Full-Length Article

Heart rate variability as a tool to follow the effect of music on stress-relieving in patients under anaesthesia: *Data from a clinical study*

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Abstract

The aim of the current study was to explore the effect of music on reducing stress during surgery under anesthesia, while utilizing heart rate variability (HRV) as a noninvasive measurement of stress-related physiological changes. HRV is related to the sympathetic and parasympathetic activity of the autonomic nervous system. The HRV data in our study was obtained from 10 patients who underwent an abdominal (n=5) or orthopedic fracture surgery (n=5) under general (n=5) or spinal anesthesia (n=5). Relaxation music was played to the patients during the anesthesia. Percentage of normalized high frequency (HF) of the HRV was calculated from the sum of HF and low frequency (LF). The music elicited an increase in the mean normalized HF during the music period compared to the period before the music was played, which was also statistically significant (P=0.035). A slight increase in the mean normalized HF was noted when it was measured during the whole anesthesia ± music" compared with the mean normalized HF before music (P=0.063). Thus, the data clearly demonstrate that music played during an operation induced an increase in the mean normalized HF data, thereby activating the parasympathetic nervous system and inactivating the sympathetic nervous system, resulting in relaxation.

Keywords: ***Heart rate variability, music effect on stress, patients under anaesthesia***

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Introduction

Stress and music

Stress is defined as a non-specific response of the body to any change in order to maintain any existing homeostasis [1]. Psychologically, the state of stress is characterized by feelings of anxiety, nervousness and helplessness [2]. Physiologically, stress has been found to cause hypertension, tachycardia and hyperventilation, resulting in ischemia, fluctuations in body temperature, urinary urgency, impaired eating behaviors, diarrhea and vomiting, as well as secretion of various hormones [3-13]. These physiological reactions are due to the fact that upon a stressful emotional response, there is an increase in the sympathetic activity of the autonomic nervous system (ANS) and a decrease in the parasympathetic activity [14,15].

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There are many ways to achieve stress relief, including listening to music. The response to music is influenced by various factors, such as the music itself and the listener's individual experience, social and cultural background. It was found that listening to music can evoke physiological changes, including a decrease in the heart rate, reduction of skin temperature, electrodermal response, respiration and hormone secretions [16-22].

The use of music has consistently been found to reduce stress levels of patients in clinical settings. A systematic review of 11 randomized clinical trials with critically ill patients demonstrated that music therapy was associated with a reduction in anxiety and stress [23,24].

Surgery is a stressful event for patients. The effect of music during surgery under general or regional anesthesia has been studied [25-27]. Patients who underwent hysterectomy and were exposed to intra-operative music, required less analgesic, were less fatigued and could be mobilized earlier the day after surgery, compared to controls [25-27]. On the other hand, measures of neuro-hormonal stress response in blood samples withdrawn from women undergoing a hysterectomy, showed that there was no significant effect on surgical stress of intra-operative music under general anesthesia [28]. Therefore, additional studies with improved controls are required and explore the beneficial effect of listening to music during anesthesia.

Heart rate variability as a toll to measure stress

The heartbeat is an electrical pulse which causes the heart's muscle to contract. The heart rate, which is the number of heartbeats per unit of time, is controlled by the ANS, which increases or decreases the heart rate. Heart rate variability (HRV) depends on the activity of the ANS and is defined as the R-R interval. HRV analysis is a noninvasive tool for the assessment of the ANS function and consequently to measure stress. Indeed, HRV has been utilized to measure stress in some studies [29-31]. It was demonstrated that music induces changes in the heart rate variability. which were found to be related to increased activity of the parasympathetic nervous system and to a decreased activity of the sympathetic nervous system, which were significantly correlated with an increase in relaxation sensations [29-35].

Thus, it may be suggested that listening to music under anesthesia could lead to a state of relaxation by improving the balance between the sympathetic nervous system and the parasympathetic nervous system, which could be detected by HRV monitoring.

Objectives

The objectives of this study were to examine the effects of hearing music on the aspects of electro - physiological (HRV) changes during surgery. The study included patients who underwent an abdominal or orthopedic fracture surgery under general or spinal anesthesia.

Methods

Research Design

This pilot study included 10 patients, all of whom signed an informed consent.

