Effect of Image Compression on Telepathology

A Randomized Clinical Trial

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• ***Context.***—**For practitioners deploying store-and-forward telepathology systems, optimization methods such as image compression need to be studied.**

Objective.—**To determine if Joint Photographic Expert Group (JPG or JPEG) compression, a lossy image compression algorithm, negatively affects the accuracy of diagnosis in telepathology.**

Design.—**Double-blind, randomized, controlled trial.**

Setting.—**University-based pathology departments.**

Participants.—**Resident and staff pathologists at the University of Illinois, Chicago, and University of Cincinnati, Cincinnati, Ohio.**

Intervention.—**Compression of raw images using the JPEG algorithm.**

Main Outcome Measures.—**Image acceptability, accuracy of diagnosis, confidence level of pathologist, image quality.**

Results.—**There was no statistically significant difference in the diagnostic accuracy between noncompressed (bit map) and compressed (JPG) images. There were also no differences in the acceptability, confidence level, and perception of image quality. Additionally, rater experience did not significantly correlate with degree of accuracy.**

Conclusions.—**For providers practicing telepathology, JPG image compression does not negatively affect the accuracy and confidence level of diagnosis. The acceptability and quality of images were also not affected.**

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Medical specialties that rely on images to formulate a diagnosis lend themselves to the store-and-forward method of telemedicine. With this method, images are captured and then forwarded, often through the Internet, to a remote expert for asynchronous review at a later time. Pathology (telepathology), radiology (teleradiology), and dermatology (teledermatology) are among the most advanced areas of telemedicine because of their image-intensive nature and minimal requirement for patient interaction.[1–3]

Telepathology in particular requires the evaluation of microscopic images to formulate a diagnosis. Store-and-forward telepathology allows a pathologist in a remote location to digitize images of a challenging case for second opinion consultation. These images are usually transmitted through the Internet, which is now widely used as an exchange medium for scientific data. Efficient methods of image transmission, especially by compression, are of great interest to the scientific community, since high-quality digital images may attain sizes of 1 megabyte or greater. While larger files generally produce better images, they also take longer to send through the Internet. Depending on the type of Internet connection and the amount of ''traffic,'' a 1-megabyte file may take 5 minutes or more to download. Its compressed version, on the other hand, may be received in less than 30 seconds.

Joint Photographic Experts Group (JPG) is a widely accepted image compression algorithm. Any Internet-connected computer today will have a web browser, such as Netscape or Internet Explorer, which is capable of displaying JPG files.[4–7] This algorithm accomplishes compression by exploiting known limitations of the human eye, particularly its inability to detect minute color and shades-of-gray details.[8] During the compression process, these small details are removed without noticeable difference if viewed with the naked eye. The final compressed image, therefore, will contain less data than the original. It is this loss of data, its possible effect on the quality of the image, and ultimately its effect on diagnosis that generates a cause for concern.

Many studies have been published on telepathology,[9–14] but only a few researchers[15,16] have actually compared noncompressed with compressed images using a structured study design. The aim of this study was not to compare the diagnostic accuracy of telepathology with that of glass slide diagnosis, but rather to determine whether the loss of data in JPG compression adversely affects the quality of images and the accuracy of diagnosis.

METHODS

Ten previously diagnosed cases were chosen from the teaching files of the Department of Pathology, University of Illinois University Hospital Chicago (UIC). Six representative snapshots from each case (magnifications ×2.5, ×10, and ×40) were captured using a Polaroid DMC 1 digital camera (Polaroid Corp,

