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The Surgeon's Mental Load During Decision Making at Various Stages of Operations*

E. Czyżewska[1], K. Kiczka[1], A. Czarnecki[2], and P. Pokinko[3]

[1] Department of Physiology, Białystok Medical School
ul. Mickiewicza 2, 15–230 Białystok, Poland
[2] Railway Hospital in Warsaw, ul. Brzeska 12, 03–737 Warszawa, Poland
[3] The Military Institute of Aviation Medicine in Warsaw,
ul. Krasińskiego 54, 01-755 Warszawa, Poland

Summary. In surgeons while opening the wound, during the operation proper, closing the skin and immediately after the operation, the ECG was recorded telemetrically for 5-min periods. From the ECG recordings, indices reflecting cardiac arrhythmia and emotional level were calculated. It is concluded that the process of decision making during the vital stages of operations causes a fall in the CHRV (the coefficient of heart rate variability), S^2 (the variance of R–R intervals) and VR (the variability range of R–R intervals). It seems that of all the indices studied, the most suitable for evaluation of the degree of mental loading due to decision making processes are the CHRV and S^2.

During all the stages of surgery studied, and immediately after the operation, an increase in tonus of the sympathetic nervous system occurs in surgeons indicating a rise in emotional level.

Key words: Heart rate variability – Decision making – Surgeons – Operation

Introduction

The determination of a reliable physiological index of loading with mental work is one of the essential psychophysiological problems. Such indices as perspiration (Kuno 1930), skin electrical resitance (White 1930), skeletal muscle tonus (Davis 1938), critical fusion frequency (Martin and Grandjean 1975) and changes in EEG tracings (Berger 1930) have been applied.

Despite the large number of investigations carried out, they do not solve the basic problem – the determination of a quantitative and reliable mental load index. In 1963, Kalsbeek and Ettema found that mental work under laboratory conditions causes a decrease in physiological cardiac arrhythmia. Since then many papers have confirmed the value of measurement of the extent of cardiac

Offprint requests to: K. Kiczka (address see above)

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arrhythmia in estimating mental load (Symposium on Heart Rate Variability 1973).

At the same time there is some doubt as to the value of determining mental load by cardiac arrhythmia measurement in more complex work situations (Firth 1973).

With this in view, we have tried to determine whether there is a relationship between cardiac arrhythmia and decision making during surgery (one of the mental activities) which according to psychologists, is a classical decision making situation in a real complex work situation (Kozielecki 1977).

It is known that cardiac arrhythmia calculated by various methods gives different values of the same R–R data (Kalsbeek 1973). In the present studies, we therefore evaluated cardiac arrhythmia by means of a few indices comparatively easy to calculate, in order to determine which of them best reflects changes in cardiac arrhythmia during decision making.

In view of the fact that during surgery there is high emotional tension, we also decided to evaluate the emotional state taking the tonus of both parts of the autonomic nervous system as its index.

Methods

Seven surgeons employed at the Railway Hospital in Warsaw were examined during 12 operations: six cholecystectomies, four appendectomies, and two strumectomies. The various periods during which the ECG was recorded were denoted by the letters: A – control period, B – skin incision, C – closing the integument, D – the operation proper.

By means of a device produced by Hellige, the ECG was recorded telemetrically on magnetic tape from bipolar precordial leads. In each of the periods, the ECG was recorded for the first 5 min. The ECG magnetic recordings were fed to an SH-71 analyser of an analogue-digital computer Nicolet 1072. The digital values of R–R intervals of the ECG and the numbers of the various intervals were displayed on the oscilloscope screen of the device. The intervals were grouped in 10 ms bins.

On the basis of these data, the following indices were calculated:

Mo = the modal value of R–R intervals in s

AMo = the mode amplitude of R–R intervals in % (ratio of the number of intervals in a modal range to the total number of intervals × 100):

$$AMo = \frac{n_{Mo}}{n} \cdot 100$$

VR = the variable range of R–R intervals in s (difference between the longest and shortest R–R interval).

BI = the Bajewskij index:

$$BI = \frac{AMo}{2\,Mo \cdot VR}$$

S = the standard deviation of R–R intervals in ms:

$$S = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^2}$$

x_i = i^{th} R–R interval in ms

$\bar{x}$ = the arithmetical mean of R–R intervals in ms:

$$\bar{x} = \frac{1}{n} \sum_{i=1}^{n} x_i$$

$CHRV$ = the coefficient of the heart rate variability:

$$CHRV = \frac{S}{\bar{x}} \cdot 100$$

S^2 = the variance of R–R intervals in ms^2:

$$S^2 = \frac{1}{n} \sum_{i=1}^{n} (x_i - \bar{x})^2$$

The values of the indices in periods B, C, and D were compared with those of period A by means of the paired Student t-test, taking differences where $p < 0.05$ to be statistically significant.