- *Patients*

Exclusion criteria for this study included: emergency surgery, cardiac arrhythmia, autonomic nervous dysfunction, pregnant women or people with lack of judgment.

38 patients were recruited to the study. However, a few days before the surgery or at the last moment, 7 patients refused to participate in the study. 6 of the surgeons and 7 of the anesthesiologists expressed their opposition to the music that was selected to be played during the surgery. The operation was cancelled in 5 cases and in 3 cases the study was stopped in the middle of the operation due to complications that were developed during the procedure (Figure 1). Thus, the study included 10 patients who underwent laparoscopic cholecystectomy or inguinal hernia or orthopedic fractures accompanied by general or spinal anesthesia.

Figure 1. *Schematic diagram of the participants follow-up/*

Total number of participants at **beginning of study** **38**

Total number of **drop outs during the study** **28**

Total number of patients who **participated** in the **study** **10**

7 patients refused to participate in the study
6 surgeons expressed their opposition to the music
7 anesthesiologists expressed their opposition to the music
5 surgeries were canceled
3 surgeries developed complications during the procedure and the study was stopped

- ECG signals

ECG signals were obtained from a conventional anesthesia monitor and from a Holter, which was attached to some patients before induction of anesthesia and to some after induction of anesthesia. After attaching the Holter, there was a waiting period of time, in which base line data were obtained followed by a second period, in which headphones were placed on the ears of the patients and music was played to them.

- The music

The music played for the patients was from the album "The Silent Path" by Robert Haig Coxon, which meets the criteria of relaxation music, incorporating a slow and stable tempo, a muted volume and smooth texture, a gentle sound and tone color, legato type melodies and simple harmonic cord progression.

Data analysis

The most commonly used analysis method of HRV is the frequency-domain method, which utilizes mathematical analysis providing information on the power distribution across the frequencies. The power spectrum is divided into three main ranges: the *very low frequency range* (VLF. 0.0033 to 0.04 Hz), which represents the slower changes in heart rate, the *high frequency range* (HF, 0.15 to 0.4 Hz) which represents faster changes in heart rate, and the *low frequency rate* (LF, around 0.1 Hz) which reflects the blood pressure feedback signals sent from the heart back to the brain. The vagal nerve which is the main conductor of *the parasympathetic* component of the ANS, is considered as a major contributor to the HF component [36]. As for the *LF* component, some consider it to be a marker of the *sympathetic* modulation of the heart rate, while others maintain that it is a parameter including both sympathetic and parasympathetic influences on the heart rate. VLF is considered to have some attachment to the sympathetic influence [37].

RR interval time series were determined using a 5-minute Hamming window (a standard for short term measurement of the frequency components of HRV) [38]. The long-term effects which were relevant but could affect the RR time series, were removed in order to achieve a linear effect of the Hamming window. To produce continuous HF and LF signals, a Fourier analysis on a 5-minute sliding window was performed.

All the calculations and analyses were performed on normalized HF data, expressed as a percentage of HF from the sum of HF and LF, according to the below formula:

$$\text{Absolute Normalized HF} = \left(\frac{HF}{HF + LF}\right) \times 100$$

Since HRV is a very unique parameter which differentiates from person to person, each patient served as his/her's own control. Data were collected before the music started (“Before Music”), during time the patients were under anesthesia and the music was played (“During Music”) and during the entire duration of the anesthesia including the time the music played (“During Anesthesia ± Music”).

Statistical analysis

The current study examined the same participates provided data at multiple time points, thus, repeated measure’s analysis, two-way mixed model and paired t-test were used. Prior to each analysis the relevant assumptions were tested: A repeated measure ANOVA with a Greenhouse-Geisser Huynh-Feldt correction and Post hoc tests using the Bonferroni correction were conducted to determine the differences between the mean normalized HF of the 3 groups. The assumption that should be tested when using the ANOVA approach to repeated-measures data is sphericity, using the Greenhouse-Geisser estimate or the Huynh-Feldt estimate. These estimates are also used to correct for departures from sphericity: the degrees of freedom were adjusted using both the Greenhouse-Geisser and the Huynh-Feldt estimates of sphericity and the Bonferroni method was used as the most robust in terms of power and control of type I error rate.

