



Handheld devices for radiologists: as good as monitors?

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KEYWORDS: emergency consultation ■ handheld device ■ image display ■ image perception ■ teleradiology

Handheld computers, such as personal digital assistants (PDAs) and smartphones, have become commonplace in recent years, and the range of social and professional applications available for these technologies has also undergone rapid expansion. The portability and flexibility offered by handheld devices invites many attractive ideas in the field of medicine, including in radiology. For instance, the possibility of radiologists having fast access to patient images from any location, either in or remote from the hospital, is immediately appealing, particularly in the context of urgent or unusual cases. However, the introduction of handheld devices as radiological displays is not a straightforward issue, with many considerations to take into account. Security and confidentiality, costs and data transfer speed all must be borne in mind when considering the introduction of handheld device-based image viewing. Perhaps the greatest and most obvious concern, however, is whether handheld devices could possibly display images at sufficient quality to allow an accurate opinion or report to be given. Can handheld displays equal the conventional monitor in radiological image viewing?

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The question of whether handheld displays are appropriate for diagnostic or other purposes has attracted the attention of the research community in recent years, with many groups attempting to find an answer. Most have made direct comparisons between radiologists' performance with handheld devices and with monitors, although the specifications of both display devices vary.

The earliest papers that considered the diagnostic efficacy of handheld devices include works by Reponen *et al.* [1,2] and Yamamoto and Williams [3]. They focused on the display of CT brain images, and concluded that the PDAs they studied provided useful information and satisfactory image quality in most cases. These early studies, however, did not provide anything close to a comprehensive clinical analysis for all images, suffering from low numbers of observers or lack of clinical evaluation.

Several more studies, often with greater numbers of images and/or observers tested, have been performed over the last decade in CT brain imaging [4–6], renal CT [7], dental images [8,9], plain radiographic images [6,10] and even mammograms [11]. The results are almost universally in agreement – handheld devices consistently perform well enough to be considered at least promising for use under certain circumstances. However, many of these works still demonstrate significant limitations, and there continue to be considerable gaps in the literature when it comes to determining whether or not handheld devices are suitable for radiological reporting or other viewing. This should not really come as a surprise. Assessing the clinical efficacy of handheld devices is a large and complicated task, due primarily to two factors: the expanding range of devices available and the massive variety in clinical image and pathology types.

There are an enormous number of handheld devices available, and testing each one individually in a thorough way is very obviously not a feasible option. Researchers in the field must select carefully when deciding which devices to test, based on the display characteristics, cost, size or other parameters that are important in their view, so that their research is applicable to that device and potentially others with the same display



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specifications. Even for devices that have been tested, the rate at which handheld technology is developing makes it virtually impossible to keep research in the field up to date. For example, the Apple iPhone was first released only in 2007 [101], and it has recently launched its fourth generation with a new and quite substantially altered display [102], which could potentially change its potential as a tool for viewing radiological images. Add to this the huge range of image types that might potentially be tested, each with different contrast and spatial characteristics, and the task of performing sufficient studies to determine which devices are useful for what task becomes even more daunting.

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So can these hurdles be overcome? It appears that handheld devices really could have some use in emergency cases and perhaps other settings. It is my opinion that, rather than concentrating our efforts solely on the assessment of different handheld devices on the market, interested members of the research community should consider turning to the perceptual factors involved in image viewing. Answering the underlying questions about what features are important in a display would allow new technologies to be developed that meet these requirements, which is surely a more efficient approach and would facilitate more optimal image viewing in the long term. What are the relative importance of spatial resolution and brightness resolution? Do

the surroundings in which the display is viewed matter? How small is too small in terms of display? These issues have the potential to influence all displays in radiology, not only the handheld variety, and many groups are performing fascinating work in the area. Whilst the purpose of this article is not to review the literature in this area, The Medical Image Perception Society is a very useful resource for those wishing to find out more [103]. While I do not intend to suggest that the perceptual issues will be any less difficult to solve than testing the efficacy of existing devices, I believe that this route of enquiry will ultimately prove more useful than direct assessments of individual technologies, which seems likely to become an endless labor.

In summary, the use of handheld devices in radiology is an attractive prospect and seems likely to offer potential benefits to both clinicians and patients through providing rapid access to images. However, we need more quality information before we can draw any firm conclusions that allow such devices to be assimilated into general radiological practice, and perhaps a shift in perspective would allow these highly promising technologies to fulfill their potential in a shorter time.

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