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Heart rate variability of anaesthesiology registrars pre and post night call at a central hospital

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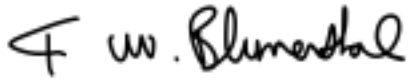
Trevor Martin Blumenthal

A research report submitted to the Faculty of Health Sciences, University of the Witwatersrand, Johannesburg in partial fulfilment of the requirements for the degree of Master of Medicine in the branch of Anaesthesiology.

Johannesburg, 2021

Declaration

I, Trevor Martin Blumenthal declare that this research report is my own unaided work. It is being submitted for the Degree of Master of Medicine in the branch of Anaesthesiology at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at any other University.



15 February 2021

This research is dedicated to my grandmother

Marian Segal

Abstract

Background

Heart rate variability (HRV) is a tool used to measure the bio-psycho-social aspects of stress. Night call is associated with increased levels of stress and therefore decreased HRV. HRV in anaesthetists is currently unknown. The aim of this study was, therefore, to compare HRV pre and post night call in registrars in the Department of Anaesthesiology at Chris Hani Baragwanath Academic Hospital.

Methods

This was a cross-sectional study using convenience sampling. Pre and post night call HRV recordings were taken from 27 registrars using the Suunto® Smart Belt. The computer-based software Kubios® was used for data analysis. Time- and frequency-based analyses were done. The normal values from a systematic review for short-term HRV were used in this study.

Results

Overall HRV was low with no significant difference pre and post night call (Low frequency to high frequency ratio (LF:HF), 3.215 vs 3.473, p=0.719). There was no significant difference in overall HRV pre and post call between male and female registrars (LF:HF, 3.331 vs 3.090, p=0.805 and 4.128 vs 2.768, p=0.296). No significant differences in overall HRV pre and post call between junior and senior registrars (LF:HF, 3.094 vs 3.391, p=0.765 and 3.034 vs 4.113, p=0.417). However, there was a significant difference in post call overall HRV in time-domain variable, standard deviation of the normalised RR interval (SDNN) (54.2 vs 42.4, p=0.048). There was a positive, statistically significant correlation between number of night calls, SDNN (r=0.456, p=0.0017) and the square root of the mean squared differences of successive NN intervals (RMSSD) (r=0.502, p=0.008).

Conclusion

In this study, registrars showed increased sympathetic nervous system dominance, with the associated decreased HRV both pre and post night call with no significant difference between these two time periods. The reasons for this decreased HRV may be multifactorial. There was no significant difference between HRV of male and female registrars or between junior and senior registrars.

Acknowledgements

I would like to thank my supervisors Juan Scribante and Helen Perrie for their invaluable guidance, patience and incredible support in person and through the numerous zoom sessions. I would like to thank Tristan Leonard my clinical supervisor for his clinical input. I would like to thank Gill Hendry for helping me make sense of all the statistics. I would like to acknowledge my fellow registrars for their assistance in collecting my data for this MMed. In addition I would like to thank my wife Hayley, for her unconditional love and support, I could not have completed this without you by my side. Finally a big thank you to my parents and family for their counsel, giving me this opportunity and always reminding me how everything works out in the end.

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Abbreviations

ANS	Autonomic nervous system
CHBAH	Chris Hani Baragwanath Academic Hospital
DNA	Deoxy-ribonucleic-acid
ECG	Electrocardiogram
ESC	European Society of Cardiology
HF	High frequency
HPA	Hypothalamic-pituitary-adrenal
HR	Heart rate
HRV	Heart rate variability
LF	Low frequency
NASPE	North American Society of Pacing and Electrophysiology
NN	Normalised RR interval
nu	Normalised unit
pNN50%	the number of interval differences of successive NN intervals greater than 50 ms
PNS	Parasympathetic nervous system
PSD	Power spectral density analysis
RMSSD	The square root of the mean squared differences of successive NN intervals
RR	Distance between two consecutive R-waves of the QRS complex on an ECG.
RSA	Respiratory sinus arrhythmia
SDANN	Standard deviation of the 5 minute Average NN
SDNN	The standard deviation of the NN interval
SNS	Sympathetic nervous system
TINN	Triangular interpolation of the NN interval histogram
VLF	Very low frequency
WITS	University of the Witwatersrand

Statement

The Research Report consists of a literature review, draft article, study proposal and appendices. The study proposal is included for background reference and is not for examination.

