

Correlation between Surgical Manipulations and the Variation of Surgeon's Heart Rate in Brain Surgery: Technical Note

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Abstract

For improvement of surgical performance and safety, we record surgeries by video cameras. However, analysis of the video records is time consuming. To help this task, we are developing methods to automatically mark up significant time points in the surgery. As a possible mean for the marking, we focused on the surgeon's heart rate. During a craniotomy of an intracranial glioma, we recorded the surgeon's electrocardiogram using a telemeter and measured the R-to-R interval (RRI). We detected the stable state of heart rate as a peak-to-peak RRI of less than 5% of the mean of RRI data from 15 consecutive heartbeats. We also quantified the frequency of brain touches by the surgeon under the surgical microscope. We examined the association between the stability of surgeon's heart rate and the brain touches using a chi-square test. As the result, the stable state of surgeon's heart rate was associated with the brain touches ($p < 0.05$, odds ratio 5.1). We edited a one-minute digest video of the surgery based on only the heart rate data, and it was sufficient to understand how the surgery was preceded.

Key words: accident prevention, craniotomy, electrocardiogram, surgeon, manipulation

Introduction

In our operation room (Intelligent Operation Theater, Tokyo Women's Medical University), we used about 10 video cameras and a variety of sensors to record various aspects of surgery, and afterwards, we analyzed the records for improvement of performance and accident prevention.^{1–3)} Usually, more than 10 hours of recorded video data are collected from each camera, resulting in hundreds of hours of data for each surgery. As the analysis of these data is highly time consuming, we are developing technologies to mark up significant time points automatically.⁴⁾ In the present study, we hypothesized that a surgeon's heart rate become stable during a delicate manipulation, so it might be an index useful for the marking up.

Materials and Methods

I. Case

The examined case was a resection of glioma

(grade 3) close to Broca's area under awake surgery. The surgeon had experienced more than 100 cases of brain tumor resection using awake surgery. We carefully explained the purpose and method of this study to the patient, and the surgeon, and obtained their informed consent prior to the surgery. The surgeon agreed to participate in the study and allowed us to attach a heart monitor and make video recordings of his behavior.

II. Recording video

We recorded the surgery using 11 video cameras from a variety of viewing angles, and thus obtained total of about 180 hours of recorded data. The time stamps included in the recordings of each camera were synchronized with an accuracy of within one second. We primarily used the microscopic video recorded with the Intraoperative Examination Monitor for Awake Surgery (IEMAS) system to classify the surgeon's manipulations.^{5,6)} We supplemented this with data recorded using the ceiling camera and the shadowless camera system to identify which hand the surgeon used for

each manipulation. The ceiling camera is a small, wide-angle video camera fixed on the ceiling of the operating room to capture the patient's whole body; the shadowless camera system consists of four wide-dynamic-range video cameras attached to a shadowless lamp, covering the focal spot of the lamp and its peripheral zone at the same time. During intraoperative magnetic resonance imaging (MRI) examinations, all cameras were turned off to avoid electromagnetic noise.

We defined the brain touch rate (BTR) as the time length during the surgeon touched the patient's brain tissue with any surgical tool held by the dominant (right) hand under the microscope in one minute. BTR for every minute of the microscopic video was measured manually with an accuracy of 1/10 of a minute.

III. Recording surgeon's heart rate

The surgeon wore electrocardiographic telemeter with three electrodes (Polygraphic Telemeter STS-1, Digitex Lab. Co., Ltd., Tokyo), and the R peaks were recorded on a millisecond timescale to calculate the R-to-R interval (RRI). The telemeter signal receiver was turned off during the MRI examinations.

We defined the low variation state (LVS) of heart rate as shown in Fig. 1. Also we defined the low variation rate (LVR) at a given time span from T to $T + 1$ minutes, as the ratio of LVS within each minute. Formally, these protocols are expressed as follows:

$$I[k] = r[k+1] - r[k]$$

$$LVS(k) = 5\% > \frac{15 \min_{-75ms \leq m \leq 7} (\max_{-75ms \leq j \leq 7} I[k+j+m] - \min_{-75ms \leq j \leq 7} I[k+j+m])}{\sum_{-75ms \leq j \leq 7} I[k+j]}$$

$$LVR(T) = \frac{|\{k : (T \leq r[k] < T+1) \wedge LVS(k)\}|}{|\{k : T \leq r[k] < T+1\}|}$$

