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MPEG digital compression and analogue videotape: a comparison of moving images and electroencephalogram data in epileptic patients

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Abstract. *Primary objectives:* The objective of this study was to compare the clinical usefulness, in the field of epileptology, of digital moving images and electroencephalogram (EEG) waveforms by Motion Pictures Expert Group compression algorithms (MPEG-1 and MPEG-2) to that of conventional analogue recording.
Research design and methods: Three epileptic seizure scenes consisting of moving images and the corresponding EEG waveforms in an epileptic patient were selected as the images to be evaluated. Each scene was recorded using MPEG-1, MPEG-2 and videotape. Ten doctors used six criteria to evaluate the quality of moving images, EEG data and audio.
Main outcomes: Analysis of variance and Bonferroni tests indicated that the image quality of MPEG-2 was superior to that of MPEG-1 or videotape for all criteria. Furthermore, MPEG-2 obtained much higher scores in EEG waveform quality than did the other modalities.
Conclusions: Our findings suggested that data from MPEG-2 images will lead to more precise diagnosis and treatment decision-making than data from analogue videotape recordings.

Keywords: Comparative study; Epilepsy; Moving image; MPEG; Telecommunication

1. Introduction

Epileptic seizures are often infrequent and difficult to diagnose in many patients. Therefore, any data concerning seizure manifestation should be preserved and made accessible to physicians and other medical experts to help make a diagnosis and to choose an optimal therapy. In cases of difficult-to-diagnose epilepsies, or in particularly complicated conditions, interactive consultations utilizing telecommunications between different physicians or hospitals are often needed [1]. In telecommunications regarding epileptology, moving images ('movies' or 'videos') of patient monitoring and synchronous electroencephalogram (EEG) waveforms play crucial roles in diagnosis accuracy [2, 3]. Particularly, epileptologists evaluate abrupt changes in EEG at the seizure onset as shown in figure 1. To record and transmit them the amount of data needs to be reduced, or better image compression encoding applied. MPEG (Motion Pictures Expert Group) digital

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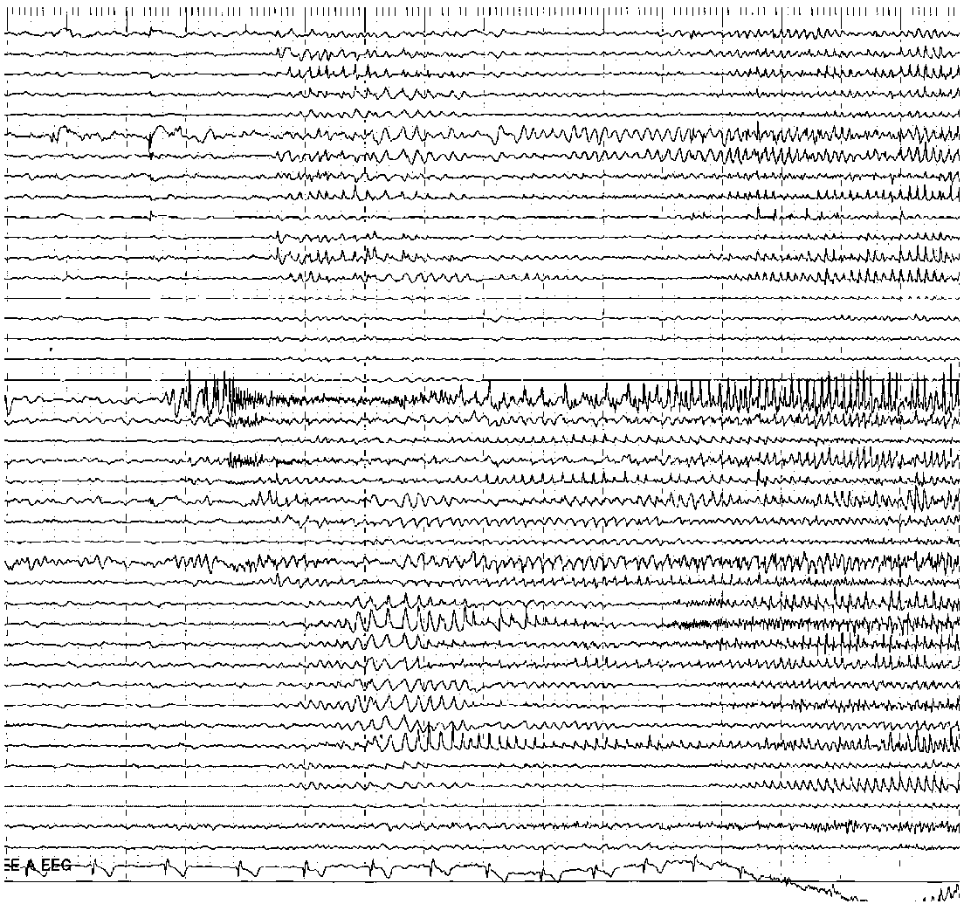