The formatting of this Research Report complies with the University of the Witwatersrand's Style Guide for Theses, Dissertations and Research Reports. The formatting of the draft article may differ from the author guidelines of the Southern Africa Journal of Anaesthesia and Analgesia, the journal to which it is intended to be submitted, in order to comply with the university's style guide

Section 1: Review of the literature

1.1 Introduction

In this review a background to shift work and burnout, the physiology of stress, work and recovery, measuring stress and heart rate variability (HRV) including methods measuring HRV in health care workers pre and post call will be discussed.

1.2 Background

According to the World Health Organization (1), occupational health “deals with all aspects of health and safety in the workplace and has a strong focus on primary prevention of hazards”. The health of workers encompasses physiological and psychosocial well-being, which is particularly pertinent to the medical fraternity. Due to the high work stress profile of medicine, there has been a concerning rise in physician burnout and suicide rate over time (2).

A meta-analysis by Vyas et al (3), deduced that shift work was associated with an increased incidence of macro and microvascular disease and injury and measures that encompass bio-psycho-social well-being should be put in place to prevent disease progression (3). According to the South African Basic Conditions of Employment Act, 1997 (4), night work is defined as working between 18:00 and 06:00. In the medical fraternity, shift work typically encompasses night duty, with longer working hours and in a study by Ferri et al (5), shifts done during the night had a greater stress load on the worker as compared to shifts done during the day. Work stress or burnout is seen in approximately 21% of training physicians (6), while 20.9% – 43.2% described symptoms of depression (7).

Burnout is defined as a form of physical, emotional and mental fatigue established through extended periods of physiological and emotional strain and stress (8). The physiological strain may manifest pathologically as raised blood pressure, cardiovascular disease and diabetes, to name a few, while the emotional and mental strains may develop into mood disorders, anxiety and even substance abuse (9).

It is because of these physiological and mental stressors that burnout in the medical fraternity has far-reaching consequences that may affect not only the healthcare provider personally but their patients, their families and the health system as a whole.

1.3 The physiology of stress

The physiology of stress within the work environment has been shown to manifest in alterations in the autonomic nervous system (ANS) and the hypothalamic-pituitary-adrenal (HPA) axis (10). This has been described by McEwen (10) as allostasis and is essential for maintaining homeostasis. Within this concept, it is made clear that an individual is able to oscillate between catabolism and anabolism to cope with these changes and adapt accordingly. However, the allostatic concept only explains the individual's ability to manage and maintain relative homeostasis under acute changes and acute phases of stress (10).

Although the individual is able to maintain homeostasis in the acute setting, organisms throughout their lives go on to experience prolonged phases or periods of acute stress, which then develops into chronic stress. This chronic stress will have altered effects on the individual's homeostasis, as described by McEwen (10).

McEwen (10), introduced the allostatic load theory. The theory establishes a link between acute stress developing into chronic or prolonged stress via the ongoing activation of the neuroendocrine stress response, the ANS, HPA axis, immune system and physiological wear and tear (11). This chronic wear and tear and disruption of homeostasis are thought to promote disease through the pathological process of an imbalance between the sympathetic nervous system (SNS), parasympathetic nervous system (PNS) and the HPA axis (12).

The SNS response is commonly referred to as the "fight or flight" response. The SNS is activated in response to stressful environments, alerting the body that a swift decision needs to be made for self-preservation. Catecholamines, cortisol, growth hormone and thyroid-stimulating hormone are released in anticipation of a "fight or flight" response. As mentioned, in the acute phase, these surges in the

SNS and HPA axis are well tolerated by the body and no long-term damage or injury is sustained (10).

Acute and chronic SNS activation is known to raise heart rate, blood pressure, muscle strength, mental processing and energy utilisation when external stress is experienced and concurrently, decreased vagal tone (12–15). According to the Framingham Heart Study (16), an independent predictor for new-onset hypertension is decreased vagal tone.

