiologic education. Podcasting represents a low-cost, efficient method for delivering audio-based educational content ("audiocasts") online. Its accessibility and ease of distribution make it a compelling tool for enhancing radiologic learning and outreach. When radiological images are presented in podcasts, the display quality of the viewing device is typically not prioritized, as these formats are not intended for diagnostic interpretation (39).

Who cares about display quality?
Acquiring and maintaining competency in radiology is a lifelong task that requires continuous learning. The authors want radiological images to be shared online for educational purposes, but no one mentions the quality of the monitors (37) or displays that learners have to work with. The use of two educator-centric learning management systems (LMSs)—Moodle and Manila—for radiology e-learning was formatively evaluated, and the implications for future use of LMSs in radiology education were explored. NeuroRAD, a neuroradiology digital library and learning community, was implemented using Moodle, one of the most widely adopted open-source LMSs. In contrast, Pediatric-Education.org, a pediatric digital library and learning community, was built using Manila, a commercial educator-centric LMS (37). Quantitative and qualitative assessments of both LMSs were conducted using web server log file analysis and user-submitted feedback forms. In 2005, NeuroRAD attracted 9,959 visitors who viewed a total of 98,495 pages, while Pediatric-Education.org was accessed by 91,000 visitors who viewed 186,000 pages (37). Users represented a broad range of medical learners who engaged with the platforms to answer clinical questions, prepare for lectures, conferences, and informal teaching sessions, stay up to date, and study for examinations. Early findings suggest that radiology learning communities can be effectively and affordably developed using educator-centric LMSs, even by radiologists with limited technical expertise. These online communities have the potential to play a significant role in supporting radiology education globally, throughout a radiologist's professional life (37). Has the quality of monitors used by medical learners ever been given serious attention?

E-learning content should be simple to deploy, deliver, and access. It can be distributed via the Internet, institutional intranets, or desktop solutions, and accessed through various browsers on desktop computers, PACS workstations, mobile phones, and handheld devices. Additionally, e-learning can help reduce or eliminate language and accessibility barriers.
Many medical centers already employ SCORM-compliant Learning Content Management Systems (LCMSs) to fulfill educational requirements set by The Joint Commission (TJC) and the Occupational Safety and Health Administration (OSHA) for hospital personnel. SCORM, a modern standard for creating and delivering e-learning content, allows learning materials to be widely distributed, reused, or modified to suit different audiences. Utilizing SCORM standards has the potential to significantly improve e-learning effectiveness in radiology. (32)

American Board of Radiology criteria
Evaluation of Commercial Off-the-Shelf Displays for Use in the American Board of Radiology Main tenance of Certification (MOC) Examination.
The study from Krupinski et al. (34) prospectively assessed the diagnostic adequacy of high-, mid-, and low-resolution commercial off-the-shelf (COTS) displays commonly found in commercial testing centers. The primary objective was to determine whether these displays could reliably present key diagnostic features necessary for decision-making in the American Board of Radiology (ABR) MOC examinations, which employ a multiple-choice format (34).

The ABR's Psychometrics Division approved two HIPAA-compliant human observer studies. Each used radiological images from nine subspecialties. Observers viewed each image twice—once on each of two displays—and rated the visibility of critical diagnostic features.

Study 1 compared 1280×1024 and 1024×768 displays across 7977 paired observations. Iden-

tical ratings were recorded in 72% of cases. The 1280×1024 display received significantly higher visibility ratings in 19% of cases (P < .0001), whereas the 1024×768 display was rated superior in only 9%. All subspecialties except nuclear medicine demonstrated significantly improved visibility on the higher-resolution display (34). *Study 2* compared 1600×1200 and 1280×1024 displays across 1090 data pairs. Ratings were identical in 63% of cases. The 1600×1200 display was rated higher in 22% (P < .0001), while the 1280×1024 was rated higher in 15%. Statistically significant advantages for the higher-resolution display were observed primarily for cardiopulmonary and musculoskeletal images (34).

Patients?

Patients utilize healthcare technologies for various reasons. Recently, the Centers for Medicare and Medicaid Services released the Meaningful Use rule, providing initial guidance for patient-facing technologies. However, a deeper understanding of patient needs and the effective use of these technologies remains necessary. There is a framework to categorize patient-facing technologies based on their meaningful use and explores how these technologies can enhance healthcare quality, safety, and population health. Additionally, barriers to achieving meaningful use of Health Information Technology (HIT) and potential unintended consequences associated with patient-facing technologies are present. The success of healthcare reform depends on improving health outcomes and reducing costs, goals achievable only by actively engaging patients in their own care. Patient-facing technologies are expected to play a crucial role in helping patients become better informed and more engaged, potentially increasing overall efficiency (33).

