Plastic Surgeon's Life: Marvelous for Mind, Exhausting for Body

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Surgery is accepted as one of the most demanding professions that create both physical and mental strain on the performers. Therefore, the authors aimed to elucidate the mental burden of surgeons, which is dedicated to operative stress. They also tested the hypotheses that participating in surgery creates mental stress on surgeons that leads to cardiovascular changes, and that this stress is more pronounced for actual operators than for first assistants. The method chosen for this purpose was an analysis of heart rate variability. Twelve surgeons (five plastic surgery staff and seven plastic surgery residents) were monitored by a digital ambulatory Holter recorder on at least two occasions. Half of the recordings were carried out on operating days and the other half on office days. Heart rate variability indices (low frequency, high frequency, high frequency/low frequency ratio, and heart rate) were analyzed from those recordings using computerized research tool software. The heart rate variability indices of the operators showed statistically significant differences between operating days and office hours in favor of an increased sympathetic and decreased parasympathetic activity for the former. For first assistants, three of the parameters, with the exception of heart rate, changed in favor of a sympathetic predominance over parasympathetic activity; these changes were also statistically significant. These results showed a sympathetic hyperactivity for both operators and first assistants during the operations. When the sympathovagal balance of the actual operators was compared with that of assistants, the former group showed a more pronounced sympathetic arousal. This difference is accepted as a proof for the mental stress of the surgery being the main factor responsible for the sympathetic hyperactivity that we detected during the operations.

Surgeons continuously face a unique mental strain that other professions rarely bring forth, and these psychological stressors are associated with alterations in cardiac autonomic control that may contribute to the development of cardiac disease. Prolonged sympathetic hyperactivity could anticipate cardiac discomfort in more experienced surgeons with marginal cardiac reserve. Such cardiac diseases would be reconsidered as occupation-related illnesses, which might be reimbursed to the physician. In addition, the legal responsibility of surgeons concerning their unfavorable results might be assessed with more understanding with a realization of their undue working conditions. (*Plast. Reconstr. Surg.* 114: 923, 2004.)

"It is tragic when a man outlives his body," said Sigmund Freud (1856 to 1939) on his deathbed. There is no doubt: our bodies fail before our minds are satisfied with life. As time passes, minds become mature, but bodies become worn out.

Because of the increasing use of technology and automation in the working area, the impact of physical stress upon humans in the professional environment has noticeably decreased, but mental-concentrative stress and psycho-emotional stress have increased.[1–3] The common agreement that surgery is one of the most demanding professions directed us to evaluate the mental stress of surgeons by the aid of a recently popularized method, heart rate variability, utilizing periodic fluctuations of heart rate to assess relative contributions of the parasympathetic and sympathetic nervous systems. The R-R interval variations present during rest represent a fine-tuning of the vagal beat-to-beat control mechanism. Whenever a mental stress is present, sympathetic activity surpasses this vagal modulation and causes some measurable alterations in heart rate variability.[4–8] Heart rate variability has considerable potential to assess the role of autonomic nervous system fluctuations in normal healthy individuals, and analysis of heart rate variability

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is appropriate to reflect the sympathovagal balance as an output of the mental load of the surgeon.[4,5,8,9–21] The purpose of this study was to assess the mental burden of surgeons, which is dedicated to operative stress, by utilizing heart rate variability indices. We tested the hypotheses that participating in surgery creates mental stress on surgeons that leads to cardiovascular changes, and that this stress is more pronounced for actual operators than for first assistants.

Participants and Methods

Twelve surgeons [five actual operators (plastic surgery staff) and seven junior residents acting as primary assistants] participated in the study. The physical characteristics of the participants are listed in Table I. All of the participants were healthy subjects without a significant family history of cardiac disease, and none of them was taking any medication. None of them were involved in a regular exercise program. Each surgeon was monitored by a three-lead digital ambulatory Holter recorder (Lifecard CF Digital Compact Flash Card Recorder, Del Mar Reynolds Medical, Inc., Irvine, Calif.), which was attached at 8:00 AM and removed at 6:00 PM. Assistants were monitored for 2 days and operators were monitored for 4 days. Half of the recordings were carried out on operating days and the other half on office days with no scheduled office surgery. The multiple measurements of the operators were used to assess the coherence and reproducibility of the recordings. All participants were instructed not to restrict any of their daily activities during the study period.