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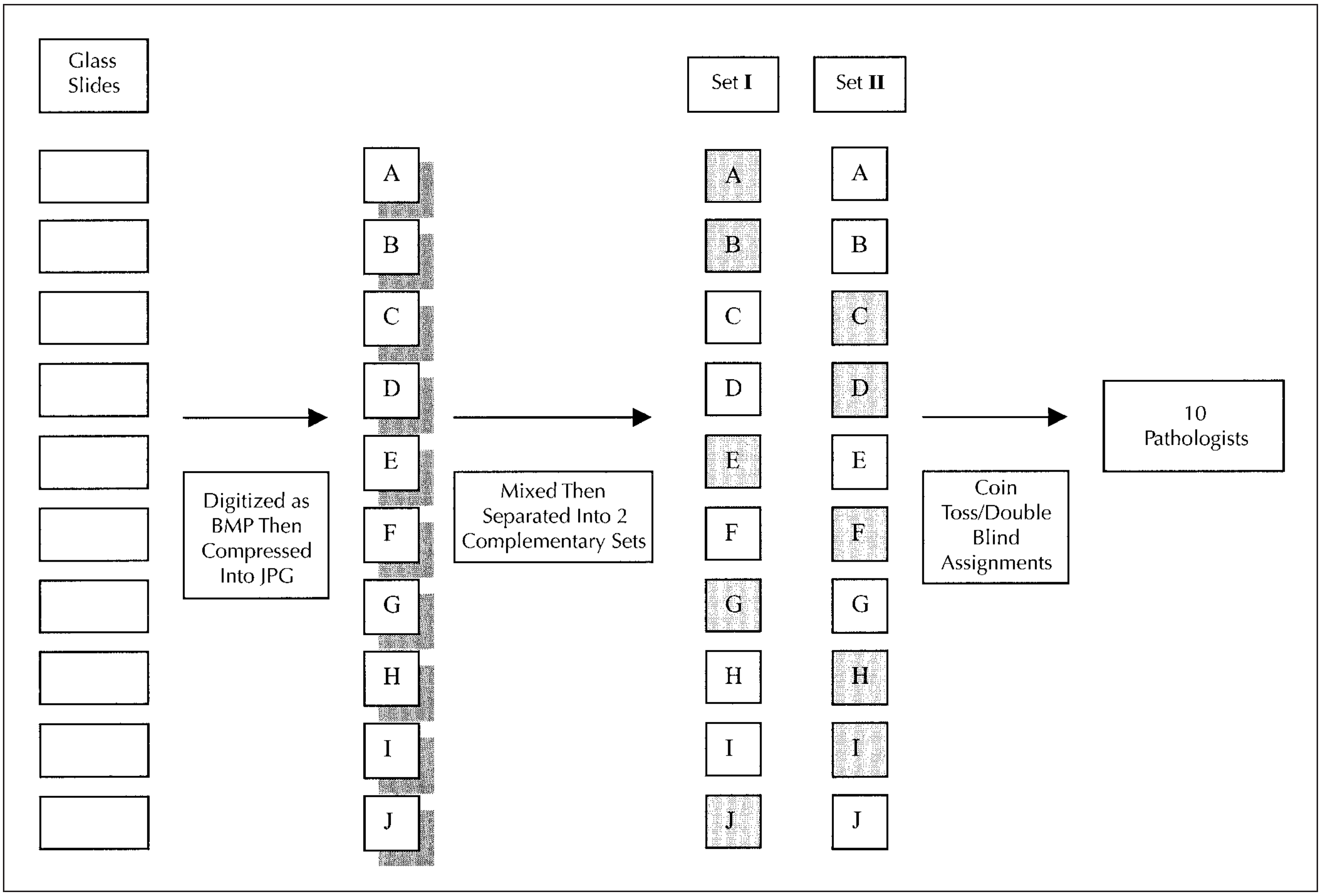

Schema for assignment of cases to pathologists.

Cambridge, Mass) mounted on a Leica DMLB (Leica Microsystems, Heidelberg, Germany). All initial images were saved in the Windows bit-map (BMP), noncompressed format (average size ~1000 kilobytes, at 667 × 500 pixel resolution). Bit-map images were then compressed using Adobe PhotoShop 5.0 (Adobe Systems, San Jose, Calif). The resulting compressed files were about 100 kilobytes at 90% compression. Images were archived on Macintosh 8100 computer (Apple Computers, Cupertino, Calif) and served on the World Wide Web using Quid Pro Quo 2.1.2 (Social Engineering, Berkeley, Calif) on a T-3 (45 megabits/s) line. The Web site was password protected and was accessible only after proper authentication. File extensions were masked server-side using randomly selected letters.