The PNS facilitates a state of “rest and digest”. During the activation of the PNS, the neuroendocrine system ensures restitution and replenishing of energy and its stores to maintain homeostasis. Due to vagal tone suppression by the SNS during stress, it is therefore expected that to function optimally, vagal tone activity predominates during the relaxation and recovery period after work shifts and other activities associated with sustained SNS activities (14). In a prospective study by Suadicani et al (17), coronary heart disease was found to occur three times as often in subjects who stated they did not partake in leisurely activities after work.

Due to the complexity of the physiological and psychophysiological systems, rhythmic variations exist to maintain stability and these are generated by the circadian clock system (18). This system follows a 24-hour cycle, ensures timekeeping and that time specific physiologically driven processes are correctly coordinated to the correct time of day and with each other (18–20). There are internal and external stimuli known as “zeitgebers” (time-givers) and these include light, food intake, social activities and alertness, which then stimulate the central circadian pacemaker found in the suprachiasmatic nuclei located in the hypothalamus and generate a rhythm referred to as the diurnal rhythm (18).

During the sleep-wake cycle or diurnal rhythm, melatonin and cortisol are released and levels peak during the night and morning, respectively. Cortisol secretion plays a pivotal role in metabolic equilibrium through processes of gluconeogenesis, lipolysis and protein catabolism. Sustained release of cortisol can lead to undesirable pathologies, such as diabetes, obesity, dyslipidaemia and associated cardiovascular disorders (21). Sleep suppresses the release of cortisol

and with frequent night duty, Broussard and Brady (22) concluded that shorter sleep durations are associated with increased evening cortisol levels (18).

Night calls are often associated with disruption of the worker's sleep pattern and regularly results in sleep deprivation. In Hong Kong, it has been demonstrated in doctors that deoxy-ribonucleic-acid (DNA) repair gene expression is at lower baseline levels in those who work night calls and that levels are further decreased after periods of acute sleep deprivation (23). The authors concluded that doctors who worked overnight on-site demonstrated a 30% increase in DNA breaks in their alkali-labile sites compared to doctors not working overnight. The defect in DNA repair has been associated with oxidative damage and as a consequence, is a precursor to the development of chronic diseases (23).

1.4 Work and recovery

It has been suggested that not only do night calls have destructive consequences on the health of night shift workers, but the recovery between these shifts plays an important role in the workers' well-being (12). The "Effort-Recovery Model" emphasises the crucial role recovery has in the process of acute to chronic stress or allostatic loading (24). The premise of the model is that the physiological and psychophysiological systems placed under stress during a working shift will return and equilibrate to their baseline resting level, to a state of metabolic, physiological and psychophysiological harmony, if resting and recovery time is adequate (12).

The process of recovery, by convention, should follow periods of work and stress. However, there are situations where this recovery process is delayed or even deficient and the body is unable to attain the harmonious physiological and psychophysiological state for optimal functioning (12). With this suboptimal state and lack of adequate recovery, the individual or worker must utilise more energy to compensate for this deficit in order to ensure they are able to carry out their work effectively (12). With this ongoing state of compensation, chronic strain ensues and this may manifest in the form of disease, chronic fatigue and substance abuse, among others (12,25,26).

In two systematic literature reviews (26,27), it was concluded that the catecholamine, adrenaline, remained elevated after taxing work shifts suggesting

suboptimal recovery (12). In driving instructors, it was demonstrated that with days of increased intensity of stress or workload, higher levels of adrenaline were noted to be present (12).

Recovery from work stress has been described as a two-pronged process. There are “internal” and “external” forms of recovery (28). Internal recovery is recovery occurring within the working environment and includes short breaks from work such as lunch and coffee breaks (12). Fatigue management and strategies in the workplace through rest breaks are essential to minimise fatigue and maximise performance (29). The importance of when, how often and how long workers should break is a determining factor in the effectiveness of recovery. In many instances, there was no recovery due to the nature of the work, for example, dealing with emergencies in the hospital setting. Some studies concluded that job settings with low control such as the ability to take controlled breaks, satisfying basic personal needs, such as toilet breaks and eating or drinking were associated with poor physiological and psychophysiological recovery (30).