Measuring Heart Rate Variability

The electrocardiogram sampled data at a rate of 1024/second. All digital data were transferred to a computer after each session and analyzed off-line using Reynolds Medical Research Tools software. An interval tachogram that consisted of series of consecutive R-R intervals was generated for a period of 5 minutes by manual corrections of all events that had not been marked as normal beats by a blind physician (Tulmac) using an editor program. The length of the tachogram and the type of analysis were selected according to the recommendations of the Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology.[4]

The power spectral density was calculated by computerized fast Fourier transformation, to evaluate the R-R interval tachograms by frequency-domain measures. Among the three main spectral components distinguished, a high-frequency component of 0.15 to 0.4 Hz and a low-frequency component of 0.04 to 0.15 Hz were analyzed. The power and frequency of each spectral component were calculated as absolute units of milliseconds squared and normalized units. The very-low-frequency component that is less than or equal to 0.04 Hz was not included in the analysis but was used for normalization of high-frequency and low-frequency components (that is, constitution of the relative values of each power component in proportion to the total power minus the very-low-frequency component). The low frequency/high frequency ratio was also calculated, which is accepted as an indicator of increased sympathetic activity.[4,5,10,12,14,22]

All of the operations were performed under standard operating conditions (i.e., 22°C temperature provided by air conditioning; surgeons wearing surgical masks and sterile garments). The starting and ending times of each procedure were carefully documented during the measurements.

Statistical Analysis

The time intervals of the operation day measurements, during which the subjects were participating in a rhinoplasty operation either as operator or first assistant, were determined and the results obtained by the analysis of these time intervals were used as operation values. The frequency domain analysis of each successive 5-minute period of a particular operation,

TABLE I
Demographic Data

	Age (years)	BMI (kg/m²)	Sex (male)	Smokers
Operator (n = 5)	30.8 ± 2.95	24.2 ± 2.52	100%	20%
First assistant (n = 7)	26.6 ± 1.14	23.8 ± 2.23	86%	43%

BMI, body mass index.

including normalized low frequency, normalized high frequency, and low frequency/high frequency ratio, was averaged separately for corresponding time intervals to estimate the representative values of every participant for each rhinoplasty. The average heart rates of the participants were also calculated. For each participant, the matching time intervals of each operation in the office days were assumed as baseline values (for instance, baseline values of a surgeon performing a rhinoplasty between 10:00 and 11:00 AM were obtained from the recordings between 10:00 and 11:00 AM on the office day) to avoid interfering with the circadian variation of the physiologic sympathovagal balance.[8,15,17,18,21,23] These baseline values were then compared with operation values using the Wilcoxon signed rank test utilizing the sum of the ranks for positive and negative differences within the operators and first assistants separately. Percentage differences of the operators' indices from baseline were also compared with those of assistants using the Mann-Whitney rank sum test. The results were expressed as mean ± SD, and $p < 0.05$ was considered statistically significant.

Results

Surgeons participated in a total of 90 operations during the study period, in 38 as the operator and in 52 as the first assistant. Forty-one of the total operations were rhinoplasties; in 16 of these, the participating surgeons were the actual operators and the remaining 25 recordings belonged to the assistants. The mean operation time for rhinoplasty procedures was 64 ± 16 minutes. No pathologic arrhythmias were encountered in the Holter recordings of participants.

The measurements recorded during the operations and the matching baseline values are listed in Table II. The effect of performing surgery on cardiac autonomic modulation of actual operators was striking. There was a statistically significant difference for all heart rate variability indices of the operators between the time during rhinoplasty operations and baseline. Heart rate, normalized low frequency, and low frequency/high frequency ratio were increased, and normalized high frequency was decreased, which are all signs of increased sympathetic and decreased parasympathetic activity. For assistants, three of the parameters, with the exception of heart rate, were changed in favor of a sympathetic predominance over parasympathetic activity, and these changes were statistically significant. These results supported a sympathetic hyperactivity for both operators and first assistants during operations. The percentage changes of indices during rhinoplasty from baseline for both groups are listed in Table III, indicating a significant difference for all parameters between the operators and the assistants; that is, sympathetic arousal of operators was more pronounced than that of assistants.

