Digital recording in microsurgery

Technical note

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The authors examine the quality of intraoperative photography in which digital recording technology, including a microdigital camera and digital video paired with an operating microscope, is used during neurosurgery. A microdigital camera developed for this purpose (1.4 million pixels) was attached to an operating microscope and used during surgery. The same surgical views with precisely the same optical conditions were taken through the microscope by using both a conventional 35-mm camera and the microdigital camera, and the quality of the final output was compared. In addition, the quality of the digital camera photographs was compared with the still photograph clipped from the digital video recording.

The quality of the photographs taken with a microdigital camera was superior to the quality of those obtained with the conventional 35-mm camera. The success rate of recording (what you see is what you get) was almost 100%. The quality of the still photographs clipped from the digital video was nearly equal to those taken with the digital camera. The microdigital camera system is superior to the conventional 35-mm camera in neurosurgery in terms of its success rate and the quality of the photography. It is also a space-saving system for storing the huge amount of data generated in the recording of surgical procedures, and the cost/performance ratio is superior to that of the conventional method. Digital technology including digital cameras and videos is very useful for clear recording of microsurgical procedures.

KEY WORDS • digital camera • digital video • operating microscope • neurosurgery

In neurosurgery, operative procedures (macro–micro) are recorded using many media, including 35-mm camera (conventional analog photography with silver halide film), video recording (analog and/or digital), and manual recording by the neurosurgeon (operative notes) in most active facilities. These visual recordings are not only a simple notation for physicians but also important source materials for the education and enlightenment of young residents, medical students, and even experienced neurosurgeons. In addition, these visual data occasionally provide important information in some medicolegal cases. A unique feature of neurosurgery is that most important surgical procedures, such as aneurysm clipping, tumor removal, anastomosis of vessels, and nerve connections, are performed with the aid of an operating microscope. Therefore, records of procedures performed with the aid of an operating microscope, including photographs recorded with 35-mm cameras, are important for neurosurgery.

However, photographs obtained intraoperatively in neurosurgery are generally taken under very severe conditions compared with those present for general photography or for photographs obtained for other scientific purposes. The brightness of the light must be limited to avoid tissue damage due to heat, and the objects are deep and move synchronously with the patient’s breath and heart beats. As a result, even if the most sophisticated adjustments are made, the quality of the final output of intraoperative recording is uneven and unreliable. The most discouraging thing is that the quality of the photographs cannot be confirmed during surgery. Badly focused images or dark slides that are not available until several days after a difficult surgery are a source of disappointment for the neurosurgeon.1

The digital camera is one of the fastest-developing items in high technology. Recently we attached a microdigital camera system, which was developed for use with a microscope, to an operating microscope. In this study, we examined the usefulness of this microdigital camera and the quality of the final output compared with that of a conventional 35-mm camera. In addition, the quality of the photographs recorded with a digital camera was compared with still photographs clipped from digital video recordings, which many neurosurgical centers have introduced recently. This is the first report of the application of a microdigital camera system during a neurosurgical procedure.

Materials and Methods

Microdigital Camera

The microdigital camera used in this study has been newly developed for applications, such as pathological examinations, in which a normal microscope is used. This
camera can be applied to any microscope, including an operating microscope, by using a C-mount. The number of pixels is 1.4 million and the camera is equipped with a high-quality CCD. The light from the surgical view is directly reflected to the CCD without passing through an aperture. The exposure time is automatically adjusted to the optimized condition in every exposure by the CCD. Digital data are transferred directly to Zip disks in 6 seconds. The dimensions of this microdigital camera are 80 mm (width) × 80 mm (height) × 130 mm (depth), and weight 700 g. This is a computer-free system and does not require an operator. The surgeon can take a photograph at any time by stepping on a foot pedal. The system is equipped with a small monitor to confirm recorded images (what you see is what you get). Therefore, the quality of recording can also be confirmed on the monitor. Poorly focused and off-center images can be discarded.

**Conventional 35-mm Camera**

For the conventional 35-mm camera the f-stop was set to 8 and the exposure time was automatically adjusted. The color-reversal tungsten film (color temperature 3200˚K) was supposed to be matched to the light source of the operating microscope being used (color temperature 3200–3700˚K).

**Digital Video**

The digital video recorder and the video camera used in this study were paired with a three-CCD camera and produced 0.82-MB pixels for each image.