External recovery is the process of recovery that occurs after a work shift has been completed, on weekends and during planned annual holiday time. External recovery is divided into three main type sets: work-related time, which involves taking work home to complete, semi-leisure time where essential home chores like cooking and cleaning are done and leisure time, being pure relaxation (12).

Leisure time can be further sub-divided into passive, low energy-requiring activities such as playing an instrument or doing pottery, or active leisure time requiring a higher energy requirement such as social and sporting activities (12,31,32). Within the sphere of medicine, this leisure time is limited due to the nature of the profession.

The recovery process is essential to maintaining homeostasis. Besides internal and external recovery and the factors that influence them, there are other conditions that may obstruct the recovery process. Cognitive processes, like rumination, have been shown to have an impact on the recovery process (33). Rumination is a perseverative thought process that focuses on negative content that has happened or is happening, which goes on to result in emotional distress

(34). In a study by Zoccola and Dickerson (35), a link was found between rumination and raised cortisol levels associated with SNS activation and hence delayed recovery. Hogan and Linden (36) determined that rumination was associated with elevated ambulatory blood pressure and its associated sequelae.

Anaesthesia and intensive care share the emotional and physical stress levels associated with looking after critically ill patients. Both are associated with long, intense working hours in high-risk, complex environments with many changing variables (37). In a study by Vandevala et al (38), in the intensive care unit, intensivists' were dealing with environmental (heavy workload, prolonged shifts), patient (witnessing pain, suffering, critical illness) and ethical issues, often leading to rumination. These effects can be extrapolated to the anaesthetist due to the shared type of patient and working environment (39).

During the COVID-19 pandemic, there has been an increase in workload and stress both physiologically and mentally in all health care workers (40). A study in Singapore found a significant increase in psychological stress among anaesthesiologists and nurses working in intensive care units (41). Another study by Sneyd et al (42), stated that the COVID-19 pandemic had significantly affected the post graduate training across six continents with cancelled educational programmes, delayed changes in rotations thus delaying academic progression and postponement of exams. All these changes in the background of the COVID-19 pandemic will have significant consequences for training anaesthetists, their seniors and their current and future patients (42).

1.5 Measuring stress

Stress is a subjective phenomenon perceived by all individuals and may manifest either physiologically, psychologically or both. Qualitative and quantitative measures of stress will enable a better understanding of the mechanics of stress and thus provide a platform to manage the acute and chronic stress periods (43).

Stress may manifest psychologically in the form of behavioural changes, altered performance, inability to cope and in some cases, self-harm (44). Cohen (45) stated that qualitative questionnaires, such as the Perceived Stress Scale and the Daily Hassles Scale were developed to investigate these psychological changes.

A disadvantage of using qualitative measurements of stress is the subjectivity of stress, as each individual perceives stress differently. It is perhaps prudent to use qualitative measurements in conjunction with quantitative measurements when assessing stress (43).

Stress manifests through physiological changes as mentioned in Section 1.3. Stress and its response play a critical role in the survival of all living organisms. Various systems such as the ANS and the HPA axis are activated, which control and release hormones, allowing the individuals to respond and act according to the stress perceived (12). It is these hormones and their effects that are measurable, thus allowing the amount of stress perceived to be approximated.

Cortisol, a stress hormone of the pituitary gland, can be measured from obtaining a blood, salivary or urine specimen. The cortisol found in blood is 90% bound to proteins and hence only 10% is free and able to be measured, while urine and salivary cortisol have a higher percentage of free and unchanged cortisol (46). Urine cortisol has some practical limitations in that a 24-hour urine specimen is needed. There are good alternatives available as surrogates for serum cortisol such as liquid chromatography-tandem mass spectrometry, but its use is limited by the absence of a single, validated reference range and inadequately standardised assays (46).

The changes in the ANS due to stress can be analysed using measurements of heart rate, blood pressure and vagal tone. HRV is a measurement used to assess and monitor the way the heart responds and functions under resting and stressed conditions. It is a useful, non-invasive and reliable tool that allows the interplay between the SNS and PNS to be observed (47).

1.6 Heart rate variability

1.6.1 Background

HRV is defined as “the variation over time of the period between consecutive heartbeats and is predominantly dependent on the extrinsic regulation of the heart rate” (47).