Paired t-test was used to examine the differences between “Delta I” [the difference in the mean normalized HF between the time the music was playing ("During Music”) and before hearing the music. – (“Before Music”)] and “Delta II” (the difference in the mean normalized HF between the entire period of anesthesia (with or without music) and before the music started: “During Anesthesia ± “Music”-“Before Music”), with a prior test for normality, which found out that the differnces are normaly distributed.

A two-way mixed model ANOVA was used to examine the interactions between the difference in “Delta I” and “Delta II” (the within participant dependent variables) to the independent variables: type of operation, anesthesia type and operation duration (the between- participant independent variables).

Effect sizes were calculated for differences in normalized HF between the groups to evaluate the differences regardless the small sample size, by the formula: difference/SD. Differences were considered significant at *Pv* < 0.05.

Results

- *Patients' demographic, surgery and anesthesia details*

The majority of the enrolled patients (n=10) were men (70%). The average age of the patients was 33.2±11.5 years, ranged between 16 to 51. Three out of the 5 patients underwent abdominal surgery with general anesthesia and the spinal anesthesia was administered to 2 other patients. As for the patients who underwent orthopedic surgery, general anesthesia was administered to 2 out of the 5 and a spinal anesthetic was administered to the other 3 patients (Table 1).

Table 1. *Characteristics of the patients included in the study.*

Variable	n(%)
Gender	
Male	7 (70%)
Female	3 (30%)
Operation type	
Surgical	5 (50%)
Orthopedic	5 (50%)
Type of anesthesia	
General	5 (50%)
Spinal	5 (50%)
Variable	**Mean ± SD Median (Min-Max)**
Age (Years)	33.2 ± 11.5 31.00 (16-180)
Operation duration (Minutes)	82.5 ± 53.0 57.5 (35-180)

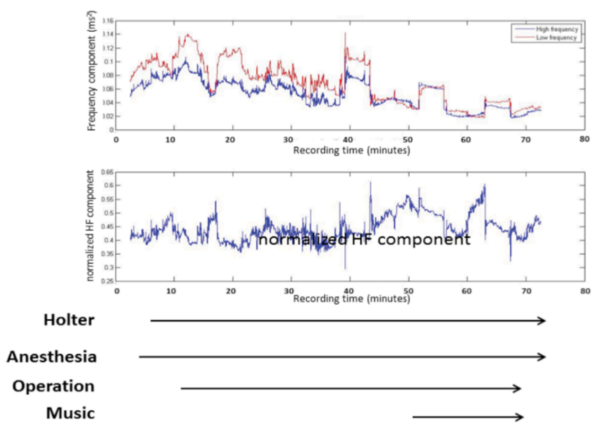
- *ECG graphs*

ECG graphs were collected, as Fast Fourier Transform (nonparametric spectrum) over 5 minutes sliding window, for each patient. A sample of one patient from each type of anesthesia is presented below (Figures 2a and 1b). The upper figure presents both HF and LF components in ms^2 (millisecond squared). The lower figure presents a normalized HF component. In addition, the time duration of the Holter monitoring, anesthesia, surgery and music, are presented.

To assess the effect of hearing the music during anesthesia, repeated measures ANOVA with a Greenhouse-Geisser correction, was conducted. The analysis revealed that the mean normalized HF differed statistically significantly between the three groups [$F(1.13,11.73) = 9.166$, $Pv < 0.05$).

Figure 2. *A sample of ECG graphs (Fast Fourier Transform over 5 minutes sliding window) collected from one patient from each type of anesthesia is presented.* ***a*** *- General anesthesia; Figure* ***b*** *-* ***Spinal anesthesia****. The upper figure presents both HF and LF components in* ms^2 *(millisecond squared). The lower figure presents a normalized HF component. In addition, the time duration of the Holter monitoring, anesthesia, surgery and music, are presented.*

2A.