Discussion

The fact that surgery requires absolute concentration of the operator and that there are periods of considerable tension during some operative procedures attracted only a few researchers who monitored the surgeons under actual work conditions. The scanty of studies concentrated on this interesting issue were mainly composed of heart rate analysis.[2,5,24–28] Heart rate alone has only limited use in determining the level of psychological strain; it is not an adequate indicator of occupational stress because stressful experiences might not be associated with increased heart rate, and heart rate can increase without any apparent connection with environmental stressors or changes in physical activity (Fig. 1).[1,17,29–31] This is probably the reason for the contradictory outcomes of the previous reports on this issue.

On a beat-to-beat basis, heart rate is not constant. Rather, there are periodic fluctuations that are indicative of the relative contributions of parasympathetic and sympathetic nervous

TABLE II
Recorded Measurements

	Operator			First Assistant		
	Rhinoplasty	Baseline	*p*	Rhinoplasty	Baseline	*p*
Normalized low frequency (nu)	86.93 ± 3.84	79.84 ± 7.52	0.001	81.03 ± 7.84	77.01 ± 9.54	0.005
Normalized high frequency (nu)	10.76 ± 5.30	15.66 ± 6.47	<0.001	14.03 ± 7.62	18.24 ± 9.62	<0.001
Low frequency/high frequency ratio	9.76 ± 4.04	5.98 ± 2.45	<0.001	7.62 ± 4.13	5.61 ± 3.03	<0.001
Heart rate (bpm)	90.56 ± 9.82	80.06 ± 10.12	<0.001	85.48 ± 8.55	87.40 ± 7.64	>0.050

TABLE III
Percentage Changes of Indices

	Operator	First Assistant	p
Normalized low frequency	9.53 ± 8.42	6.00 ± 9.90	0.010
Normalized high frequency	−32.00 ± 11.42	−21.31 ± 17.98	0.003
Low frequency/high frequency ratio	66.09 ± 35.81	43.36 ± 42.70	<0.001
Heart rate	13.45 ± 5.50	−2.08 ± 6.17	<0.001

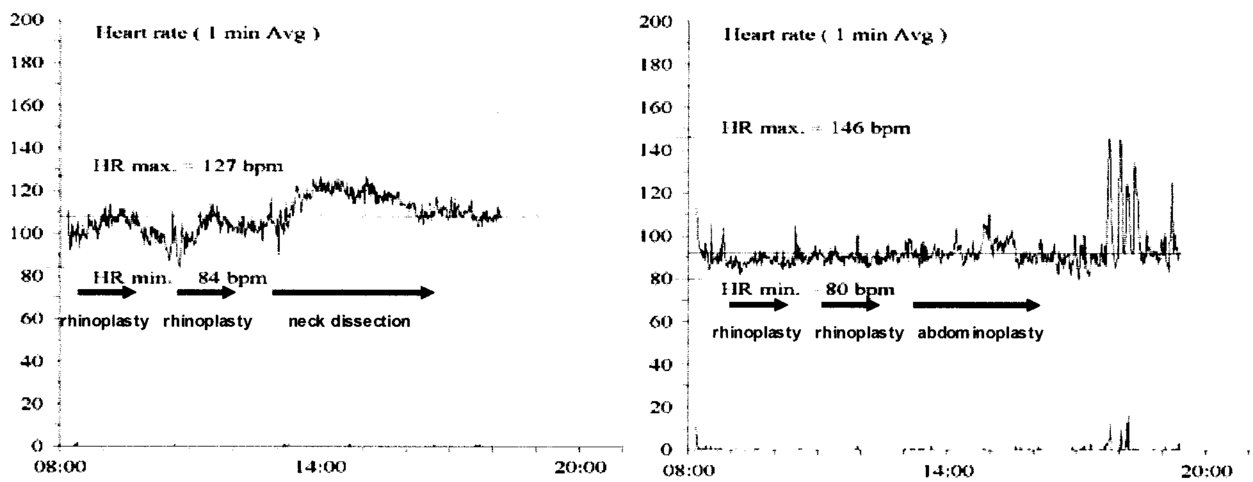

FIG. 1. Recordings from the operation days of two different operators. (*Left*) This recording of heart rate seems to be a good indicator of the sympathetic activity related to surgery; (*right*) this recording does not give any idea of this activity. Nevertheless, heart rate variability analysis yielded sympathetic hyperactivity during these periods for both operators.