The use of heart rate variation stems from the assessment of heart rate and the variation in its rhythm beginning as early as 2 000 years ago (48,49). The pulse of a patient was first used in ancient forms of medicine, including Chinese and Indian medicine, around 800 BC and was termed pulse diagnosis (49).

Stephen Hales, in the eighteenth century, used arterial blood pressure readings taken from intra-arterial lines of animals and assessed the height blood would rise in a column (49,50). Throughout the nineteenth and twentieth centuries (48), research focusing on the heart, its rate, rhythm and link to the ANS lead to valuable information, as shown in Figure 1. In 1965 the fetal electrocardiogram (ECG) was first used in pregnant women to assess whether the fetus was distressed by looking at the inter-beat interval (51). However, fetal ECG can be invasive and the less invasive cardiotocograph is used, which measures the fetal heart rate and uterine contractions concurrently and reflect the changes in the ANS (52). A decrease in variability in the heart rate (decreased fluctuations in heart rate) between tracings is suggestive of fetal distress and further management is required (51). It is these increased or decreased fluctuations in heart rate that are measured and termed HRV, which is currently used in obstetric practise (53) and multiple applications within the adult population (54).

An individual's baseline HRV, either increased or decreased, is determined by the current physical and mental health status of the patient. Gang and Malik (55) and Ahmad et al (56), used HRV in patients in an intensive care unit as a diagnostic and prognostic indicator of cardiac autonomic modulations. Emotional states of happiness and sadness have been shown to alter HRV as illustrated in a study by Shi et al (57). Due to the non-invasive nature of its measurement, its use is particularly useful in patients with head injuries or brain death (55).

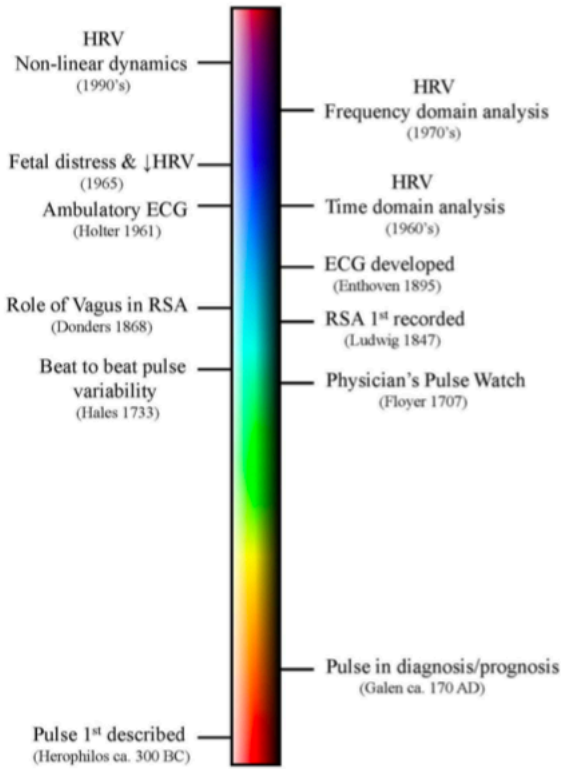


Figure 1: Heart rate variability evolutionary timeline (38)

An important attribute of HRV is the concept of respiratory sinus arrhythmia (RSA). Ernst (49) referenced Carl Ludwig's theory of RSA, where fluctuations in the heart rate can be a response to changes in the breath cycle, with inspiration being associated with increased heart rate while expiration is associated with decreased heart rate (49). Katona and Jih (58) demonstrated that respiratory rate had an impact on vagal tone and was able to separate the two, thus illustrating the connection. The implication was that the degree of RSA correlated with changes in vagal tone. From this initial study, RSA or external factors such as stress were shown to modify vagal tone.

1.6.2 Methods of measuring and analysing heart rate variability

With the development of technology, knowing an individual's health now goes beyond seeing a doctor and getting a clean bill of health. Various devices have been developed, ranging from a simple home-based finger prick test for diabetes to a more complex 24-hour Holter monitor used to assess blood pressure, heart rate and rhythm. An essential aspect of the well-being of a patient is self-care and insight into their health (59). Polar® and Fitbit®, to name a few, are companies focused on bringing health information to individuals.