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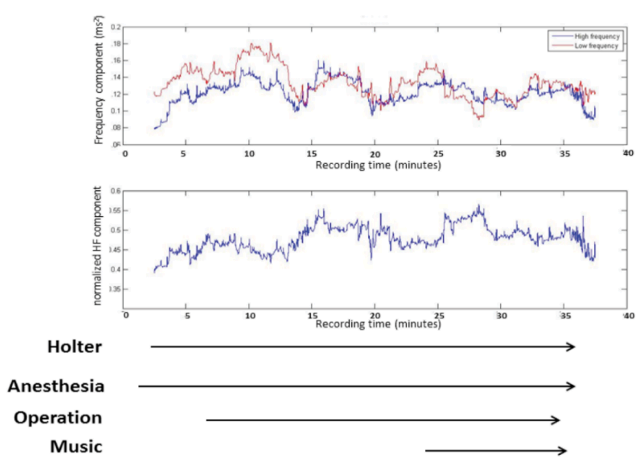


- *Analysis of the differences in mean normalized HF between the "Before Music" group, "During Music" group and "During Anesthesia ± Music" group*

Post hoc tests using the Bonferroni correction revealed that music listening elicited a significant increase in the mean normalized HF in the "During Music" group compared with the mean normalized HF in the "Before Music" group (50.30 ± 7.50 *vs.* 46.15 ±6.19, respectively), (*Pv*= 0.035). However, the slight increase in the mean normalized HF of the "During Anesthesia ± Music" in comparison to the mean normalized HF of the "Before Music" group was not significant (48.72 ± 6.85 *vs.* 46.15 ±6.19, respectively; *Pv=0.063*). Nevertheless, the mean normalized HF found in the "During Music" group was statistically significant slightly higher than the mean normalized HF found in the "During Anesthesia ± Music" group (50.30 ±7.5 *vs.* 48.72 ± 6.85, respectively) (*P*v= 0.05) (Table 2).

Effect size was calculated to evaluate these differences disregarding the small sample size. The results showed a large difference effect for the "During music-Before music", and a moderate difference effect for the "During Anasthesia±music-before music" (Table 2)

Table 2. *Mean normalized HF of the 3 groups and comparison to the "baseline level".*

Normalized HF	Mean ± SD	95% CI	*Pv**	Effect Size* (definition)
"Before music" (baseline level)	46.15 ± 6.15	41.73-50.50		
"During music"	50.30 ± 7.50	44.94-55.67	0.035	0.671 (Large)
"During anesthesia ± music"	48.72 ± 6.85	43.82-53.61	0.063	0.425 (Moderate)

* *Compared to "baseline level*

- *Analysis of the differences in mean normalized HF between the "Before Music", "During Music" and "During Anesthesia ± Music" for each patient*

For each patient, the difference in the mean normalized HF between the time the music was playing ("During Music") and before hearing the music was calculated and defined as " "Delta I" ,– ("Before Music") " "Delta II" was calculated as the difference in the mean normalized HF between the entire period of anesthesia (with or without music) and before the music started: "During Anesthesia ± "Music" - "Before Music (Table 3). A paired sample t test was conducted to examine the differences between "Delta I" and "Delta II". The test revealed that "Delta I" was significantly higher then "Delta II" [$t(9) = 2.93$, $Pv = 0.017$], with a mean difference/improvement of 1.585 ± 0.54 (95%CI: 0.362-2.809).

- *Analysis of the different interactions between "Delta I" and "Delta II" in correlation to different variables*

To examine the different interactions between "Delta I" and "Delta II" in correlation to different variables, a two-way mixed model ANOVA on the participants' mean normalized

HF was conducted. "Delta I" and "Delta II" served as a within-participant dependent variable and different relevant grouping variables served as between-participants independent variables.