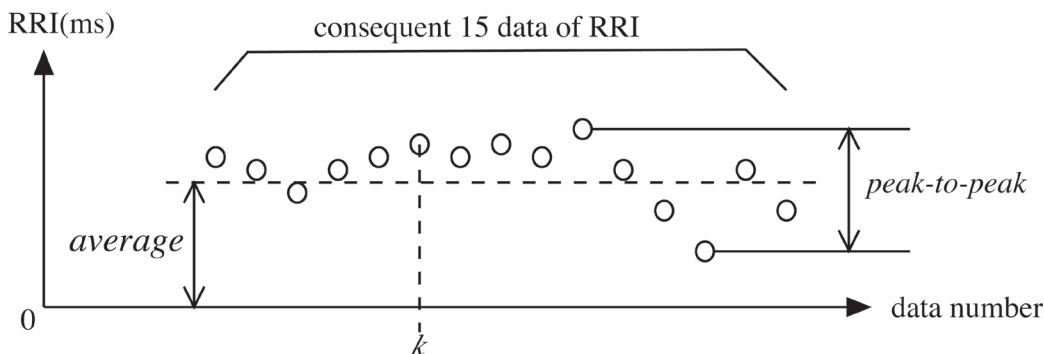


Fig. 1 Protocol of the low variation state (LVS). If the peak-to-peak of R-to-R interval (RRI) is less than 5% of the average from 15 consecutive heartbeats, the data is considered to indicate LVS.

where $r[k]$ is the time point of k -th R peak in minutes, $I[k]$ is the RRI representing the time between the k -th R peak and the next R peak, and $LVS(k)$ is a logical function, which takes a binary value to show if the k -th R peak belongs to the LVS, T is a time point in minutes, and $LVR(T)$ is the ratio of the LVS during the time point T .

IV. Statistical analysis

We classified each minute of surgery as $LVR = 0$ or $LVR > 0$, and as $BTR = 0$ or $BTR > 0$. We then applied a Pearson's chi-square test to the classification, where the prospectively determined p value was 5% to reject the null hypothesis that LVR and BTR are independent of each other. We also measured the strength of the correlation between LVR and BTR using odds ratios, with odds ratios larger than 4, i.e., an error rate less than 20%, used to improve the efficiency of the analysis through several repetitions.

Results

The surgery took 16 hours, included three intraoperative MRI examinations, and one intraoperative linguistic functional test. We recorded cardiac telemeter data and the video records from when the surgeon first entered the operation room (11:18 A.M.) to the surgeon left the room for the final time (00:17 A.M.), and obtained 779 minutes of data. The obtained data comprised 480 minutes of operation under the microscope, 111 minutes during which three MRI examinations were conducted, 150 minutes of operation without the microscope, and 38 minutes lost because the surgeon temporarily left the operation room (Fig. 2). We measured LVR and BTR for each minute of the 480 minutes of operation under the microscope.

The obtained data consisted of 10 minutes of $BTR = 0$ and $LVR = 0$, 5 minutes of $BTR = 0$ and $LVR > 0$, 131 minutes of $BTR > 0$ and $LVR = 0$,

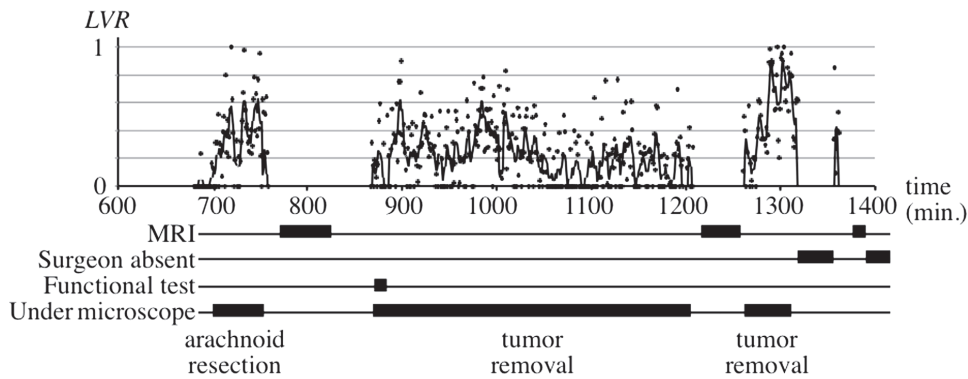


Fig. 2 Dots in the chart show low variation rate (LVR) throughout the surgery. The curve shows LVR that was smoothed using a running average with a width of 5 minutes. Horizontal bars under the chart show major processes and events in the surgery.

and 334 minutes of $BTR > 0$ and $LVR > 0$. The chi-square test revealed a relation between LVR and BTR (chi-square = 10.38, $p < 0.05$, and the odds ratio was 5.1.) On the scatter plot of BTR to LVR in each minute of the surgery (Fig. 3), 95% of the data points comply with the relation $BTR \geq 0.61 LVR$, indicated by the slanted line in the figure.

