Medical Physics
The International Journal of Medical Physics Research and Practice

Lossy compression should not be used in certain imaging applications such as chest radiography

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Citation: Medical Physics **26**, 1773 (1999); doi: 10.1118/1.598783
View online: http://dx.doi.org/10.1118/1.598783
View Table of Contents: http://scitation.aip.org/content/aapm/journal/medphys/26/9?ver=pdfcov
Published by the American Association of Physicists in Medicine

Suggestions for topics suitable for these Point/Counterpoint debates should be addressed to the Moderator: William R. Hendee, Medical College of Wisconsin, Milwaukee: whendee@post.its.mcw.edu. Persons participating in Point/Counterpoint discussions are selected for their knowledge and communicative skill. Their positions for or against a proposition may or may not reflect their personal opinions or the positions of their employers.

Lossy compression should not be used in certain imaging applications such as chest radiography

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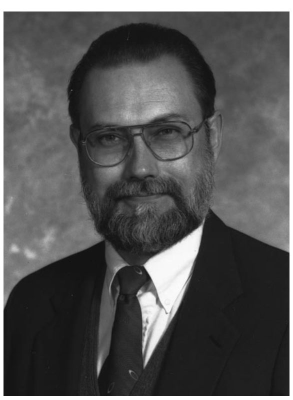
(Received 30 June 1999; accepted for publication 30 June 1999)

[S0094-2405(99)04209-1]

OVERVIEW

Computational techniques are frequently used to compress image data so that transmission and storage requirements are reduced. If the computational techniques result in no loss in image resolution, the technique is referred to as lossless compression. Greater compression of data may yield some loss in spatial or temporal resolution, and is referred to as lossy compression. In some radiologic examinations [e.g., gastrointestinal (GI) studies], some resolution loss may be tolerable, whereas in others (chest examinations and mammography) it conceivably could result in missed pathology. Without lossy compression, however, data requirements can be overwhelming for transmission, storage and retrieval of images such as chest films. The unanswered question, addressed in this Point/Counterpoint issue, is whether some degree of lossy compression can be tolerated in chest radiography.



Arguing for the Proposition is E. Russell Ritenour. Dr. Ritenour has been at the University of Minnesota since 1989. He is Professor and Chief of Physics, Department of Radiology, Medical School and Director of Graduate Studies in Biophysical Sciences and Medical Physics in the Graduate School. Receiving his Ph.D. in physics from the University of Virginia in 1980, he completed an NIH postdoctoral fellowship in medical physics at the University of Colorado Health Sciences Center, where he remained for nine years and served as Director of Graduate Studies in Medical Physics from 1984 to 1989. His research interests include radiologic quality assurance, distance learning systems, and computer-based instruction.

Arguing against the Proposition is Andrew D. A. Maidment. Dr. Maidment received his Ph.D. in Medical Biophysics from the University of Toronto in 1993. He is currently Assistant Professor of Radiology and Director of Radiological Imaging Physics at Thomas Jefferson University in Philadelphia. He has authored more than 65 peer-reviewed journal articles, proceedings papers and abstracts. He has won several awards, including First Place in the 1994 Young Investigators Competition of the International Union for Physical and Engineering Sciences in Medicine. He is active in the ACR and AAPM, including chairing Diagnostic Imaging TG 16, Standards for Noise Power Spectrum Analysis. His research interests include digital mammography, 3D imaging of the breast, digital radiography detector physics and PACS.

FOR THE PROPOSITION: E. Russell Ritenour, Ph.D.

Opening Statement

At present, the only published medical standard for image quality in the realm of digital image transmission is the ACR Standard for Teleradiology.[1] It states that ‘‘When a teleradiology system is used to produce the official interpretation, there should not be a significant loss of spatial or contrast resolution from image acquisition through transmission to final image display.'' The phrase ''significant loss'' is sufficiently vague that, until recognized standards-setting organizations, such as the AMA, DICOM, FDA, or the ACR, provide specific guidance in this area, I argue that, for legal reasons, the use of lossy compression is not advisable.