Results

From 0.66 s in period A, the mode (Mo) fell significantly to 0.62 s in period C and 0.61 s in period D (Fig. 1). The mode amplitude (AMo) increased significantly from 10.5% in period A to 13.2% in period C and 13.6% in period D. The variability range (VR) of R–R intervals fell significantly from 0.29 s in period A to 0.22 s in period D. In period A, the mean Bajewskij index (BI) was 29 and rose significantly in periods B, C, and D to 40, 49, and 56 respectively.

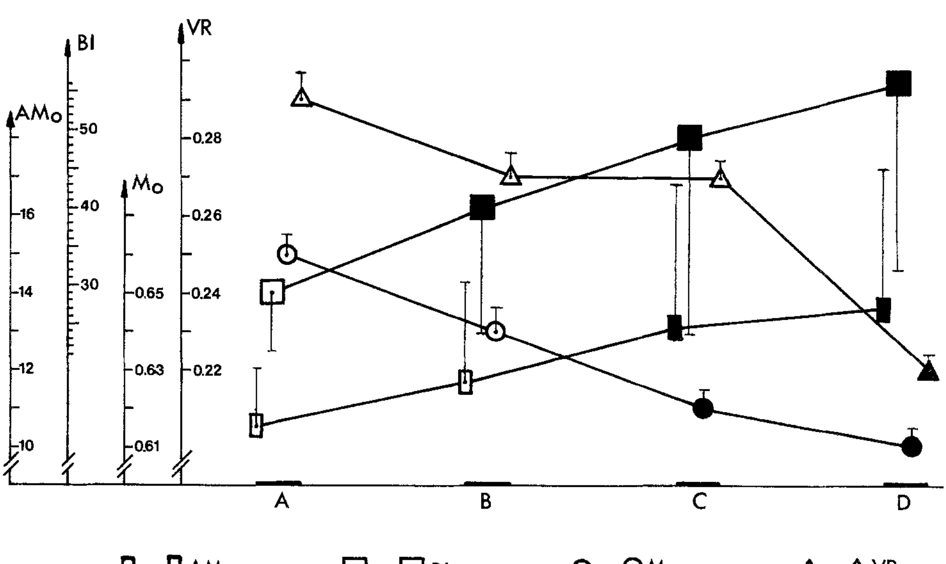

Fig. 1. The behaviour of the indices of cardiac arrhythmia (AMo, BI, Mo, VR) during various periods of surgery. A – control period, B – opening of the integument, C – closing of the integument, D – the operation proper. Closed figures – significant statistically changes. Open figures – insignificant statistically changes

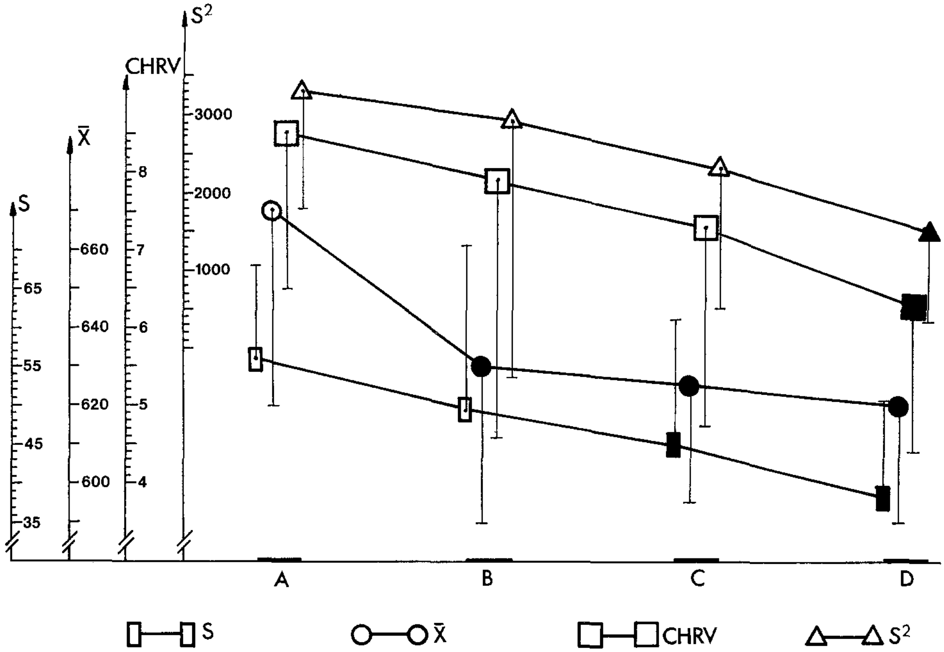

Fig. 2. The behaviour of the indices of cardiac arrhythmia (S, $\bar{x}$, $CHVR$, S^2) during various periods of surgery. A – control period, B – opening of the integument, C – closing of the integument, D – the operation proper. Closed figures – significant statistically changes. Open figures – insignificant statistically changes