Figure 1. Example of Electroencephalogram waveforms at seizure onset. Typical ictal discharge pattern of the EEG was high-frequency repetitive spikes (low-voltage fast activity) recorded from a small number of electrodes followed by a diffuse decremental-incremental pattern. Presurgical evaluation required the recorded ictal discharge pattern to be clearly identified from background activity.

compression has been widely accepted for reducing the size of medical video files while retaining a high degree of fidelity to the original image. For example, it has been indicated that MPEG-1 digital video is equivalent to videotapes for diagnostic echocardiography [4, 5]. However, since MPEG-1 has low-level compression algorithms, the resulting quality is insufficient for solving problematic and complex epileptological diagnostic cases [1]. Therefore, more sophisticated compression algorithms, such as MPEG-2, need to be used to record moving images and the corresponding EEG data from epileptic seizures. MPEG-2 is the broadcast industry standard, but there are few studies confirming the clinical usefulness of digital MPEG-1 and MPEG-2 in the field of epilepsy. In particular, no study has evaluated the image quality of smooth curves such as EEG waveforms, even though the quality of EEG waveforms is crucial for the diagnosis of epilepsy [6].

We evaluated the clinical usefulness, in the field of epileptology, of MPEG-1 and MPEG-2-encoded moving images for patient monitoring and EEG data in comparison to conventional analogue recording. Specifically, we critically studied image quality, smoothness and sensitivity to abnormalities of EEG waveforms.

2. Methods

2.1. *Creating the master moving images*

The master moving images including patient monitoring and EEG data during seizure in an epileptic patient were simultaneously recorded on sVHS videotape, with the use of an EEG system, in the National Epilepsy Center, National Nishi-Niigata Central Hospital. Many Japanese hospitals that treat epileptic patients record moving images of seizure manifestations and the corresponding EEG data onto sVHS videotapes. The total time recorded was 90 min. The moving images of the patient during epileptic seizure were recorded using a standard analogue video camera and transmitted as video and audio signals to an EEG system, where they were transformed to RGB signals by an analogue-digital converter, the video capture utility of EEG. The moving images and the synchronous EEG waveforms edited on a screen were transformed from RGB signals to video signals (NTSC). A microphone built into the video camera directly recorded the conversation between patient and nurse. The master videotapes are usually utilized at epileptological conferences.

2.2. *Creating the moving images for evaluation*

Four scenes (Scenes-1, -2, -3 and -4) of the epileptic seizure were selected from the master moving images. Scene-4 was the same as Scene-1 and was chosen to evaluate the interobserver variability of the scores by readers. Each scene was recorded in colour using MPEG-1, MPEG-2, and sVHS videotape. The recording time was 40 s for all scenes. In total, 12 scenes with EEG data were prepared for evaluation. Ten doctors evaluated the three matched movies in MPEG-1, MPEG-2 and videotape formats. The image size of MPEG-1 was expanded so that it filled the computer monitor, thus the three types of images were viewed at the same size. MPEG-1 and MPEG-2 movies were compressed by Canopus MPEG-2 Video Encoder MVR-D2000 on a personal computer, Fujitsu DeskPower SV267 (CPU:Pentium II 266MHz, Memory 224MB). MPEG viewing was set to 30 frames per second.

2.3. *Presentation of the moving images*

Figure 2 shows the hardware configuration of the experimental system. The colour images of MPEG-1, MPEG-2 and the videotape were displayed on a 14-inch colour video monitor (Sony PVM-14M1J). The doctors evaluated the quality of image and audio in the order of Scenes-1, -2, -3 and -4. However, in each scene, the order of MPEG-1, MPEG-2 and videotape displayed was randomly allocated. The doctors were blinded to the order of the images displayed in each scene. A Canopus MPEG Station Version 1.10 was used to reproduce the encoded MPEG-1 and MPEG-2 movies, and a digital/video signal switcher used to change the MPEG movie to the videotape movie format. Instrument settings were optimized and held constant throughout the study.