Two test sets were prepared (Figure). Set 1 had 5 cases in noncompressed (BMP) and 5 in compressed (JPG) format, and set 2 was its complement. Participants were assigned randomly to a set by coin toss.

Using Internet Explorer 5.0 (Microsoft Corporation, Redmond, Wash), 5 pathologists each from UIC and the University of Cincinnati (Cincinnati, Ohio) viewed the randomly assigned sets on the Internet at their convenience and assessed the images according to protocol. Server-side and client-side caching was allowed to minimize the effect of variable Internet transmission. Parameters measured were acceptability of a case for diagnosis, accuracy of diagnosis, confidence in diagnosis, and image quality (if found acceptable for diagnosis). Each rater's level of experience was also recorded.

The final diagnosis based on the glass slides from UIC was used as the reference diagnosis. Three of the authors (PAF, MF, and HC) independently compared the respondents' diagnoses with the reference diagnosis (blinded). By consensus, they classified the responses into 4 categories: no diagnosis (n = 0), no difference (n = 1), minor difference (n = 2), and major difference (n = 3). A response was labeled "no difference" if it agreed completely with the reference diagnosis, "minor difference" if it signified a minor disagreement in terminology with no alteration in management, and "major difference" if the disagreement required a major change in management, usually benign to malignant or vice versa.

Categories for confidence level were no response (n = 0), very confident (n = 1), quite confident (n = 2), and not confident (n = 3). Categories for image quality were: no response (n = 0), excellent (n = 1), very good (n = 2), fair (n = 3), and poor (n = 4). Comparison of proportions was used to analyze results.

RESULTS

Ten pathologists examined 10 cases each for a total of 100 samples (50 compressed, 50 noncompressed). Seven of the 100 samples were labeled unacceptable (poor and unfit for diagnosis). Of these 7, 4 were from the compressed set (8%) and 3 from the noncompressed (6%). The acceptability rates for compressed and noncompressed samples were not statistically different (at 95% confidence interval [CI]). Reasons given for unacceptability were "too dark," "too few images," and "no intermediate power." From the 93 samples judged acceptable, respondents concurred with the reference diagnosis in 71 cases (Table). The accuracy rates for compressed and noncompressed samples were not statistically different (at 95% CI).

Six responses had minor disagreements with the reference diagnosis. An equal number of compressed and noncompressed samples were classified as such (6% each).

Respondent Agreement With Reference Diagnosis								
	Unacceptable		Complete Agreement		Minor Disagreement		Major Disagreement	
Diagnosis	Noncompressed	Compressed	Noncompressed	Compressed	Noncompressed	Compressed	Noncompressed	Compressed
A. Mucinous adenocarcinoma	2	. . .	2	2	1	1	1	1
B. Complete hydatidiform mole	. . .	. . .	4	2	2	2	. . .	. . .
C. Pheochromocytoma	1	2	1	4	. . .	. . .	2	. . .
D. Carotid body tumor	. . .	1	4	4	. . .	. . .	. . .	1
E. Nephroblastoma	. . .	. . .	6	4	. . .	. . .	. . .	. . .
F. Endometrial carcinoma	. . .	. . .	4	6	. . .	. . .	. . .	. . .
G. Medullary carcinoma	. . .	. . .	6	4	. . .	. . .	. . .	. . .
H. Tubulovillous adenoma	. . .	. . .	. . .	. . .	. . .	. . .	4	6
I. Prostate adenocarcinoma	. . .	1	4	5	. . .	. . .	. . .	. . .
J. Crohn disease	. . .	. . .	6	3	. . .	. . .	. . .	1

Sixteen responses had major disagreements with the reference diagnosis. Nine of these were from the compressed set (18%) and 7 from the noncompressed set (14%). The disagreement rates for compressed and noncompressed samples were not statistically different (95% CI).