Discussion

We examined a brain surgery, and found that the surgeon's LVS and the BTR were correlating. As shown in Fig. 3, when LVR was high, BTR was also high at most time points. However, despite time points of high BTR a low LVR was also observed frequently in the following manipulations: e.g., picking up a resected piece of tumor, stopping a small bleeding on brain surface using a bipolar coagulator, or applying a piece of cotton for suction. Time points with low BTR and high LVR might appear when the surgeon moved the microscope.

To see the performance of LVR as an index of the significance of the manipulations, we edited a digest video of microscopic sight throughout the surgery by picking up time points with high LVR mechanically. We obtained a 60 second video comprising 59.5 seconds of operation on the brain, and 5.5 seconds of the microscope handling. Using the digest video, we could observe the full sequence of surgical processes under microscopic sight, and were able to understand how the surgery has been performed.

As known as respiratory arrhythmia, the variation in RRI decreases during breath holding and increases during deep breathing (Fig. 4).⁷⁾ Even in everyday situations, we frequently perform breath suppressions to stabilize the position of our hands. Therefore, we believe that LVS reflects

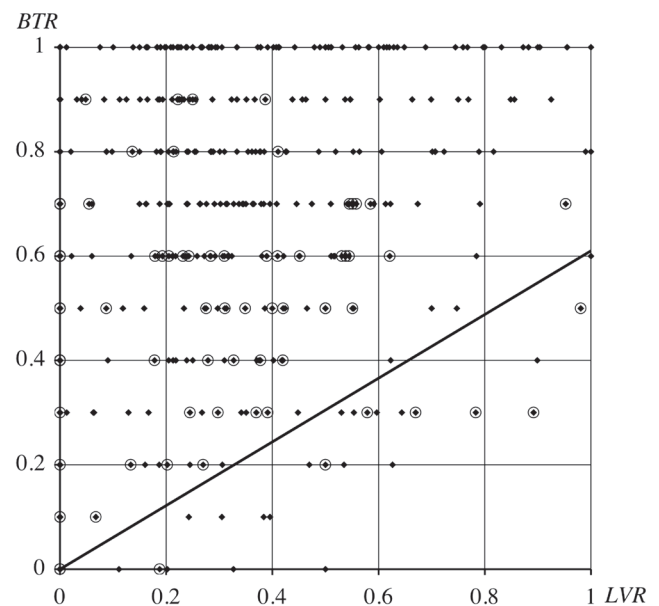


Fig. 3 Scatter plot of the brain touch rate (BTR) versus the low variation rate (LVR) in each minute of surgery. Data points highlighted with a circle include motion of the surgical microscope. The slanted line shows $BTR = 0.61 LVR$.

the surgeon's breath suppression during delicate manipulations.

Since this is a preliminary study, we are planning further researches. To verify the reproducibility of this method, we are planning examinations on more cases and surgeons. Also, we shall compare the performance of the video editing task between automatic editing based on LVR and the conventional manual editing.

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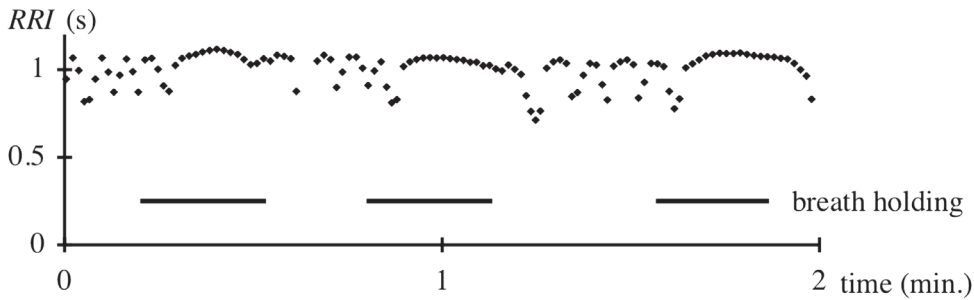


Fig. 4 A demonstration of respiratory arrhythmia by a volunteer. Breath holding caused reduced variation of R-to-R interval (RRI).

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Conflicts of Interest Disclosure

All of the authors have nothing to be disclosed as Conflicts of Interest (COI). Kyojiro Nambu, Yoshihiro Muragaki, and Hiroshi Iseki are members of the Japan Neurosurgical Society, and their COI status have been disclosed to the COI committee of the society. Yasuo Sakurai is not a member of the society, and he has nothing to be disclosed as COI.

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