**Operating Microscope**

The operating microscope used in this study was a very conventional one and has been used for more than 10 years in our operating room. Its light source is metal halogen (color temperature 3200–3700˚K).

**Clinical Experiment**

Exactly the same operative scenes were taken simultaneously with both the microdigital and the conventional analog camera to achieve precisely the same conditions of exposure. The same intensity of light was distributed to both cameras by the beam splitter. The setup of this system is shown in Fig. 1. Exposures were made under conditions of normal control of respiration by an anesthesiologist without intentional stopping of respiration. Digital video images were also recorded under exactly the same conditions as with the digital camera. Two representative intraoperative scenes of microneurosurgery were recorded, that is, a maximum magnification of the brain surface and a deep dark scene.

**Evaluation of Images**

The quality of the images was compared using two different kinds of printing and slide preparation. Both sets of data were printed out by using the best technique available. Analog reversal films were printed as photographs by using a conventional method, and digital data were also printed out by using a digital printer with no artificial correction by such means as image retouching software. Analog data were directly printed to slides (reversal films) and digital data were also printed to slides through a computer.

Both photographs and slides were checked by an individual who was unaware of the recording methods used. The criteria used for the evaluation did not pertain to the general photographic quality of the images but rather were based purely on a neurosurgeon’s point of view. That is, the evaluation was entirely based on how clearly the anatomical structures and surgical procedures were recorded.

**Sources of Supplies and Equipment**

The microdigital camera (model HC-300Z) was purchased from Fuji Photo Film Co., Ltd., Tokyo, Japan. The Zip disks were acquired from Iomega Co., Ltd., Roy, UT. The Contax 35-mm camera was obtained from Kyocera, Kyoto, Japan. The color-reversal tungsten film (ISO 320) was purchased from Eastman Kodak, Inc., Rochester, NY. The digital video recorder (model DSR-80) was acquired from Sony Corp., Tokyo, Japan, and the video camera (model GP-K 1000S) was from Panasonic Corp., Tokyo, Japan. The operating microscope (model M695 D2-OH) was obtained from Leica Co., Ltd., Heerbrugg, Switzerland.

**Results**

**Maximum Magnification of Brain Surface**

Under conditions in which the brightness of the light is not reduced, the final output of the digital camera was highly adequate in the surgeon's view, and the exposure time was less than 10 msec, which was short enough that no artifacts were produced by respiratory movement or artery pulsation. With the 35-mm camera, the exposure time was automatically set to approximately 1/8 second (125 msec). The quality of the final outputs to print was not consistent and many of the images were poor because of the movement of the object. Indeed, a professional printing technique was necessary to obtain satisfactory quality comparable with that in photographs taken with a digital camera. However, prints made from a 35-mm silver halide film and shown in Fig. 2 are the best photographs in our series. Some of the best analog records were
practically equal to those taken with a digital camera, as shown in Fig. 2 right.

**Deep Dark Scene**

In difficult conditions of extremely dim light and large depth of field, the digital camera was used successfully to record images that would be of acceptable quality for a neurosurgeon. In these conditions (deep dark scene), the exposure time was automatically set to approximately 80 msec. With the analog camera, the print was often dark because of the dim light, or out of focus because of the movement of objects during the long exposure time. The exposure time was automatically set at approximately 0.5 seconds under these difficult conditions. It was obvious in this instance that the quality of the final output of the digital camera was superior to that of the analog camera (Fig. 3). The rate at which the final printed product minimally satisfied the neurosurgeon’s criteria was almost 100% with the digital camera recording, whereas the rate was less than 50% with the analog camera.

**Comparison of Analog With Digital Video Records**

The quality of the photographs clipped from the digital video recording was almost as clear as that recorded by a digital camera. For visual recognition on the part of neurosurgeons it was practically the same, although in magnified views the difference in pixel size is apparent, as shown in Fig. 4.

**Discussion**

The quality of a photograph taken with a digital camera is theoretically inferior to that of a photograph taken with an analog camera and printed on silver halide film. The theoretical number of matrices in silver halide film is thought to be 20 million, which is 10 times more than that of the most recent advanced digital camera system (1–2 million), although this number is dependent on the film’s International Organization of Standardization/American Standards Association number (the density of the particle). Therefore, in normal photography, a digital camera is used for limited purposes and rarely by a professional photographer. However, as shown in this report, under some intraoperative conditions the quality of images recorded with a microdigital camera is obviously superior to that of the images recorded with an analog camera. The source of this discrepancy is unclear.