2.4. *Methods of evaluation*

The 10 doctors in the National Epilepsy Center, National Nishi-Niigata Central Hospital, separately evaluated image quality. The median, 25 percentile and 75 percentile of their clinical experience were 19.0 years 10.75 years, and 21.25 years

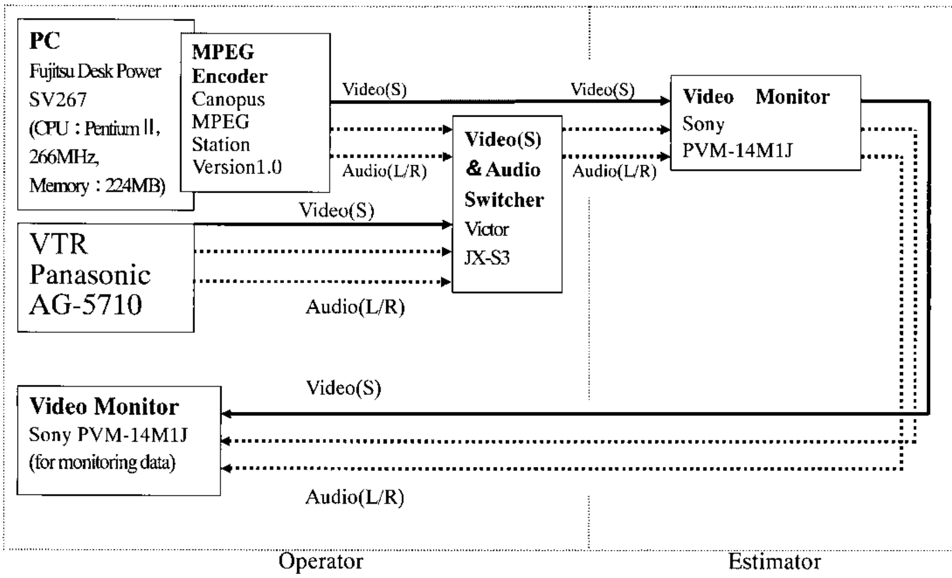

Figure 2. Schematic of the experimental system. The doctors (the estimators) evaluated the quality of patient monitoring and EEG waveforms for four scenes in MPEG-1, MPEG-2 and videotape format on a 14-inch colour video monitor. The order of MPEG-1, MPEG-2 and videotape was randomly allocated for each doctor.

respectively. Doctors evaluated the quality of the MPEG-1, MPEG-2 and videotape images displayed. The criteria for evaluation were; (1) the quality, (2) the smoothness, (3) the sensitivity to abnormal parts of EEG waveforms, (4) the quality of the moving images of seizure manifestation, (5) the smoothness of the moving images and (6) the quality of the audio. The score for each evaluation criteria was referred to graphically, using the double-stimulus impairment scale method; doctors marked an 'X' at the appropriate point on a line segment divided into five levels, Excellent (4 ∼ 5) , Good (3 ∼ 4) , Fair (2 ∼ 3) , Poor (1 ∼ 2) and Bad (0 ∼ 1) [7].

2.5. *Statistical analysis*

The numerical data quantifying the mark 'X' on the line segment of the double-stimulus impairment scale method was statistically analysed using BMDP software [8]. The paired data obtained from the same images in Scenes 1 and 4 was compared by the paired t-test (BMDP3D). The mixed analysis of variance (mixed ANOVA) with two fixed effects (scenes and sort of movies) and one random effect (doctors) was performed to test the equality of the scores for MPEG-1, MPEG-2 and videotape, adjusting for the three types of image, the four scenes and the 10 doctors (BMDP3V). A mixed model was used to adjust for the effects of the doctors and the scenes;

$$y_{ijk} = \mu + \alpha_i + \beta_j + \gamma_{ij} + d_k + e_{ik} + f_{jk} + \varepsilon_{ijk}$$

where

y_{ijk} = the value of score,
μ = the overall grand mean,

α_i = the fixed effect of ‘type of moving image’ (i = 1,2,3),
β_j = the fixed effect of ‘scene’ (j = 1,2,3),
γ_{ij} = the fixed effect of ‘type of moving image’ by ‘scene’ interaction,
d_k = the random effect of ‘doctor’,
e_{ik} = the random effect of ‘type of moving image’ by ‘doctor’ interaction,
f_{jk} = the random effect of ‘scene’ by ‘doctor’ interaction,
ε_{ijk} = random error following normal distribution.

Three mixed ANOVA with only two categories (video and MPEG1, video and MPEG2, MPEG1 and MPEG2) and using Bonferroni’s correction of the level of significance were performed to evaluate the pairwise differences between the three moving images for each of the criteria. For all statistics, a p-value less than 0.05 was considered statistically significant.

3. Results

3.1. *Evaluation of interobserver variability*

First, we evaluated the interobserver variability of the scoring by statistically testing the equality of the distributions of the scores between Scenes 1 and 4. The scores were the 180 paired data (3 types of moving images $\times$ 6 criteria $\times$ 10 doctors), consisting of the two scores for the same moving picture designated as Scenes 1 and 4. Paired t-test results showed that there was no evidence of any significant difference in the distributions of Scenes-1 and -4 ($p = 0.101$). Therefore, we accepted the score data of Scene 1 and eliminated those of Scene 4 from our analyses.