Anesthesia type

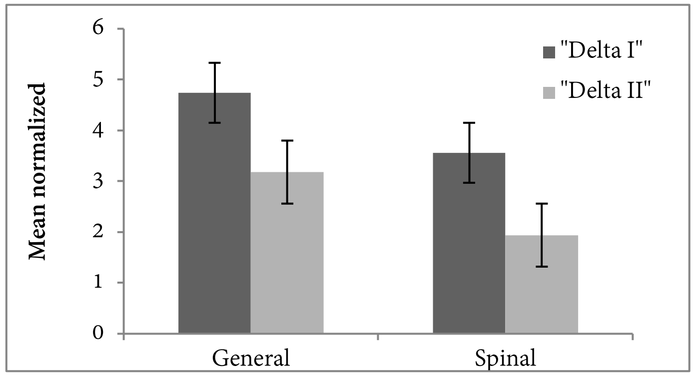
"Delta I" and "Delta II" were analyzed according to the anesthesia type. The results show that the music indeed induced an increase of the mean normalized HF in both general and spinal anesthesia. The increase of the mean normalized HF in the general anesthesia was higher than that observed in the spinal one, with regard to both "Delta I" and "Delta II" (25% and 40% increase, respectively). In both types of anesthesia "Delta I" was higher than "Delta II" (33% for the general anesthesia and 45% in the spinal anesthesia), but a non -significant interaction between the anesthesia type (general or spinal) and the difference between the "Delta I" and for "Delta II" was noted [F(1, 8)=0.003, *Pv*=0.9 58] (Table 3, Figure 3a).

Table 3. *The effect of the anesthesia type, operation type and operation duration on the increase of mean normalized HF upon listening to music.*

		Mean	Standard Error	95% CI	
				Lower bound	Upper bound
Total	"Delta I"	4.147	1.316	0.288	8.006
	"Delta II"	2.562	0.918	-0.131	5.255
Anesthesia type					
General	"Delta I"	4.738	1.951	0.238	9.238
	"Delta II"	3.184	1.341	0.091	6.277
Spinal	"Delta I"	3.556	1.951	-0.943	8.056
	"Delta II"	1.940	1.341	-1.153	5.033
Operation type					
Abdominal	"Delta I"	2.822	1.859	-1.465	7.109
	"Delta II"	1.588	1.288	-1.382	4.558
Orthopedic	"Delta I"	5.472	1.859	1.185	9.759
	"Delta II"	3.536	1.288	0.566	6.506
Operation duration (Minutes)					
>57:50	"Delta I"	4.298	1.972	-0.250	8.885
	"Delta II"	3.120	1.348	0.011	6.229
≤57:50	"Delta I"	3.996	1.972	-0.552	8.543
	"Delta II"	2.004	1.348	-1.105	5.113

Delta I" - the difference in the mean normalized HF between the time the music was playing ("During Music") and before hearing the music ("Before Music").
"Delta II" - the difference in the mean normalized HF between the entire period of anesthesia ("During Anesthesia ± "Music") and before the music started ("Before Music")

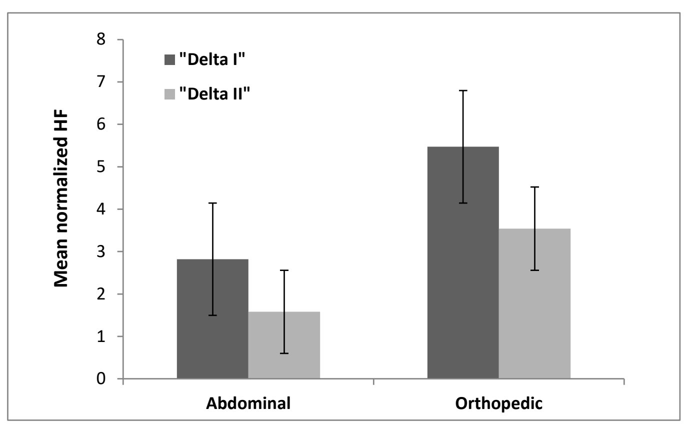
Figure 3. *Effect of the anesthesia type, operation type and duration time on the increase of mean normalized HF upon listening to music* ***a****. Effect of the anesthesia type on the increase of mean normalized HF upon listening to music.*



Type of surgery

When "Delta I" and "Delta II" were analyzed according to the type of surgery, an increase of the mean normalized HF in both abdominal and orthopedic surgery was observed. The increase of the mean normalized HF in the orthopedic operation was higher than that observed in the abdominal operation in both "Delta I" and Delta II", by 48% and 55% respectively. In addition, it was demonstrated that in both types of surgery "Delta I" was higher than "Delta II", by 44% in the abdominal surgery and by 35% for the orthopedic surgery. Nevertheless, the difference between the 2 "Delta I" and for "Delta II" in relation to the operation type was not significant [F 1, 8) = 0.39246, *Pv*=0.548[(Table 3, Figure 3b).

