E-Readers and E-Paper

M. Castillo

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The music industry has undergone considerable changes from records to cassettes to compact discs to MP3s and is now again being threatened by music streaming through the Internet. Web sites that allow free streams to be incorporated into personalized playlists are currently the most significant threat to an industry already burdened by financial difficulties. These problems are not unique to music but are also affecting the movie industry and the written word.

Last century, one of the major threats to popular literature was the introduction of the pocket book. Pocket books were first manufactured in Germany (1931) and then in Great Britain (1935) by Penguin Books. In the United States, the first pocket books appeared in 1939. Cheaper paper, small size, and gluing instead of stitching allowed these books to be sold at a comparatively low price (initially around 25 cents!). Because the words "Pocket Books" referred to the brand of product sold by Simon and Schuster, the term "paperback books" was then popularized, partly by the Beatles number 1 song "Paperback Writer." We seem to have survived paperback books, both mass-produced and trade versions, only to be threatened again by e-books.

E-books are the electronic version of printed literature. E-books are available in several formats, a fact that serves to fragment their worldwide market. E-books may be "protected" or be found on public domain Websites. Proponents of e-books list their advantages over print as follows: easily searched and cross-referenced, easier to move and transport, little storage space required, possible adjustment of font size, embedded animations, cheaper price, and, perhaps, more environmentally friendly (all of these features are found in the electronic version of *American Journal of Neuroradiology* [*AJNR*]). Many e-books take advantage of text-to-speech programs that allow individuals with a disability or those only wanting to listen the possibility of using them. E-books are relatively cheap because about 20% of the price of a regular book represents expenditures in printing, binding, and transportation. Currently e-books are not widely used and account for only about 3% of all literature sales. Most are produced at the same time as their print versions, but some are available only electronically, with their paper versions offered as a print-on-demand service (similar to *AJNR's Special Collections*).

Today, most major publishers offer many of their products, particularly bestselling ones, on e-books. Huge efforts such as Project Gutenberg[1] and Online Books Page from the University of Pennsylvania[2] offer free and paid e-books. The Library of Congress hosts the World Digital Library,[3] but as of this writing, only a rather disappointing 1170 items were found in it (the site contains more items other than books, such as maps). The Europeana project[4] is a similar start-up collection. This last project generated much interest when the server failed on its opening day as reported on November 21, 2008 by the *New York Times*.

Most of the disadvantages of e-books are related to the fact that a piece of hardware (computer or a mobile device such as e-reader or iPhone [Apple, Bothell, Washington]) is needed to access them. Current disadvantages of e-readers include the need for electrical power, relatively low-resolution screens, lack of color in some, a limited number of books and magazines available, fragility if dropped, inability to be read in strong or weak lighting situations, and, of course, these run a greater risk of being stolen than do books. Because e-readers require many materials to be built, their environmental impact is thought to be higher than that of paper books. In addition, constant changes to formats and resolution make them less durable than paper books. There are many e-readers, but today the market is dominated by: the Sony Reader Digital Book and Amazon's Kindle (which comes in 2 different sizes) (both at www.amazon.com). The larger Kindle DX is presumably geared toward the textbook market. The basis of these e-readers is e-paper.

As e-readers are designed to simulate books, e-paper is designed to simulate printed ink on conventional paper. The difference between your computer or iPhone screen and e-paper is that the latter is not backlit. One can easily read a regular book because light reflected by its pages results in high contrast between the white background and the dark ink used for letters. E-paper utilizes the same principles and, unlike computer screens, is not backlit. While the high background-to-letter contrast found in conventional paper allows one to read a book under a wide range of lighting conditions, the gray background and nearly black letters of e-paper can only be distinguished in better light conditions (the E-Ink Corporation[5] is developing whiter background e-paper currently). A benefit of reflective screens (e-paper) is that they avoid "computer fatigue."

Electronic paper has been available since the 1970s. Electrophoretic displays use electricity to arrange "ink" particles in the display and form letters or pictures (the Sony Reader and Kindle use this type of display). There are other types of e-paper, but they all share the fact that once a page is "printed" on the screen, no more energy is drawn from the batteries, thus making them last very long. Once a page is refreshed, power is needed to rearrange the water/oil interfaces that form letters and pictures. This low-energy consumption is why e-paper is also used for some portable game devices (Game Boy; Nintendo, Kyoto, Japan), mobile telephones, and remote controls. Because power is not always on, they may be used in airplanes most of the time.

Major disadvantages of e-paper include its relatively low refresh rates (pages are slow to "turn" and magnify) and its current inability to display colors (generally only 16 shades of gray are available). One of the beauties of e-ink is that when it is applied to incredibly thin and flexible electrophoretic plates, it can be mounted in all kinds of materials, including T-shirts! Experts predict that e-paper will soon achieve superb resolution, ultrafast refresh cycles, and the ability to display colors (Samsung and Fujitsu already manufacture different versions of color e-paper, which are not widely available). Thereafter, e-paper may be used in picture frames and even televisions. It is also easy to imagine carrying the daily newspaper in a roll of e-paper that can be updated constantly via wireless Internet (the Kindle already partly does this). Although e-paper is expensive when compared with traditional paper, many experts feel that by 2015 its price will decrease considerably. Apple will soon be introducing its color e-reader (iTablet). Plastic Logic is in the process of creating a large-size e-reader that supports a wide variety of formats.