Respondents were asked to assess their confidence level in each of the cases they examined. The pathologists reported no significant differences in confidence levels in either compressed or noncompressed samples (at 95% CI). There were also no significant differences in the image quality assessments of compressed and noncompressed samples (95% CI).

Of the 16 responses with major disagreements with the reference diagnosis, 10 were made by pathologists with less than 7 years of experience and 6 by those with more experience. This difference was not statistically significant (95% CI).

COMMENT

We compared the effect of compression on a pathologist's ability to diagnose using static telepathology techniques. It should be emphasized that the ''diagnostic'' aspect of the study was only one of the parameters used for comparison and was not the end in itself. Therefore, our results are best viewed within their relations to each other (compressed vs noncompressed) rather than by their absolute relation to the reference diagnosis. An important caveat, therefore, is that the results obtained in this study are applicable to telepathology only. They cannot be extrapolated to a comparison between telepathology and glass slide diagnosis, since the respondents did not evaluate the original glass slides.

Several technical limitations were observed while conducting this study. The cases chosen had varying degrees of diagnostic difficulty. As pathologists well know, some cases may only require one slide or one area to formulate a diagnosis, whereas others may need more. For example, some cases may be so challenging that even 20 images may not be sufficient, or special stains might be required to arrive at a diagnosis. This variability between amount of data presented (the images) and the amount of information that can be extracted from them (for diagnosis) is a known limitation of static telepathology. The best way to control this variable in this study was to provide identical amounts of data (6 images per case) to the respondents. It was important that they saw the same number of images from each case, as this ensured they were able to make the diagnosis from the same data and not because they received more information from seeing additional images. If the respondents could not cull enough information from a given case, it was recorded as such, and the case was rated ''unacceptable'' in its current form.

Interrater and intrarater variability was also cause for concern. We limited these effects by presenting the pathologists with equal amounts of compressed and noncompressed data. This way, we were able to use the respondent as his or her own control by applying the rater variable across both experimental and control populations.

There was also the limitation imposed by carry-over errors. Carry-over errors occur when compressed images are derived from flawed originals. A defective original noncompressed image would necessarily give poor compressed counterparts. This may explain why all respondents missed case H (tubulovillous adenoma). It is important to identify such errors, since these may detract from the value of a good telepathology system when the actual flaw may be due to poor technique or human error.

The level of resolution chosen was the best achievable using commercially available off-the-shelf software and currently standard monitor resolutions. To emphasize the ease of use of the Internet, the study employed a Web browser interface for presentation. By doing so, minimal training (point-and-click), if any, was required from the respondents. This is consistent with our goal of reproducing conditions in a typical pathologist's workstation.

The respondents included 4 attending pathologists, 2 sixth-year fellows, 1 fifth-year fellow, and 3 chief residents. Although it was expected that experience would be a significant factor in telepathology, the results showed that this may not be the case. A possible explanation is the familiarity of the younger respondents with computer-based displays. This premise is consistent with the findings of Krupinski et al,[17] who noted a negative correlation between years of clinical experience with performance when viewing images from a monitor display.

In summary, image compression using commonly available software can reduce image files to approximately one-tenth their original size. Such compression may be beneficial in reducing transmission time over the Internet. User acceptance of JPG-compressed images for diagnosis is not significantly different from that with noncompressed formats. Other factors, such as poor selection of fields, poor lighting, and insufficient number of image samples, can influence acceptability by causing carry-over errors. It should be stressed that these factors are independent of the compression algorithm and are related more to technique and methodology. Once deemed acceptable, however, compressed images are diagnosed correctly and incorrectly with the same frequency as noncompressed images. Lastly, no difference in performance was observed between young and experienced pathologists for both image formats.

Store-and-forward telepathology is useful for second-opinion consultation for pathologists and physicians with access to the Internet in locations where rapid courier services are not available. We believe that this study provides evidence to support the use of JPG compression in telepathology. These findings may also apply to other image-dependent telemedicine applications in dermatology and radiology.

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