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Original Article

# Global manipulation of digital images can lead to variation in cytological diagnosis

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## Abstract

**Background:** With the adoption of a completely electronic workflow by several journals and the advent of telepathology, digital imaging has become an integral part of every scientific research. However, manipulating digital images is very easy, and it can lead to misinterpretations. **Aim:** To analyse the impact of manipulating digital images on their diagnosis. **Design:** Digital images were obtained from Papanicolaou-stained smears of dysplastic and normal oral epithelium. They were manipulated using GNU Image Manipulation Program (GIMP) to alter their brightness and contrast and color levels. A Power Point presentation composed of slides of these manipulated images along with the unaltered originals arranged randomly was created. The presentation was shown to five observers individually who rated the images as normal, mild, moderate or severe dysplasia. Weighted κ statistics was used to measure and assess the levels of agreement between observers. **Results:** Levels of agreement between manipulated images and original images varied greatly among observers. Variation in diagnosis was in the form of overdiagnosis or under-diagnosis, usually by one grade. **Conclusion:** Global manipulations of digital images of cytological slides can significantly affect their interpretation. Such manipulations should therefore be kept to a minimum, and avoided wherever possible.

**Key words:** Author guidelines, ethics, image manipulation, photomicrographs, telepathology

## INTRODUCTION

Digital imaging is an integral part of any scientific research. It offers several advantages over conventional analog photography. The advent of telepathology and the adoption of a completely electronic workflow by most journals today have vastly necessitated the use of digital photomicrographs. However, most journals that accept digital images for publication do not provide a guideline for the same. In the process of making digital images suitable for publication or presentation, a pathologist can inadvertently manipulate the images in such a way that they convey wrong information.[1-3] There have been several instances in the past where manipulated images were also used unethically, the publications of Hwang *et al*, in 2004 and 2005 being a case in point.[4]

Few journals that do provide guidelines for image submissions specify that only global manipulations are permissible.[5-8] A study was therefore done to analyse the impact of such global manipulations of digital images on their diagnosis.

## MATERIALS AND METHODS

Fifteen digital images from Papanicolaou stained cytological smears of normal and dysplastic oral epithelium were taken. Using GNU Image Manipulation Program, these images were manipulated to alter their brightness, contrast and their color levels. Two sets of manipulated images were obtained for each original photomicrograph. Images were then rotated and/or flipped in such a way that no two images resembled each other. Only global manipulations were done, as allowed by various journal guidelines.

A Power Point slideshow was created with the fifteen original images and their thirty manipulated variants arranged randomly. Five observers were asked to evaluate and grade the degree of dysplasia (as no dysplasia, mild, moderate and severe dysplasia) in each of these 45 images. Evaluation of all the slides was done by each observer in a single sitting. The grades assigned to each original photograph and its manipulated counterparts were compared for each observer separately and the results tabulated.

## RESULTS

Inter-observer variation was not analysed as the subjective bias in the grading of dysplasias is very high. We therefore used the diagnosis given for the original photomicrograph as the baseline, and compared the diagnosis for the modified images with this, for each observer separately. Wide variations in the diagnosis of manipulated duplicates were observed.

In total, only 59% of the diagnoses of altered duplicates matched with those of the unaltered originals. However, the observers underdiagnosed 21% of the images and over-diagnosed 20% of the images.

Among observers, overdiagnosis ranged from as low as 13% to as high as 30%. Overdiagnosis was usually in the form of one grade above what was diagnosed in the original photomicrograph. However, in as many as four cases, interpretation was two grades above the initial diagnosis.

Under-diagnosis ranged from 10% to 40% among individual observers. More importantly, severe dysplasia was underdiagnosed as normal morphology in two cases and as mild dysplasia in one case.

Table 1 shows the correlation of diagnosis for all pairs of original versus manipulated images. Table 2 illustrates the level of agreement between original and altered images for each observer. A κ value of 0.75 and above is usually considered good correlation. None of the observers in our study showed such a good correlation. The level of agreement (κ) ranged from as low as 0.096 to as much as 0.612.