Some devices have more sophisticated hardware and software, which allow more than just steps walked and distance covered to be collected and analysed (60). Heart rate and HRV measurements are two of the more sophisticated domains found in the more advanced fitness devices, which when collected and analysed give valuable data regarding the wearer's health. The advantages of such devices are their ease of use, mobility and minimally invasive techniques of attaining the data (61).

The Suunto® system is such a device used to record and analyse heart rate and HRV. It was shown by Bouillod et al (62), that the Suunto® Memory Belt is an accurate and simple system that allowed RR interval recording. Due to the inbuilt memory, transmission to a receiver is not needed, thus minimising artefacts (62). In a study by Menghini et al (63), devices worn on the wrist were associated with higher rates of measurement error. It is therefore suggested for research and accuracy purposes that a chest strap such as the Sunnto® system be used.

All medical tests, whether clinical such as heart rate, or biochemical such as haemoglobin levels have normal values. This allows a comparison of the test subject's result to these normal values and informs the physician or researcher to what degree the test subject's results deviate from the normal. In a systematic review by Nunan et al (64), it was noted due to multiple factors, inconsistent normal values for HRV were reported. Cognisance of such inconsistencies must be taken into account when comparing HRVs to a normal value. With respect to assessing and collecting data for HRV for interpretation, the duration for HRV assessment can be divided into three groups. Twenty-four-hour, short-term (5 – 15 minutes) and ultra-short-term (< 5 minutes) (54). It has been recommended to take readings ≥ 5 minutes to ensure the data is reliable and the results collected have been comparable to 24-hour HRV readings (65,66).

A study in the Netherlands by van den Berg et al (67) established ultra-short normal values in two time-domain variables, in five age groups in people aged 11 days to 91 years through ten-second ECGs. It was found within the study that from birth to increasing age, certain statistical trends calculated decreased and only small difference between males and females was noted. Table 1 shows the normal ultra-short values for the standard deviation of the NN interval (SDNN) (ms) and

the square root of the mean squared differences of successive NN intervals (RMSSD) (ms) for both males and females.

Table 1: Normal ultra-short values for SDNN (ms) and RMSSD (ms) for both males and females (67)

	SDNN		RMSSD	
	Male	Female	Male	Female
<1 month – 19 years	99.6 – 60.7	109.2 – 67.3	153.1 – 70.1	161.9 – 80.4
20 years – 29 years	48.5	56.0	51.9	63.7
30 years – 39 years	37.5	43.4	37.7	47.7
40 years – 89 years	30.4 – 15.6	33.3 – 16.1	29.9 – 17.9	35.8 – 19.2

There are many different ways to measure HRV and this is more complex than commonly understood and this may lead to incorrect conclusions and extrapolations (68). In 1996, the Task Force of the European Society of Cardiology (ESC) and the North American Society of Pacing and Electrophysiology (NASPE) (68) specified methods to analyse HRV, namely time-domain and frequency-domain analysis.

Heart rate is portrayed as a signal and it is, therefore, useful to analyse both the time- and frequency-domain as each conveys different information about the same phenomenon. Some aspects of the signal may be easier to identify and quantify in the time-domain and other aspects easier in the frequency-domain. Consequently, the use of time- and frequency-domain analysis is complimentary as the one does not exclude or prohibit the other.

Time-domain analysis

Time-domain analysis measures either instantaneous heart rate or uses the intervals between consecutive heartbeats from an ECG (48). On an ECG (Figure 2), the RR interval (R peak of one QRS complex to the next R peak of another QRS complex) is measured between 0.5 and 5 minutes (68). The RR interval may, however, include arrhythmias (atrial or ventricular), which are then removed and only sinus rhythms are measured, resulting in normalised RR interval, known as the normal to normal interval (NN) (69). Artefact recognition and RSA may also

influence time-domain measurement and other forms of analysis are employed to address such artefacts (69). Time-domain analysis uses statistical or geometric methods or both, is easier to measure, however, can be associated with less detailed information as compared to frequency-domain analysis.