Security?

The primary challenge in healthcare information security lies not in technology but in the absence of cohesive security policies. Security policies should guide technology implementation, not the other way around. These policies clearly define what needs protection, the extent of protection required, and the individuals authorized to access protected resources (31). Clinicians using mobile apps in radiology must be aware of essential security protocols designed to prevent unauthorized access. These include robust passcode policies, safeguards against repeated failed login attempts, network-managed passcode enforcement, and device-level protection measures to secure sensitive clinical data (24, 14).



Figure 2: Head-CT scan on smartphone

The interpretation of head CT scans for telestroke network patients by vascular neurologists using ResolutionMD™ on smartphones showed excellent agreement with interpretations made by spoke radiologists using a Picture Archiving and Communication System (PACS), as well as those by independent telestroke adjudicators using desktop viewers. In a telestroke network environment, VNs' noncontrast CT identification of radiological contraindications to thrombolysis of patients with acute stroke with ResMD™ on a Smartphone was in excellent agreement with those of spoke hospital radiologists and the independent telestroke adjudicators (30).

Apps?

Many medical applications for smartphones have been developed and widely used by health professionals and patients. The use of smartphones is getting more attention in healthcare day by day. Medical applications make smartphones useful tools in the practice of evidence-based medicine at the point of care, in addition to their use in mobile clinical communication. Also, smartphones can play a very important role in patient education, disease self-management, and remote monitoring of patients. Client applications for Hospital Information Systems (HISs), such as electronic health records (EHR), electronic medical records (EMR), and picture archiving and communication systems (PACS), provide the flexibility of accessing patient information securely from anywhere at any time. A total of five articles discussed the use of smartphones to access patients' clinical information. HIS client applications for smartphones provide some of the functionality of their PC counterparts. E.g. OsiriX

Mobile™ is the client application for OsiriX PACS™, which processes and displays images using the DICOM standard for digital image storage (29). 2017 an App Review of Management Guide for Incidental Findings on CT and MRI found it to be easy to use and named it an attractive app providing a simple clickable algorithm for incidental CT and MRI findings based on ACR white papers (5). The 2015 review of the Radiology Physics 300 app concluded that it is an easy-to-use tool offering a quick overview of radiology physics, featuring well-crafted multiple-choice questions accompanied by clear and informative answer explanations. (12)

The convenience and interactivity of the online world have significantly influenced consumer behavior, transforming the ways we purchase products and plan vacations. It is inevitable that consumers will soon demand healthcare services with the same ease of use they experience when booking flights or managing bank accounts. The healthcare industry itself relies on periodic and mandatory data analysis for outcomes assessment, clinical benchmarking, quality improvement, guideline development, and decision-making. Both the federal government and healthcare organizations are collaborating to develop more robust and cost-effective healthcare informatics solutions. The Meaningful Use (MU) initiative aims to establish new standards for healthcare informatics across the United States (28).

Menu-set measure (2012)	Adoption with modular RIS
Medication reconciliation	Probably excluded
Care summary at transfer/referral	Probably excluded
Immunisation-registry data	Probably excluded
Drug-formulary checks	Probably excluded
Structured laboratory results	Probably excluded
Syndromic surveillance data	Probably excluded
Patient education resources	May conflict with clinicians
Electronic access within 4 business days	May need a portal; outside radiologists' purview
Preventive / follow-up reminders	Difficult for 20% of patients
Condition-based patient lists	Third-party options outside PACS

Table 3: Historical menu-set summary adapted from Siddiqui et al. (28). EHR: electronic health record; PACS: picture archiving and communication system; RIS: radiology information system.

The rapid adoption of new technology has significantly transformed our culture, commerce, and communication, and holds the potential to revolutionize medical education and practice. This study (27) examined how medical educators and learners currently utilize mobile computing devices, such as iPhones™, in medical education and clinical practice, and explored their anticipated future applications (27).
Key messages are: Mobile computing devices are rapidly becoming commonplace in clinical settings. This emerging technology has the potential to enhance medical education and patient care but also brings possible challenges. Policy-makers should actively engage with users to understand their needs, ensuring the technology's benefits are maximized while minimizing unintended consequences. Mobile computing devices have been rapidly adopted by medical learners and teachers at researcher's school, and it seems likely that their presence will soon be ubiquitous. This new technology offers the potential to enhance learning and patient care, but also has potential problems associated with its use, and may redefine how we manage information in medicine (27).