systems. In 1963, Kalsbeek and Ettema[32] found that mental work under laboratory conditions causes a decrease in this physiological cardiac arrhythmia. Since then, many articles have confirmed the value of measuring the extent of cardiac arrhythmia to estimate mental load.[5,8,11–13,27]

Heart rate variability is the oscillation in the interval between consecutive heart beats and between consecutive instantaneous heart rates.[4–7,10,12,15,16,27] It is widely recognized as an important index of autonomic function in normal individuals, and decreased heart rate variability over a 24-hour period has been shown repeatedly to be a strong predictor of fatal outcome after a myocardial infarction.[8,13,15,33–36] Furthermore, decreased heart rate variability has been associated with increased risk of all-cause mortality in community studies.[37,38] In addition, results of the Atherosclerosis Risk in Communities study recently showed that decreased heart rate variability is associated with the risk of developing nonfatal and fatal coronary heart disease.[39]

Analysis of variability starts with a sequence of measurements called a time series. In studies of heart rate variability, these measurements are of successive normal-to-normal R-R intervals.[40] Power spectral analysis of heart rate fluctuations to quantitatively evaluate beat-to-beat cardiovascular control was introduced by Akselrod et al. in 1981.[41] Power spectrum density analysis is a technique for separating out the sine waves from which a time series is composed (Fig. 2).[5] This has important physiological significance because certain frequency ranges appear to correspond to distinct physiological mechanisms. Respiratory sinus arrhythmia, for example, usually appears as a peak near 0.25 Hz.[7,8,11,20,40–42] It has been demonstrated that high frequencies of heart rate variability are associated solely with cardiac parasympathetic nervous system activity, and that lower frequency heart rate variability is associated with both parasympathetic nervous system and sympathetic nervous system activity. In addition, the low frequency/high frequency ratio selectively indicates sympathetic nervous system activity.[4,5,10,12,14,16,18–20,22,31]

Stress, suicide, alcoholism, and drug use have been widely discussed as occupational hazards of surgeons. Physical and chemical factors, especially radiation and anesthetic gases, have also been considered as possible risks to

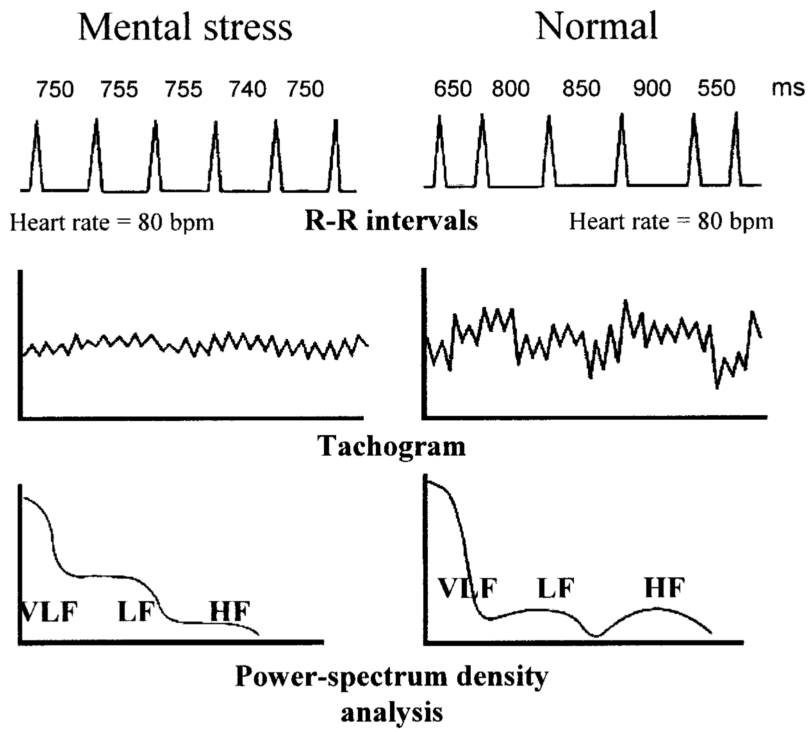

FIG. 2. Comparison of heart rate variability during normal mental state versus under mental stress. *VLF*, very low frequency; *LF*, low frequency; *HF*, high frequency.