## DISCUSSION

The advent and use of digital images in pathology and medicine cannot be understated. More and more institutions and hospitals are now adopting telepathology as a way of making better use of available resources. Telepathology has also been useful in regions where local pathologists are not available, and where immediate transportation of specimens to a central pathology department is unsuitable.[9]

Telepathology can be either static or dynamic, depending on how it is being used. In dynamic telepathology, live images of a slide or sample are streamed to the pathologist over internet. Although this results in more accurate diagnosis, the costs and economics involved are usually prohibitory to its large scale use. In static telepathology, images are dispatched to the pathologist either through

**Table 1: Correlation in the diagnosis of all pairs of original versus altered images for all observers**

| Diagnosis in original images | Diagnosis in altered images | | | |
|---|---|---|---|---|
| | Normal | Mild | Moderate | Severe |
| Normal | ***35 (73)*** | 11 (23) | 2 (4) | 0 (0) |
| Mild | 13 (27) | ***25 (52)*** | 8 (17) | 2 (4) |
| Moderate | 3 (7) | 9 (22) | ***21 (53)*** | ***7 (18)*** |
| Severe | 2 (14) | 1 (7) | 3 (22) | 8 (57) |

The figures in bold italics indicate that the diagnoses matched with those of original images. Figures in parenthesis are in percentage.

**Table 2: Levels of agreement between original and altered images for each observer individually**

| Observer | No. inspected | No. matched | % matched | Kappa (κ) |
|---|---|---|---|---|
| Observer 1 | 15 | 9 | 60.00 | 0.602 |
| Observer 2 | 15 | 2 | 13.33 | 0.096 |
| Observer 3 | 15 | 7 | 46.67 | 0.414 |
| Observer 4 | 15 | 10 | 66.67 | 0.612 |
| Observer 5 | 15 | 5 | 33.33 | 0.376 |

email or any other means, and the pathologist makes a diagnosis from these images. There is more possibility of variations in diagnosis by this approach. However, it works out to be a cost-effective procedure. Any lab or hospital with the bare minimum facilities like a working computer and a basic internet connection would be able to make use of this method.

Many journals today accept mostly digital submissions of manuscripts for publication. This necessitates the use of digital images for uploading to the journal's website. While this is a very convenient method to quicken the process, it also has some inherent disadvantages associated with it. Digital images vary widely depending on the instrument used to take the image, the settings in the camera, the person taking the photograph and also the post-processing done.

Publication of photomicrographs in journals can also be considered as a form of static telepathology, in the sense that images are used to convey the findings and messages of the authors. However, till date there are no comprehensive guidelines on handling of digital images for scientific publications or presentations. The instructions to authors provided by most journals prove to be grossly inadequate in terms of submission of digital images. Most journals mention the format of the image needed (either .jpeg or .tiff format), the maximum size permissible and the minimum resolution required. Very few journals mention specific instructions about manipulation of such images. Those that do, merely mention that only global manipulation of images is permissible.

Our study to assess the effect of image manipulation on cytological diagnosis of epithelial dysplasia shows that even global manipulations can lead to huge variations in diagnosis. Although more than 50% of the diagnoses correlated with the originals in each case, it is a matter of concern that very often the diagnosis changed in altered images. In all three grades of dysplasia, there was difficulty in maintaining a consistent diagnosis, and the interpretations varied widely for each of the observers.

Similar studies done elsewhere across the globe also reflect our findings.[10,11] In the present study, the digital images given for interpretation consisted of original as well as altered photomicrographs. Alteration was done only in the form of increase or decrease in brightness, contrast and/or color saturation. Such manipulations are possible when the pathologist or researcher tries to make an image suitable for publication by compensating for improper photographic technique. The awareness and adoption of new technology among health professionals is comparatively lower, although this awareness has been on the rise in recent times. It is therefore possible that researchers hand over the job of clicking photographs and uploading them for submission to someone else. Many a time, this job is assigned to a computer technician, who has no idea about the potential implications of such faulty manipulations.

The issue about ethical and unethical also emerges in such a situation. There have been a few instances where images were manipulated intentionally to depict a finding that was non-existent in the first place. The controversy regarding the stem cell study by Hwang *et al*, brought this issue to the limelight.[4] The authors involved in that particular study used manipulated images to show a stem cell line that was non-existent.

Unethical image manipulation is much more prevalent than being acknowledged. An analysis by the Office of Research Integrity in U.S. found that as much as 68% of cases of research misconduct in 2007-08 involved falsified images.[12] While intentionally unethical image manipulation would form just a small fraction of this, it has to be acknowledged that the problem does exist.

Educating students and researchers about the dos and don'ts in image manipulation should help reduce the incidence of improper images in most cases.[13] Journal editors and institutional and departmental heads can also help by encouraging researchers to publish their findings as is. Better guidelines that are far more comprehensive and all inclusive can help prevent falsified images, but the onus ultimately lies in the researcher himself.

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