It is conceivable that in the near future, the entire electronic contents of the *AJNR* will fit into a single e-reader. Currently, a *New England Journal of Medicine* (*NEJM*) subscription is available for the Kindle. Unfortunately, you must pay both the *NEJM* and Amazon fees. Springer is said to offer more than 30,000 electronic books (though I have never used one). Elsevier has 4800 e-books and plans to have 80% of its contents in this fashion by 2012.[6] Blogs and RSS feeds may be displayed in some e-readers. It seems that all biomedical publishers are embarking on some activity related to making their contents available on e-readers. The general press has hailed the Kindle as the savior of newspapers. There is no question that the specialized biomedical press will follow a similar road in the near future. Our on-line publisher, HighWire Press, is currently also exploring this option, and we will let our readers know when it becomes available.

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M. Castillo
Editor-in-Chief

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EDITORIAL

FDA Investigates the Safety of Brain Perfusion CT

On October 8, 2009, the US Food and Drug Administration (FDA) issued an initial notification regarding a safety investigation of facilities performing brain perfusion CT (PCT) scans. This alert indicated that the FDA had become aware of radiation overexposures during PCT imaging performed to diagnose stroke at a single, particular facility. Because of incorrect settings on the CT scanner console, more than 200 patients over a period of 18 months received radiation doses that were approximately 8 times the expected level. While this event involved a single kind of diagnostic test at 1 facility, the magnitude of these overdoses and their impact on the affected patients were significant. About 40% of the patients lost patches of hair as a result of the overdoses.

This episode highlights the importance of CT quality assurance programs. These should include regular reviews of CT protocols by a specialized CT physicist, testing scan protocols on dose phantoms, and the monitoring of actual doses received by patients for each type of CT protocol. Some institutions have chosen to designate a dedicated CT technologist in charge of ensuring that all CT protocols respect the ALARA (as low as reasonably achievable) principle. CT quality assurance programs should not be restricted to PCT protocols, but should be applied to all CT protocols, both neuro and non-neuro. Indeed, although the incident reported above involved PCT (which may be more prone to substantial radiation overexposure if performed incorrectly due to the cine nature of the acquisition), any CT protocol might have been involved, as was demonstrated in a recent unrelated incident at a community hospital in Arcata, California.[1] CT protocols with inappropriate acquisition parameters—for whatever reasons—might nonetheless be saved on scanner consoles, and subsequently applied by technologists to multiple patients before protocol errors are detected and corrected. Such errors can be difficult to discover,[2] especially considering that overexposed CT protocols are unlikely to decrease image quality (rather the opposite!), and hence can go unnoticed unless specific attention is paid to the technical scan parameters. Moreover, if patients receive higher than "reasonably achievable" CT radiation doses, but not sufficiently high to produce obvious epilation, there may be no other indication of potentially increased risk of long-term radiation effects. Importantly, the American College of Radiology (ACR) has established a voluntary CT accreditation program in which institutions are invited to submit patient and phantom images, along with dose measurements, from their proposed CT protocols, to demonstrate that they abide by ACR dose guidelines (ACR CT Accreditation Program Requirements, 2007). Along these lines, it might be desirable for neuroimagers to create a repository of optimized CT protocols, representing all types of CT scanners from all vendors, as well as all types of CT studies, which would be freely shared by the radiology community at large.

Radiologists and technologists should be familiar with and aware of the dose indices normally displayed on the CT scanner console. These indices include the volumetric CT dose index ($CTDI_{vol}$) and the dose-length product (DLP). The $CTDI_{vol}$, which was introduced to take into account the pitch of helical acquisitions, represents the average dose delivered within the reconstructed section, and is calculated as the weighted CTDI divided by the pitch.[3] The DLP is the $CTDI_{vol}$ multiplied by the scan length expressed in centimeters. It gives an indication of the energy imparted to organs, and can be used to assess overall radiation burden associated with a CT study. CT scanners now routinely record the $CTDI_{vol}$, and, in some cases, the DLP. Although the $CTDI_{vol}$ is not the dose to a specific patient, it is an index of the average radiation dose from a CT series.[3] For each protocol selected, and for each patient, the dose indices displayed on the control panel should be carefully monitored and determined to be within a reasonable range to prevent accidental overexposure. Radiologists and technologists should also become acquainted with dose modulation software[4] and, in the immediate future, with iterative reconstruction algorithms, which can replace filtered back projection, and have the potential to decrease image noise, while maintaining signal intensity, at a lower radiation dose.[5]

Hence, there is a need for continued, increased knowledge and awareness among radiologists and technologists regarding radiation dose, its measurement, and what can be done to decrease the risks associated with it. Radiologists have a responsibility as patient advocates to educate their clinical colleagues so that radiation dose is an important consideration in