Figure 3: Sonography of liver on smartphone

Smartphone applications (apps) for radiologists are increasingly popular (26). These apps assist radiologists not only by providing quick reference information but also by enhancing daily workflow, particularly through image viewing applications known as Digital Imaging and Communications in Medicine (DICOM) viewers. This development signals a shift toward an increasingly mobile medical environment, presenting both exciting opportunities and significant concerns for radiologists. In conclusion, radiology currently benefits from a broad selection of useful applications that can be employed by both experienced radiologists and medical professionals in training. Given the growing number of app developers, there remains considerable potential for further innovation, and there is no reason why radiologists themselves should not assume a leading role in

the development of such tools. Limitations in image interpretation on smartphones represent a drawback of DICOM viewer applications. The ethical and legal implications associated with the expanding use of smartphone apps in clinical practice warrant further investigation (26).
Certain measures can be taken to ensure the secure transfer of information over public and home networks, especially in light of the growing use of mobile devices in radiology. As radiology continues to advance technologically, a solid understanding of key technical principles is essential for practicing radiologists. The use of mobile devices—such as laptops, tablets, and smartphones—for interpreting radiologic studies has become increasingly common, despite the varying quality of display systems on these devices (24).
Radiology training programs nationwide are increasingly equipping residents with iPads and other mobile devices. Yet, many lack a clear strategy (25) for integrating these tools into a cohesive educational framework. One effective application is video recording of lectures, which offers several advantages. It provides access to educa-tional content for residents unable to attend in person due to vacation, post-call fatigue, or procedural duties. Moreover, recorded lectures can be reviewed anytime, at any pace, supporting flexible, self-directed learning. Mobile devices naturally complement this mode of study, encou-raging independent learning in a more accessible, user-friendly format. Still, integrating new technologies into the radiology education workflow is not without its challenges—there's a steep learning curve and numerous potential barriers to adoption. Nonetheless, mobile technology is not a passing trend; it's a permanent fixture. What's needed now is a clear, purposeful vision for how these tools can enrich the educational journey of radiology residents. By leveraging their capabilities to modernize teaching and close the gap between clinical practice and digital learning, we can help ensure a bright and evolving future for radiology education (25).

Portals?

Current evidence remains limited regarding the impact of patient portals on health outcomes, healthcare costs, or service utilization. While patients generally view these tools positively, broader adoption may hinge on addressing barriers related to race, ethnicity, and health literacy. As a relatively new technology, the tangible benefits of patient portals are still not well defined. A more comprehensive understanding will require studies that account for contextual factors, implementation strategies, and associated costs (23).

Handheld computers and mobile devices give healthcare professionals portable access to clinical information. The review by Mickan et al. examined evidence concerning handheld computing in clinical practice (22). Such access can support decision-making, but benefits depend on the application and context. Claims about diagnostic accuracy require task-specific evidence rather than an assumption that portable access alone improves outcomes.

The regulatory discussion in the cited 2013 review reflects the former Medical Devices Directive (MDD) framework (21). By the time of this article's publication, medical device software in the EU was governed by Regulation (EU) 2017/745 (MDR). Qualification and classification depend on intended purpose. Under Rule 11, software providing information for diagnostic or therapeutic decisions is generally class IIa, with higher classes applying to specified higher-risk decisions; other software may fall into class I (45). A viewer should not be assigned a risk class solely because it can display a medical image.

These distinctions also matter when evaluating mobile viewing: education, image review, and primary diagnostic interpretation are different tasks. Regulatory status, clinical validation, display characteristics, and the viewing environment must be considered together. The 2013 review described technical limitations using then-current devices and guidance; its iPhone 5 comparison is a historical example, not a current performance benchmark (21).

In the historical example discussed by Rodrigues et al., the iPhone 5 offered 1,136 x 640 pixels on a 10.2 cm screen, compared with cited reporting-display guidance of 1,280 x 1,024 pixels and 42 cm (21). These values should not be read as a universal contemporary standard for all jurisdictions or devices. Suitability for primary interpretation requires task-specific validation and compliance with applicable requirements (43, 45).