Malpractice cases require both sides to present their evidence in a way that a nontechnical individual can understand. The outcome of this process is particularly difficult to predict when the technology in question (and its accompanying literature) is still at a relatively early stage of development. I maintain that the literature in the area of medical efficacy of the effects of lossy compression is at an early stage. At such an early stage, both sides of a case may be able to use credible expert witnesses to construct convincing cases because individual studies may, legitimately, produce diametrically opposite results. The reasons for disagreement, which include insufficient statistical power, the presence of confounding factors, the difference between correlation and causation, are notoriously difficult to explain to a lay audience.

Some of the issues that relate particularly to the subject of image quality in radiology PACS and teleradiology are also difficult to communicate to a jury of lay people. These issues include differences in image quality among different modalities, the role of display systems, patient data management, and communications infrastructure in the delivery of patient care, and the rapidly evolving technology used in digital storage and transmission. Not the least among these is the difficulty of answering the deceptively simple question: At what point in the imaging chain is the ''original'' image ''acquired''?

As the medical literature on a new technology reaches a higher level of maturity, key issues are recognized and the criteria by which implementation of the new technology will be deemed successful are identified. Multicenter clinical trials often appear at this stage, although not in all cases. When the literature has reached such a level of maturity, it is possible to recognize consensus through the appearance of the reports from government advisory groups, and academic and professional societies.

In summary, I maintain that the use of lossy compression for some imaging procedures is inadvisable at the present time. There is no appropriately citable medical standard. The primary reason for this lack of standards is the relatively early stage of development of medical literature in this area. It is an appropriate time for government advisory groups, and academic and professional societies to begin to set standards in this important area of medicine. But, it is an inappropriate time for individual radiologists to use lossy compression in clinical practice.

Rebuttal

I agree that there is a large and continually growing body of literature showing that lossy compression may be used without significant degradation of image quality. However, I maintain that this issue has two components: technical and legal. A vital link in the chain of events that leads to a medical standard is, as of this writing, missing. This link is the presence of citable reviews and recommendations from medical advisory groups. Without that link, individual radiologists put themselves at legal risk.

I do not suggest that the medical community wait for long. On the contrary, the existence of this issue speaks to a need for action. Fortunately, there are some developments in this area. One example is a project of the AAPM Committee on Research and Technology Assessment.[2] This project seeks to evaluate the effects of compression in musculoskeletal and thoracic images. The committee plans to submit the results of the study to the ACR specifically for the purpose of extending the current ACR Standard on Teleradiology. As of this writing, NIH funding for this project is being sought. A corollary development is the possibility that a forthcoming revision of the JPEG standard will include wavelet compression, one of the most successful methods of achieving ''substantial equivalence'' with a high compression ratio. If so, it will probably be adopted by DICOM since they already support JPEG. This would help to standardize procedures and specifications.

Compression standards should be and will be adopted. However, until they are, I will continue to advise the physicians with whom I work to avoid the use of lossy compression in images used for primary diagnosis, particularly in imaging applications such as chest radiography.

AGAINST THE PROPOSITION: Andrew D. A. Maidment, Ph.D

Opening Statement

Lossy compression (LC) is an indispensable part of medical imaging. The need for LC is clear—image sizes exceed the practical and economic limits of telecommunications and storage devices. Moreover, the initial fears that LC would mask subtle pathology have proven to be unfounded. Study after study is showing that all imaging applications should be considered as candidates for LC, albeit with potentially different techniques and compression ratios.

There is a definite need for LC in the transmission and storage of medical images. A typical radiographic study will be between 20 and 100 MB. If it is necessary to send such data in a timely fashion (i.e., a few minutes), either expensive high speed networks are required (e.g., T1 or faster), or LC must be utilized. When one considers storage of these images for five or more years, even small institutions performing 10 000 cases per year can quickly accumulate multiple terabytes of data. LC reduces both storage hardware and media costs, while speeding retrieval since more image data can remain on fast devices longer.