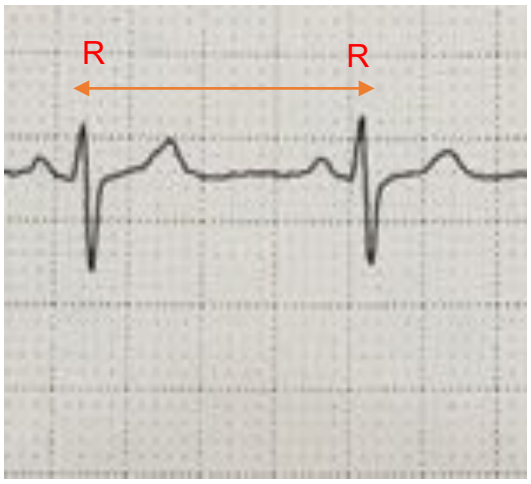


Figure 2: ECG with R-R distance (R:R wave) peak

There are two classes of statistical time-domain analysis measurements: the first is derived from taking direct measurements from the NN interval or heart rate and the second from the differences between the NN intervals (68). The SDNN is the easiest variable to calculate and is attained by square rooting the variance. SDNN measurements are usually dependent on the length of recordings, and thus, short-term 5-minute and nominal 24-hour long-term recordings are appropriate options.

The RMSSD, the number of interval differences of successive NN intervals greater than 50 ms (pNN50) and the proportion derived by dividing the NN50 by the total number of NN intervals are valuable measurements derived (58). These measurements are all strongly correlated in estimating high-frequency (HF) variation used to analyse HRV (68). All variables within the statistical method have ms as their unit of measure with the exception of pNN50, which uses percentages.

Within geometric methods, the NN intervals can also be converted into geometric patterns allowing simple formulae to judge the variability of the graphic or geometric properties (68). There are multiple geometric methods for assessing HRV. These include the histogram, the HRV triangular index and its modification, the triangular interpolation of the NN interval histogram (TINN) and Poincaré plots.

The histogram evaluates the relationship between the total number of RR intervals detected and the RR interval variation (68,70). The triangular index and the TINN assess the major peaks of the histogram as a triangle, with its baseline width corresponding with the amount of RR interval variability (68,70). Geometric methods are, however, dependent on the duration of the readings (at least 20 minutes) but are, however, less influenced by the quality of recorded data (68). Many of the time-domain variables correlate with each other and it has been recommended by the ECS and NASPE task force to use the following parameters: SDNN and HRV triangular index for overall HRV, SDANN (standard deviation of the five minute average NN) for long-term HRV components and RMSSD for the short HRV components. RMSSD method is preferred to pNN50 and NN50 because of its better statistical properties (68). RMSSD represents the short-term parasympathetic branch while SDNN and HRV triangular index represent total variability. It would be desirable to have an increase in RMSSD, HRV triangular index and SDNN values, as this would indicate an increased HRV (68). Table 2 shows standard measurements proposed by the ECS and NASPE task force (68). The value of these statistical parameters is seen through the use in their interpretation of abnormalities such as bigger values seen with pre-ventricular contractions, atrial fibrillation, and sick sinus syndrome as compared to smaller values seen in complete heart blocks, bundle branch blocks and dilated or ischaemic cardiomyopathies (47).

Table 2: Normal values for HRV variables over 24-hour recordings from the ECS and NASPE task force (68)

Variable	Units	Normal values (mean±SD)
Time-domain analysis		
SDNN	ms	141±39
RMSSD	ms	27±12
HRV triangular index		37±15
Frequency-domain analysis		
LF	nu	54±4
HF	nu	29±3
LF/HF ratio		1.5 – 2.0

Frequency-domain analysis

Frequency-domain analysis may be defined as an association between different frequency ranges of the SNS and PNS as described by Akselrod et al (71). Power spectral density (PSD) analysis is applied to HRV measurements for interpretation, as seen in Figure 3. PSD calculations are classified into nonparametric and parametric and have comparable results.