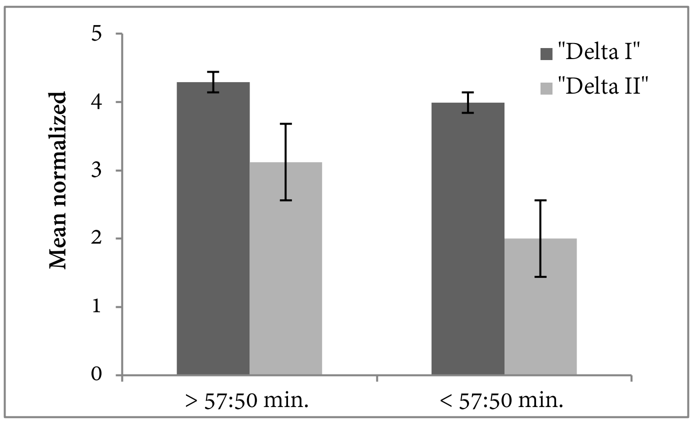
b. *Effect of the operation type on the increase of mean normalized HF upon listening to music.* ***c.*** *Effect of the operation duration time on the increase of mean normalized HF upon listening to music.*



Operation time

Operation time was divided into 2 categories, according to the median value of 57:50 minutes. The data revealed that when the operation lasted less than the median time, the increase in mean normalized HF was higher than the increase when the operation lasted longer. There was an increase of 8% when the time of "During Music" was compared to the mean normalized HF "Before Music" (i.e. "Delta I"), and of 36% when the time of "During Anesthesia ± Music" was compared to the mean normalized HF "Before Music", i.e. "Delta II". "Delta I" was higher than "Delta II", both when duration of surgery was shorter (by 27%) and when time of surgery was longer (by 40%). Nevertheless, the results were not significantly different between "Delta I" and "Delta II" in relation to surgery duration [$F(1, 8)=.54$, *Pv*=0.48[(Table 3, Figure 3c).

Figure 3c



Discussion

This was a pilot study aimed to explore the effect of music on reducing stress during surgery under anesthesia. A noninvasive measurement of stress-related physiological changes of the HRV, that produced data during the surgery was implemented.

Different frequency bands of the HRV power spectrum are known to be related to the sympathetic and parasympathetic activity of the ANS. Surgical stress provokes hypothalamic activation of the sympathetic ANS. It has already been demonstrated that stress-related sympathetic activation may be represented by change in the HRV pattern, thus HRV measurements could serve as a diagnostic and prognostic tool of autonomic dysfunction in patients [39-41].

In the present study, 10 patients underwent an abdominal or orthopedic fracture surgery when general or spinal anesthesia was administered. ECG signals were obtained and each patient served as his/her control. Continuous HF and LF signals were recorded throughout the whole procedure and arranged in 3 groups: "Before Music", "During Music" (only during time the music played) and "During Anesthesia + Music" (during the entire duration of the anesthesia including the time the music played).

Analysis of the data revealed that the mean normalized HF showed a statistically significant difference between the three groups (*Pv* < 0.05). The music elicited an increase in the mean normalized HF in the "During Music" group compared with the mean normalized HF in the "Before Music" group, which was also statistically significant (*Pv* = 0.035). Moreover, the increase in the mean normalized HF in the "During Music" group compared with the base levels "Before Music" was significantly higher than the increase found when the mean normalized HF found in the "During Anesthesia ± "Music" was compared to the base levels "Before Music" (P = 0.017). The overall decrease in the HF component both in the "During Music" group and in the "During Anesthesia ± "Music" group might seem to be a result of the anesthesia itself being a major contributor to the stabilization of the normalized HF component.

However, the statistically significant difference between the effect of the "During Music" and the "During Anesthesia ± "Music", in which the HF was higher in the first group, clearly demonstrated the direct effect of the music. In addition, it might be suggested in light of the lower increase of the HF in the "During Anesthesia ± "Music" in comparison to the higher increase in the "During Music" in which the anesthesia and the music were administered at the same time, that indeed the music induced an additive effect to the anesthesia in terms of elevating the HF power. Thus, the data clearly demonstrate that music played during an operation induced an increase in the mean normalized HF data, leading to the down-regulation of LF/HF ratio, thereby activating the parasympathetic nervous system and inactivating the sympathetic nervous system, resulting in relaxation.