3.2. *Comparison of the scores among MPEG-1, MPEG-2 and videotape*

Table 1 depicts the means and standard deviations for the criteria and for each moving image, based on the scores from the 10 doctors. For all criteria except for the quality of audio, MPEG2 movies obtained the highest and videotape the lowest mean of the scores. The standard deviation, which represents the dispersion of scores, tended to be bigger for videotape than for MPEG-1 and MPEG-2. The result of mixed ANOVA suggested that the distributions of scores were significantly different between MPEG-1, MPEG-2 and the videotape. The result of pairwise tests with Bonferroni’s correction is shown

Table 1. Means and standard deviations of scores for each image and criterion and the result of Bonferroni tests.

Criterion	Type of moving images: Video	MPEG1	MPEG2	Results of Bonferroni Test*
(1) Quality of EEG waveforms	1.77 ± 0.66	1.94 ± 0.35	2.98 ± 0.61	V vs. M2, M1 vs. M2
(2) Smoothness of EEG waveforms	2.06 ± 0.62	2.16 ± 0.57	2.93 ± 0.52	V vs. M2, M1 vs. M2
(3) Sensitivity of abnormal EEG data	1.96 ± 0.56	2.11 ± 0.51	2.98 ± 0.58	V vs. M2, M1 vs. M2
(4) Quality of moving images	1.92 ± 0.73	2.17 ± 0.65	2.93 ± 0.62	V vs. M2, M1vs. M2
(5) Smoothness of moving images	2.09 ± 0.68	2.31 ± 0.58	2.93 ± 0.50	V vs. M2, M1 vs. M2
(6) Audio quality	2.71 ± 0.58	2.69 ± 0.58	3.05 ± 0.52	M1 vs. M2

*The pairs described in this column have a significant difference at an adjusted significance level of 0.05 using the Bonferroni method. ‘V’, ‘M1’ and ‘M2’ represent Video, MPEG1 and MPEG2, respectively.

in the fifth column in table 1. The score of MPEG-2 was superior to those of MPEG-1 and videotape, for all criteria except for quality of audio. Consequently, we determined that the MPEG-2 moving images were clinically more useful than those of MPEG-1 or videotape, but that MPEG-1 digital movies were equivalent to VHS videotape for the diagnosis and patient monitoring of epilepsy.

4. Discussion and Conclusion

Moving images of patient monitoring and synchronous electroencephalogram (EEG) waveforms play crucial roles in the diagnosis of epilepsy. In particular clear EEG waveforms are required for accurate diagnosis. This study demonstrated that MPEG-2 digital moving images have a higher quality than those of MPEG-1 or videotape for monitoring epileptic seizure manifestations and reading EEG waveforms. Certainly, the clinical usefulness of MPEG-2 patient monitoring compared to MPEG-1 and videotape could have been expected from a theoretical consideration of the MPEG compression algorithms [9]. However, no previous study has evaluated the quality, smoothness and sensitivity of MPEG-2 movies in EEG waveforms.

Currently, many Japanese hospitals that treat epileptic patients record moving images of seizure manifestations and the corresponding EEG data onto sVHS videotapes. Additionally, the videotapes are sent to a few primary epilepsy centres with expert epileptologists for consultation reading the diagnosis and treatment. The results of this study indicated that in the future, physicians who seek advice from a primary epilepsy centre should convert patient movies and the corresponding EEG waveforms to MPEG-2 digital images using relatively cheaper encoding software, and send them to the epilepsy centre via the Internet. Consequently, the digital encoding by MPEG-2 should lead to more precise diagnosis and decision making.

There are many kinds of digital EEG machines being made by medical equipment companies, and the format for saving EEG waveforms is quite different among them, although it is likely to be standardized with ASTM and EDF. Therefore, EEG waveforms are not always exchangeable from one hospital to another. New-generation digital EEG machines able to simultaneously record the moving images of patient's seizure manifestation and the EEG waveforms by MPEG-2 digital encoding, enable rapid access to patient data and greatly facilitate image review and quantification among several doctors, as well as side-by-side comparisons with previous EEG examinations. We can now select from a range of appropriate software for displaying MPEG-2 moving images, allowing a flexibility of cost for different facilities. Therefore, with telecommunications, most expert epileptologists will be able to browse MPEG-2 moving images and EEG waveforms sent by physicians from their own clinics' PCs, and thus more easily compare MPEG-2 with previous EEG examinations. For saving movies and EEG waveforms in an MPEG-2 format, approximately two gigabytes of data storage is needed for 1 h of video, necessitating a large-scale peripheral storage system to save such enormous quantities of data. It would be realistic to directly convert any necessary moving images and the corresponding EEG waveforms to the MPEG-2 format with an examiner's EEG machine and send them to a few primary epilepsy centres on the Internet. We anticipate that falling prices of digital technology and the establishment of formatting standards for digital EEG should bring about an increase in the numbers of Internet connected digital EEG laboratories.

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