Additional concerns include the adverse impact of ambient lighting on image quality and the absence of the rigorous calibration and quality assurance protocols that standard reporting workstations undergo. To be used for primary diagnosis, smartphones would need to be integrated into similar quality control systems.

Therefore, despite FDA approval of certain mobile DICOM viewers, caution is warranted when considering their use for primary diagnostic purposes on smartphones. Due to inherent display limitations, smartphones are better suited for image review rather than diagnosis. While radiologists are typically aware of these constraints, other healthcare professionals may not fully recognize the associated risks and limitations (21).

Smartphones and tablets open up new possibilities for professionals in diagnostic imaging (20). With their intuitive interfaces and high-quality displays, these portable devices can be used not only for diagnostic image review, but also for reference, education, clinical consultations, and even patient communication.

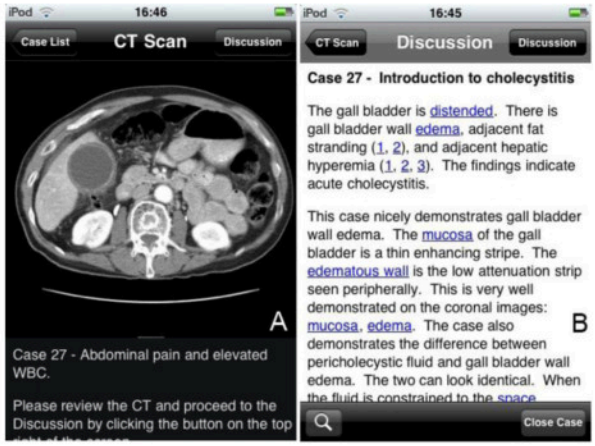


Figure 4: CT-scan on iPad with discussion (20)

Focused ultrasonography of the airway may be useful in the prediction of difficult intubation. Mobisante MobiUS™ system was able to acquire clinically useful images of the suprahyoid airway and muscular architecture in the mouth floor and allowed accurate measurements of linear distances for easier intubation access (19).

Internet?

When personal computers first emerged, they were designed primarily for individual use. But as inherently social beings, humans quickly sought ways to connect—and the internet made that possible. The rise of mobile IT devices accelerated this trend, enabling like-minded individuals to connect, collaborate, and form functional units within a shared digital space.

Today, it's becoming routine for colleagues to exchange materials via cloud platforms and work together on complex projects, regardless of physical location. The idea that "humans are social animals" reflects a deep-rooted drive for communication and collaboration. Looking ahead, this instinct will continue to shape our relationship with technology. IT devices, cloud infrastructure, and collaborative software will remain central tools for connection, coordination, and collective progress. We were never meant to work in isolation (18). Within parts of the medical community, the iPad is seen as a transformative tool in healthcare deli-very—particularly in the field of medical imaging, where its versatility supports a wide range of applications (17).

Dams et al. found no statistically significant differences in radiological assessment among the selected LCDs, but measured technical differences, including grayscale and luminance-uniformity concerns. Their results support evaluating performance rather than purchasing by price alone; they also underscore the importance of calibrating and verifying displays (16).

Audience Response Systems (ARS) can support interactive radiology education, but their effectiveness depends on teaching design rather than technology alone (15). Mobile tools similarly require appropriate educational content, usable interfaces, and reliable references.

The 2015 review by Lewis et al. described inconsistent app quality and limited oversight at that time (13). Its observations should not be interpreted as a claim that medical apps remain wholly unregulated. Under the MDR, software qualification and classification depend on intended purpose (45). Educational software and software used for diagnostic decisions therefore require separate consideration.

Digital Divide?

The digital divide is well-documented and continues to raise concerns that certain patient

groups may disproportionately benefit from access to patient portals. There are findings that indicate regular internet use and ownership of a personal computer partially explain disparities in portal use for messaging healthcare providers—particularly across age, race, and income groups. However, differences related to education and sex remained statistically significant even after accounting for internet access and care preferences.
As patient portals become more widespread, it is critical to identify which populations face limited access and to understand the barriers they encounter. Addressing these disparities will require expanding internet access across diverse sociodemographic groups, designing intuitive and inclusive portal interfaces, and ensuring seamless access across multiple platforms—including mobile devices. These measures could play a key role in reducing inequities in the use of secure messaging and digital health communication (11). A patient-directed, interoperable, internet-based image-sharing system is both feasible and offers superior accessibility compared to traditional CD-based methods, while maintaining comparable levels of patient satisfaction regarding privacy (10).