Intraoperative photography in which an analog camera is used in conjunction with an operating microscope has had a history of trial and error. Even now, many neurosurgeons who use high-quality operating microscopes and analog cameras complain about the poor quality of intraoperative photographs. Generally, the best parameters are thought to be a high f-stop number (narrow aperture) and long exposure time, as Fox has reported. This set of conditions is somewhat contradictory, because the main source of image distortion is believed to be the movement of objects such as the arteries, brain, and nerves synchronously with the heart pulsation, and a long exposure time.
results in more movement artifacts. In fact, the movement artifact caused by arterial pulsation can be ignored because it is hardly noticeable on the photograph without magnification. However, respiratory movement causes substantial distortion in photographs. Therefore, to obtain optimally focused photographs, respiration would have to be temporarily stopped by controlling anesthesia during film exposure; however, this manipulation cannot be permitted for ethical reasons.

Another factor that seriously weakens the quality of the photographs taken with an analog camera is the mismatch between the color temperature of the film (daylight or tungsten film) and the most recent advances in bright light sources (halogen and xenon) for operating microscopes. The color temperatures of the available films (3200˚K, 5500˚K) are too low for this strong light source. In other words, if the most advanced operating microscope with a strong light source (high kelvin) is used, it is theoretically impossible to get the best performance from these films. Some filtering can resolve this mismatch between color temperature of the film and the source of light. However, it is very difficult in practice to adjust the filter, and the filter inevitably lessens the strength of the light.

In other words, if these parameters could be optimally adjusted to various conditions during microsurgery for each exposure made through an operating microscope, photographs taken with an analog camera could theoret-
ically be superior to those taken with a digital camera. However, these ideal conditions can never be achieved during actual neurosurgery. The most serious practical problem is that the opportunity and time for photography is limited and repetition of the attempt is impossible during the actual surgery.

The exposure parameters for a digital camera are controlled by a CCD camera, which determines the best regulation of exposure time for each shot. Indeed, in most images of the deep magnified view, the exposure time with the digital camera used in this study was less than 300 msec. This short exposure time can limit movement artifacts caused by respiration and arterial pulsation. In addition, the operating surgeon can confirm every result immediately after the exposure. Moreover, the CCD camera can regulate the exposure (color temperature), making it compatible with the quality of a given light source (tungsten, halogen, or xenon).

Therefore, the explanation of the superiority of the digital camera, with its small pixel number, to the analog camera, with its large pixel number, is as follows. First, with the digital camera one can control the exposure time through the CCD better than with the analog camera. Second, the quality of the images being recorded can be confirmed during surgery. Third, a mismatching between the color temperature and the light source can never happen with a digital camera, which does not use silver halide film.

Advances in digital technology have led to the clinical application of digital video as a tool for recording microsurgical procedures at a reasonable cost. Using the digital video, still pictures are easily clipped from video recordings. As shown in this paper, the image quality is practically equal to that of the digital camera. Therefore, digital video is also a good choice of tools for recording both still pictures and videos, although the cost of this equipment is still expensive compared with the digital camera.

Twenty-six images, which is more than the number on a normal analog film, can be stored on one Zip disk, and if image compression software is used, more than 160 can be stored there. Thus, the cost is compatible or superior to that of a conventional system when we consider the cost of film printing and storage space for these records. The cost of a digital camera is five times more than that of an analog camera. However, in our estimation, if the success rate of analog camera recording is 50%, the cost for 2000 successful slides (10 slides for each surgery and 200 surgeries per year), the cost of the digital camera is approximately $10 US (the price of memory media such as a magnetooptical disk) and that of the analog camera is approximately $2000 US. Therefore the ongoing cost for a digital camera is tremendously lower than that for an analog camera. In addition, a variety of modifications are available using image retouching software and a surgeon can make use of these digitized data for printing surgical records on a personal computer. The only drawback to using the digital camera with an operating microscope in neurosurgery is that a waiting time of more than 6 seconds is necessary between exposures due to the time needed for data transfer from camera to Zip disk.

References


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