Furthermore, in both types of anesthesia the increase in the mean normalized HF in the "During Music" group was higher than "During Anesthesia ± Music" in comparison to the mean normalized HF of the "Before Music", indicating that the music induced relaxation independent of the anesthesia type.

The effect of music on the HRV component was also tested by others. Orini et al., found that listening to pleasant music, the HRV rate elevated (for more than 80% of the duration of the stimuli) and the power of the HF modulation was lower (for more than 70% of the duration of the stimuli) than while listening to unpleasant stimuli [42]. In elderly patients undergoing elective surgery who received psychological and music intervention 30 min before surgery, the mean HF power was significantly higher after the procedure than before (*Pv*<0.01) and the ratio of mean LF to HF power decreased compared to before the intervention (*Pv*<0.05) [43]. In a study which was aimed to explore the relieving effect of music intervention on preoperative anxiety by using HRV analysis, 43 adult patients were scheduled to undergo impacted tooth extraction under intravenous sedation and local anesthesia. Those subjects listened to music from the time that they arrived at the outpatient clinic until immediately before entering the operating room. The LF/HF changes from baseline among those who listened to music was significantly lower as compared with those who did not listen to music [44]. Cotoia et al., tested the effects of listening to Tibetan music on anxiety and autonomic responses in 60 patients waiting for urologic surgery. In the music group the State Trait Anxiety Inventory Questionnaire score decreased compared with baseline while it did not change in the control group and the mean LF/HF ratio was slightly reduced [45].

Mojtabaviet al., conducted a systematic review to examine the effect of musical interventions on HRV. After collecting data from 29 original articles (24 pre-post intervention studies and five randomized controlled trials) that were eligible with a total of 1368 subjects they came to the conclusion that music acts on the cardiac ANS, thereby increasing parasympathetic activity and HRV [46].

Interestingly, it was found that different types of music alter differently cardiovascular parameters. The systolic, diastolic blood pressure and heart rate decreased when classical music was played compared to heavy metal or controls ($p<0.001$) [47]. The different changes in heart rate upon listening to different type on music can also affect achievements of various kinds, including sporting achievements. It was found that music-assisted dart-throw training with slow-paced music was effective in significantly inhibiting a performance-related increase in heart rate and was associated with the greatest dart throwing improvement after training [48]. An additional interesting issue is the effect of music on patients with cardiovascular diseases and during cardiovascular interventions. Regrettably, data collected from a total of 29 studies comprising 2579 patients were included and 18 studies with 1758 patients investigated the effect of music on patients undergoing coronary angiography or open-heart surgery did not detected any effect of music intervention on the cardiovascular system [49]

It is important to note that a literature review we carried out attempting to find articles that examined the effect of music on the HRV component in patients undergoing surgery under anesthesia, did not yield any results. Most of the articles found dealt with the effect of music played before surgery while others tested the effect of the music after the surgery. Thus, to the best of our knowledge the current study is the first one demonstrating the effect on ANS activity of music played during surgery and the consequent levels of stress by monitoring the changes in the HRV components during the surgery.

However, the major problem of the study was its small sample of patients with varying surgical methods and also varying anesthesia procedures. There was a seeming lack of willingness in patients to participate in the study. It was also difficult to receive consent from the surgeons and anesthesiologists to play the selected music during the operation. Moreover, it was hard to obtain an available operating theater in which the music could be heard and where a Holter monitoring during the surgery was available. Thus, it is difficult to make definitive final conclusions and future wider studies with larger samples should be performed in order to reinforce the results observed in the present study.

Conclusion

To conclude, data of the present study clearly demonstrate that upon playing relaxing music to patients undergoing a surgery, either during a general or spinal anesthesia, increases the HF component of the HRV. As a result, the ratio of LH/HF is decreased, leading to a state in which the parasympathetic ANS is activated, inducing relaxation. Since the current study consisted of a small sample of patients, further extensive and large studies are required to establish the HRV as a useful tool to measure the relaxation levels of patients upon listening to music during surgery.

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