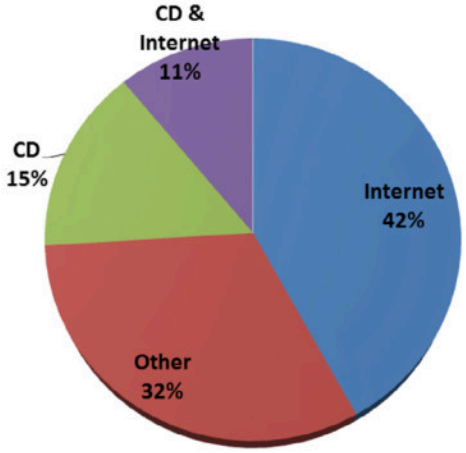


Figure 5: Modality used by patients to share their medical images with their physicians (10)

Mervak et al. analysed radiology-related messages submitted through a patient portal (9). Patients were particularly concerned about receiving imaging results, especially for CT and MRI. Their findings support timely communication and opportunities to clarify results. This study concerned patient inquiries and should be distinguished from Greco et al.'s study of patient-directed image exchange (10).

Patient portals and image-sharing systems serve related but distinct needs: access to reports, explanation of findings, and transfer of images. Their evaluation should reflect those specific purposes (9, 10).

Since the late 1990s, mobile devices, wireless networks, and software have advanced significantly, reaching a level of speed, processing power, and sophistication that now enables real-time interpretation of radiologic studies. Given the time-critical nature of emergency radiology (ER), mobile interpretation aligns well with the need for rapid, on-the-go diagnostic input—allowing radiologists to read studies anytime, anywhere.

While these devices are well-suited for use by radiologists outside the hospital and by clinicians or surgeons at the bedside or in the operating room, they still come with limitations. Regulatory approval for primary diagnostic use within hospital settings remains limited. In the context of emergency radiology, we propose that one of the most valuable uses of mobile devices lies in enhancing communication—specifically, enabling radiologists to consult directly with patients about their imaging results and to engage with the clinical team during rounds and handovers. This approach not only deepens our understanding of the patient's presentation but also supports education for both patients and providers, while increasing the visibility and perceived value of the radiologist as an integral member of the clinical care team (8). Today, we are confronted with an explosion of data, and the challenge lies in how to effectively integrate, analyze, and interpret it. A key priority is the ability to distinguish meaningful information from "noise" in order to reduce the risk of mis-interpretation and diagnostic error (7).

ESR -Paper 2018:
While mobile device screens are not suitable for the primary interpretation of projectional radiographs or mammography, their resolution, luminance, and pixel size are generally sufficient for technically adequate display of computed tomography (CT) examinations. Several studies have demonstrated that CT interpretation on high-quality tablet screens is feasible. However, it is not recommended for primary diagnosis due to several potential limitations.
One key concern is screen cleanliness: the touch-screen interface, manipulated by fingertip contact, can easily accumulate smudges that obscure fine image details. Moreover, while stationary radiology workstations allow for controlled ambient lighting, such control is not possible with mobile devices. This is particularly relevant as tablets often have glossy screens, which are

more prone to distracting reflections than standard workstation monitors. As a result, tablet-based CT interpretation may only be appropriate under optimal viewing conditions—and even then, with caution (6). To successfully integrate new imaging technologies into routine clinical practice, radiology leaders must take an active role from the outset—starting with regulatory approval, continuing through early clinical validation, and extending to securing reimbursement and engaging key stakeholders to drive broad adoption (4).