The standard deviation (S) of the R–R intervals fell significantly (in relation to period A, when it was 56) to 45 in period C (closing of the integument) and 38 in period D (Fig. 2). The mean value of R–R intervals ($\bar{x}$), 671 ms in period A, fell significantly in periods B, C, and D to 630 ms, 625 ms and 620 ms respectively. The coefficient of the heart rate variability ($CHRV$) in the control period (A) was 8.5, a significant fall in this coefficient to 6.3 being noted only during the operation proper – period D. Similarly, the variance of R–R intervals (S^2) fell from 3,337 in the control period to 1,579 during the period of the operation proper (D).

Discussion

On the basis of the interviews with the surgeons investigated and an observations of their behaviour, we accepted that the greatest emotional and decision making load occurs during the operation proper, less during skin suturing and least during the initial incision. As a "control" period, we chose a few minutes just after surgery when the surgeons, having finished the operation successfully, were relaxed and did not discuss the operation.

In enhanced levels of emotion, vegetative symptoms indicating the stimulation of the sympathetic nervous system occur (Best and Taylor 1966).

Bajewskij (1970) distinguished three ranges of *Mo* indicating tonus of both parts of the autonomic nervous system. During vagotonia the *Mo* is greater than 1.0 s, during normotonia it is within the range of 0.7 s–0.9 s and during sympathecotonia, 0.5 s–0.7 s. Simultaneously with a decrease in *Mo* the *VR* decreases and a slight rise in *AMo* occurs. In our studies, during all the periods of surgery and in the "control" period, the *Mo* remained within the range characteristic of sympathecotonia, falling from 0.66 s in period A to 0.61 s in period D. Together with a decrease in *Mo,* the *VR* decreased and the *AMo* increased (Fig. 1). The direction in which these parameters changed indicates a rise in tonus of the sympathetic system and therefore a rise in emotional level from period A through periods B and C to period D. In the "control" period the *Mo,* though highest in this period, remained within a range indicating sympathecotonia that is, an enhanced state of emotion. This is probably due to the tonic character of an emotional state i.e., the persistance of this state for some time after the stimulus has ceased to act (Konorski 1969).

The *BI* rose significantly in periods B, C, and D of surgery. The rise in *BI* occurring together with a rise in sympathetic nervous system tonus may indicate that it is more a measure of emotional level than an indication of ability to work as Bajewskij and Kudrjawcewa suggest (1975).

In period D (the operation proper) statistically significant changes in the all indices studied occurred but the only changes to occur in period D while there were no changes in periods B and C were noted in the *CHRV,* S^2, and *VR.* It may, therefore, be supposed that each of these parameters is equally good as regards determination of the degree of mental loading due to the processes of decision making. However, with the same range of *VR,* a different distribution of the histogram may occur which in effect will give different results of both *CHRV* and S^2. We are thus left with S^2 and *CHRV.* Mulder and Mulder (1970) also noted a fall in S^2 during mental loading with binary choice tasks of differing intensity. Since, however, the *CHRV* is easier to calculate than the S^2 we would prefer the former.

The *CHRV* has been calculated in other applied studies and found to be a good measure of mental loading of business directors (Krause et al. 1977; Krause and Sowa 1979) and students taking examinations (Czyżewska 1977). The fall in this index was not very great in our studies (of 2.3). Czyżewska (1977), in investigations on students while preparing their answers to questions during a difficult examination and while actually answering the questions, noted a mean fall in this index of 4.7, 4.8.

The comparatively slight fall in the index observed in the surgeons was in all probability due to the fact that the operations were not very difficult. According to the *CRV* (California Relative Value 1969) scale by which operations are evaluated from 0.12 to 80, appendectomy is rated at 9.5 and cholecystectomy at 14.5.

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Abbreviations. Mo – the modal value of R–R intervals in s; *AMo* – the mode amplitude of R–R intervals in %; *VR* – the variability range of R–R intervals in s; *BI* – the Bajewskij index; *S* – the standard deviation of R–R intervals in ms; $\bar{x}$ – the arithmetical mean of R–R intervals in ms; *CHRV* – the coefficient of the heart rate variability; S^2 – the variance of R–R intervals in ms^2; for detailed explanations of the abbreviations used see under Methods

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