The most common concern is that LC may suppress relevant details or inject spurious noise into images. Such concerns are largely unfounded. The effect of LC depends upon the compression ratio and method. As the compression ratio is increased, the first noticeable effect is the removal of high frequency decorrelated noise, followed by increased blurring and finally by the introduction of artifacts.[3] Detectability degradation from LC can therefore be treated as being equivalent to SNR reductions from other sources. Zhao *et al.*[4] have shown that detectability is equivalent for 4.5:1 LC images and uncompressed images. They have also shown that 17.4:1 LC images are equivalent to uncompressed images, if the LC images are acquired with 25% higher input SNR. Stated another way, a 200 speed LC screen-film image compressed 17:1 would be equivalent to an uncompressed 300 speed screen-film image. Numerous studies have shown that LC can even improve image quality. For example, JPEG LC has been shown to reduce speckle in ultrasound images. LC has also been shown to offer improvement in the detection of lesions in chest radiographs.[5]

Medico-legally, LC is little different from other forms of image processing. All digital imaging modalities perform image or data processing prior to display. We accept such manipulations through articles of faith and the presumption that FDA approval is an endorsement of the efficacy of the device. In fact, the ACR and FDA both allow LC; they only require that the use of LC and the compression ratio be noted on compressed images. The ACR also suggests that the compression ratio be user selectable. Trained observers can thus learn to recognize compression artifacts just as they do gridlines or processor artifacts, and compensate for them appropriately.

In summary, not all forms of LC are equal. Some will be better suited to one type of image than another. Moreover, scientific studies must be performed prior to acceptance of specific LC uses. However, there has been sufficient proof in the literature over a sufficiently broad range of applications[6] to demonstrate the universal acceptability of LC.

Rebuttal

It most certainly is not ''an inappropriate time'' to begin use of lossy compression (LC). I agree that LC lacks an authoritative standard, but there is a DICOM Working Group addressing this exact issue. It is important to realize that radiographic interpretation of LC images occurs daily throughout the world. It is through LC that university medical centers can provide subspecialty radiological expertise to small rural communities that otherwise would be served by people who may not be adequately qualified. Is there a greater loss of information in LC of images or in the unskilled interpretation of images?

In spite of many jokes to the contrary, people should not live their lives in fear of lawyers. Rather, lawyers and the law can be seen to serve a constructive purpose in society. They require us to consider the consequences of our actions. One might argue that in spite of concerns of potential future lawsuits, medical science and in fact all fields of human endeavor continue to develop and grow. However, it is equally possible that legal and ethical accountability subconsciously drives us to continuously improve our existence. Such improvements necessarily take into account societal needs, and the cost that society is willing to pay for such improvements. LC is just one of the many improvements that allows us to implement digital imaging in radiology with the concomitant improvements in image quality, medical care, and the accessibility to such care. I would argue, therefore, that timely adoption of LC in radiology is a priority so long as the conditions that require LC exist. However, as with all innovations in radiology, LC must be properly utilized. Thus, it is important that we educate users of the uses and potential abuses of lossy compression.

[1]ACR Standards for teleradiology: Diagnostic radiology standard No. 12. Reston, VA, American College of Radiology, Rev. 26, 1996.
[2]Perry Sprawls, Chair, AAPM Committee on Research and Technology Assessment (personal communication).
[3]K. Pearsons, P. Palisson, A. Manduca, B. J. Erickson, and V. Savcenko, ''An analytical look at the effects of compression on medical images,'' J. Digital Imaging **10**, 60–66 (1997).
[4]B. Zhao, L. H. Schwarz, and P. K. Kijewski, ''Effects of lossy compression on lesion detection: Predictions of the nonprewhitening matched filter,'' Med. Phys. **25**, 1621–1624 (1998).
[5]V. Savcenko *et al.*, ''Detection of subtle abnormalities on chest radiographs after irreversible compression,'' Radiology **206**, 609–616 (1998).
[6]*Understanding Compression*, edited by P. Drew (SCAR, Reston, VA, 1997).