Silosky et al. published performance characteristics and quality assurance considerations for displays used in interventional radiology and cardiac catheterization facilities. While display performance for image acquisition and primary diagnostic interpretation has been extensively studied, limited data exist on displays used in Interventional Radiology (IR) suites and Cardiac Catheterization (CC) laboratories. This study aimed to evaluate the performance of large-format displays in these environments and to explore the challenges of implementing display quality assurance (QA) protocols. Ten large-format displays from IR and CC suites were assessed. Visual inspection using test patterns was followed by quantitative analysis of key performance metrics, including luminance ratio, luminance response function, and luminance uniformity. Ambient lighting conditions were also measured. Luminance ratios ranged from 243.0 to 1182.1 (mean: 500.1 ± 289.2). Deviation from the DICOM Grayscale Standard Display Function ranged from 11.2% to 38.3% (mean: 26.2% ± 10.9%). Luminance uniformity showed a mean maximum deviation of 13.2% ± 3.5%, and an average deviation from the median luminance of 7.8% ± 1.0%. Ambient light levels varied widely (29.1 to 310.0 lux; mean: 107.6 ± 80.4 lux). While no mura or dead pixels were identified, physical damage such as scrapes, scratches, and smudging was common. Silosky et al. provide essential baseline data on the performance of large-format displays in IR and CC suites. These findings may serve as benchmarks for developing and implementing display QA programs tailored to interventional environments (3). Current and emerging mobile applications integrated into the imaging workflow serve to enhance patient care. At the practitioner level, the University of Washington (2) has curated a list of 12 mobile apps tailored for daily radiology use. Ultimately, though, the most important evaluators are the end users—both healthcare professionals who engage with the technology and the patients who interact with it. Patient feedback, in particular, plays a crucial role in refining these tools, fostering an ongoing cycle of improvement and innovation in applied medical technology. The growing indispensability of the Internet and mobile applications in healthcare has been further accelerated by government initiatives promoting the adoption of health information technology. These digital tools are foundational to the future of healthcare, which increasingly depends on precision medicine—anchored in radiomics, genomics, and advanced imaging. Radiology stands as a central pillar in this evolving ecosystem. Sustained development in this area is not only necessary but must be factored into the planning and budgeting of any future radiology infrastructure (2).

Regulatory authorities, long accustomed to evaluating the safety and efficacy of static, fixed-function medical devices, now face the complex challenge of overseeing the dynamic and mobile, ever-evolving nature of artificial intelligence (AI) on mobile devices in healthcare. In response, Australia's Therapeutic Goods Administration (TGA) has begun to articulate clearer regulatory expectations for AI-enabled medical devices. The TGA emphasizes that proactive engagement, staying informed about emerging regulatory frameworks, and seeking pre-submission consultations can be effective strategies for navigating this evolving regulatory landscape (1).

Conclusions

Modern displays and integrated calibration tools can reduce the manual effort required for quality assurance. We argue that QC programmes should be proportionate to the clinical task, validated display performance, and viewing environment, rather than reproducing procedures designed for older technologies.

Comparisons of selected displays support performance-based selection, but do not demonstrate that ongoing QA is unnecessary (16, 34, 38). Primary diagnostic interpretation, clinical image review, education, and patient access should be assessed separately (43, 44).

Quality assurance and resource use
Automatic calibration and integrated photometers can reduce manual work. Their outputs nevertheless require validation, and built-in sensors need appropriate verification and maintenance. AAPM recommendations address these issues for modern flat-panel displays (43, 44).

Calibration to the DICOM Grayscale Standard Display Function is one component of display assessment. It does not by itself establish suitability for every diagnostic task or remove the effects of ambient light, surface contamination, or physical damage (3, 43).

Acceptance testing establishes baseline performance. Subsequent checks should reflect the display category, clinical task, documented stability, and applicable requirements. Evidence from calibrated display comparisons or certification examinations should not be extrapolated to every display, viewing condition, or longitudinal QA programme (16, 34, 38).

We favour reducing unnecessary manual testing when reliable automated tools and validated stability data justify doing so. This is an argument for better-targeted quality assurance, not for abandoning assurance of diagnostic display performance.

Regulatory frameworks and local protocols should allow efficient, proportionate approaches while retaining safeguards for diagnostic accuracy and patient care. The evidence reviewed here does not establish that routine QC is redundant in all CT or MRI settings.

Correspondence to:
Frank Mosler, MD
https://orcid.org/0000-0002-2039-4911
Specialist in Radiology
Specialist in Diagnostic Neuroradiology
Specialist in Interventional Neuroradiology
Interventional Pain Therapy (SSIPM)
Fellow RSA
Senior Consultant
Department of Diagnostic, Interventional and Pediatric Radiology, Inselspital, Bern University Hospital, University of Bern, Bern, Switzerland
University of Bern
Freiburgstrasse 10
CH-3010 Bern
Switzerland



Conflict of interest:

The authors declare that there were no conflicts of interest within the meaning of the recommendations of the International Committee of Medical Journal Editors when the article was written. Further statements and declaration:

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