which surgeons are exposed.[43] Aside from the physical burden originating from the nature of the task, a physician's, especially a surgeon's, work environment contains a number of severe stressors not commonly faced by personnel outside the health care sector.[44–46] Physical discomfort and fatigue in the operating room, for example, are frequently experienced by surgeons despite universal air conditioning of operating suites.[45] Various factors that cause increased production and decreased loss of body heat are responsible from the significant discomfort of the operating surgeon. Muscular activity of the surgeon, increased work of breathing resulting from hyperventilation, airway resistance imposed by surgical masks, the heat and moisture trapped beneath these masks, occlusive garments, and radiation of operating room lights are the most prominent factors.[28,45] Operating rooms and the surgical garments have been designed largely with bacteriologic or safety considerations in mind. The environmental engineering considerations have been very few, and for the most part, operating room paraphernalia seem more apt to be a disadvantage to the operator than to improve his or her comfort or performance.[45] Despite the extensive data supporting the conclusion that "with the exception of high-risk surgery, the wearing of masks by the surgical team is of unproven value," tradition continues to put a strain upon surgeons.[28,47–55] The temperature and humidity increases observed beneath the surgical mask are in a range at which performance deterioration can be seen.[28,45]

The pure psychical stress results in cardiocirculatory and metabolic effects in the sense of an "alarm reaction" (first phase of the adaptation syndrome, including increase of heart rate and blood pressure as well as glycogenolysis and lipolysis), which prepares a subsequent physical reaction without the possibility of having this reaction really performed. There is evidence that such metabolically or energetically not "consumed" stresses have negative long-term effects on human health.[1] This is in contrast with beneficial light exercise, which is actually a metabolically "consumed" stress. Sympathetic arousal is also the precipitator of myocardial ischemia during mental stress.[8,12,56] Meanwhile, parasympathetic activity predominance is in some way protective not only with respect to cardiovascular morbidity but also with respect to general survival.[4,8,36]

Fatigue, operative difficulty, anesthesia, and previous experience were proposed as possible causes of sympathetic arousal of the surgeons[26]; however, the relative contributions of the surgical theater milieu, the surgeon's restrictive garments, and the mental stress caused by the procedure itself to the sympathetic hyperactivity encountered in the surgical staff are not clear. Although Becker et al.[24] and Foster et al.[25] concluded that there was little evidence of strain resulting from the psychological stress of operating, their studies were based solely on heart rate, which is not considered a reliable index for such an assessment, as explained before. The analysis of heart rate variability, which is also used in our study, seems to be the most objective and reliable noninvasive methodology available for this purpose.

Cardiovascular mortality among physicians is similar to that of other professions, but within the medical profession, surgeons appear to be especially at risk of dying of ischemic heart disease.[43,44] It is concluded either that doctors do not use their professional knowledge and skills in a way that reduces their own mortality risk or that they are exposed to occupational hazards that cancel out such an effect. These hazards were thought more likely to be mental than physical or chemical.[25,43] In their comprehensive study comparing surgeons and general practitioners with respect to cardiovascular and psychosocial risk factors among physicians, Arnetz et al.[44] revealed that overall psychosocial arousal was consistently higher among the surgeons and that the surgeons perceived themselves as having a higher degree of intellectual discretion (i.e., a more stimulating job). The speculation by Arnetz et al. that "such psychosocial factors act independently of traditional risk factors and could contribute to the enhanced risk for surgeons" has been supported by many studies published in the last decade, and sustained psycho-physiological activation has been identified as a risk factor for development of hypertension, cardiac arrhythmias, blood lipid disturbances, diabetes mellitus, and probably coronary heart disease.[1,3,5,9,13,36,57–61]

Our results definitely show that the surgical staff experienced sympathetic hyperactivity compared with their baseline recordings; these results were attained using the office day values as baselines. The fact that ordinary surgical outpatient clinic work has its own stressors for a particular surgeon and is not a relaxation state at all appreciates our results.

The greatest difference observed between the operation and baseline values was in the low frequency/high frequency ratio for both groups. This index is specific to sympathetic nervous system activity, and this degree of an increase (66 percent for operators, 43 percent for first assistants) suggests a discrete sympathetic overactivity in the operations for all of the surgeons. The augmentation of the sympathetic arousal during operations was statistically significant for both operators and assistants, but it was more pronounced for the former. The only parameter that persevered in both groups was the heart rate of the assistants. The heart rates of assistants were fairly similar during operations and office work. The most reasonable explanation of this persistence also exists in our results; the baseline heart rates of assistants were higher than those of the operators. The office work of assistants (residents) is physically more demanding than operators' work. It is well established that this degree of moderate physical activity leads to a decrease in vagal activity with a concomitant increase in heart rate, but it has limited effects on the sympathetic nervous system.[16,25,26,29] Thus, alterations in the heart rate variability parameters of sympathetic activity are minimal. In other words, the higher rates of the residents in the operations could not be related to the physical work involved, but those in office time could be. Besides, the relatively short operation time for rhinoplasty helps residents not to lose their concentration throughout the procedure. It is hard to judge the impact on our results of the higher incidence of smoking among assistants (Table I) and their tiring night work.

The degree of hyperactivity is more evident in operators, and this observation led us to consider the mental strain of the operator as the primary factor responsible for this change. The difference in cardiac responses to operative mental strain between the actual operator and the assistant has previously been shown in limited studies.[5,26] Yet, it is not logical to exclude the assistants from experiencing mental strain during an operation, although they are not influenced as much as the operators are. However, there is another stressor that is specific to them which can sometimes be devastating: assisting a senior surgeon. In any case, more detailed and controlled studies, which are actually hard to perform on such an issue, are needed to clearly reveal the reasons for the sympathetic arousal observed in operators and assistants.

If it is assumed that outpatient clinics represent the average form of clinical activity encountered in other specialties, then surgeons as a group experience regular periods of sympathetic overactivity in operating theaters that do not occur in other medical professions. Also, the nature of the work to be performed, apart from its intensity and duration, is of decisive importance when considering an individual's capacity to endure prolonged work stress. Working in a standing position, as is the case for surgeons most of the time, may represent a greater circulatory strain than working in a sitting position.[62]

The one clear implication of the observations of this study is that these "stressful" experiences, if sustained by surgeons with marginal cardiac reserve, might well anticipate discomfort if this degree of sympathetic hyperactivity is sufficiently prolonged. This proposal also urges us to consider such cardiac diseases as occupation-related illnesses, which might be reimbursed to the physician.

The high cortisol levels of surgeons designated by Payne et al.[29] suggest that there may be a long-term physiological cost of which we are not necessarily aware. The increase in surgeons' heart rate was shown to be accompanied by a rise in serum free fatty acids and triglycerides, which may be implicated in the pathogenesis of atheroma and ventricular arrhythmia.[1,25,60,63] It has been shown that the heart rate of surgeons when operating can be reduced to normal levels by β-adrenoceptor blockade. The drug also can prevent the rise in serum fatty acids and triglycerides.[25] Our results advocate that it is worth considering the use of β-adrenoceptor blockade as protection, especially in high-risk surgeons.

Although minimal tolerance, if any, is shown for unfavorable surgical results, our results suggest that the aroused emotional state of surgeons during an operation make them more prone to make mistakes as a result of physical and mental fatigue and strain. This sympathetic hyperactivity, which might have a significant negative impact on a surgeon's performance, especially during difficult and long procedures, should be taken into consideration where liability is concerned. This point questions whether the level of legal responsibility of surgeons can be categorized as well according to their working conditions. That is a question that needs to be investigated further.

Conclusions

The psychological stress measured during operations is associated with a significant degree of change in heart rate variability parameters. This suggests that during surgical procedures, the balance of cardiac autonomic control of operators and first assistants is shifted in favor of relative sympathetic nervous system predominance. These findings imply that surgical psychological stressors are associated with alterations in cardiac autonomic control, which has been shown by others to contribute to the development of cardiac disease. We strongly believe that our study will constitute an objective methodology for the future research that is needed to explore the possible causes of and solutions to the physical and mental burden experienced by surgical staff. A more detailed analysis of the surgeons' work environment is likely to give us a better understanding of factors that would increase our ability to cope and enjoy work, despite occasional demanding circumstances.

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