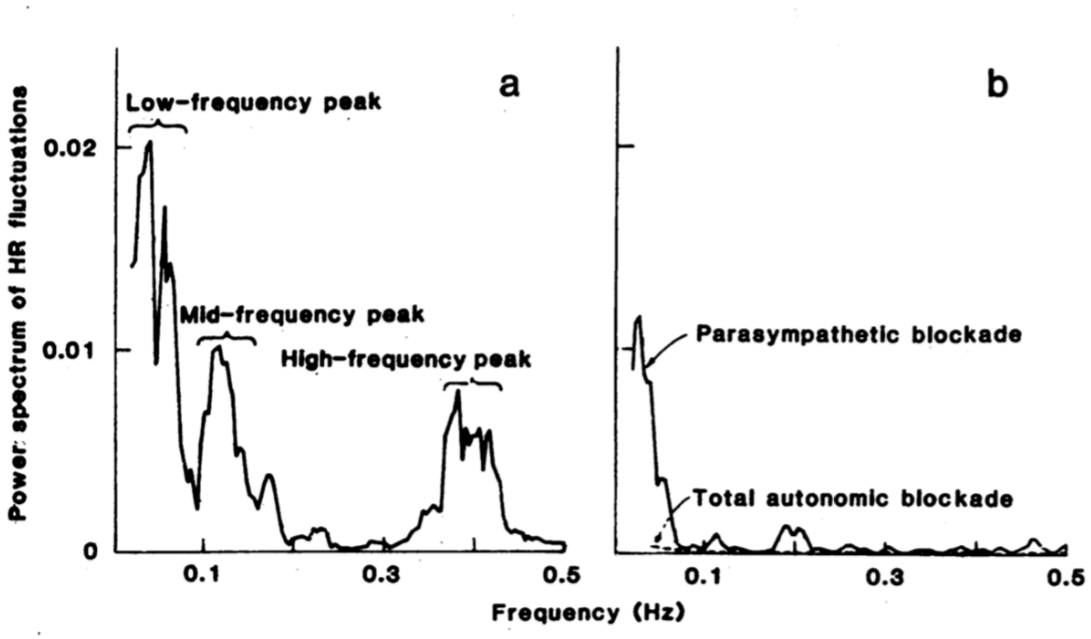


Figure 3: Power spectrum analysis (71)

Nonparametric methods have the advantage of having a simplistic algorithm (mostly fast Fourier transformation) and higher processing speed (68). Parametric methods are more advantageous in that that they have smoother spectral components that can be independently distinguished from preselected frequency bands, easier post processing of the spectrum with automatic calculation of low-frequency (LF) and HF power components and accurate estimation of PSD even on smaller numbered samples (68). Within the frequency-domain analysis, there are spectral short-term and long-term components. Short-term components are calculated from readings of 2 – 5 minutes with three main peaks identified, very low frequency (VLF) <0.04Hz, LF 0.04-0.15Hz and HF 0.15-0.4Hz (48,68). The interplay of power distribution and central frequency between LF and HF is not fixed and varies with autonomic modulation of the heart period. VLF is less defined and the physiological process to the change in heart period is questionable and is therefore not advised to be used in readings ≤ 5 minutes (68). VLF, LF and HF measurements are usually made in absolute values of power (ms^2), however, LF and HF may also be measured in normalised units (nu), which represent the controlled balance between the SNS and PNS (48,68).

Long-term recordings over a 24-hour period also utilise spectral analysis of the NN interval and utilise VLF, LF, HF and incorporate the ultra-low frequency

component. However, it is possible that during long-term recordings, there may be a period where frequencies remain unchanged. Thus at analysis, the results may have to be obtained from the shorter 5-minute segments and averaged over the entire 24-hour period, all of which will result in details being obscured about the autonomic modulation of RR intervals (68). HRV measures fluctuations in autonomic inputs to the heart rather than the mean level of autonomic inputs. Therefore, both autonomic withdrawal and high level of sympathetic tone lead to decreased HRV (72). The HF and LF components represent the PNS and SNS systems, respectively. Therefore having an increased HF component and a decreased LF component, the balance would favour an increased HRV. This is also reflected by a lower LF/HF ratio.

The study by van den Berg et al (67) only measured two of the time-domain variables (SDNN and RMSSD) for 10 seconds, representing ultra-short recordings while the ECS and NASPE task force (68) gave normal values for the 24-hour recordings for both time-domain and frequency-domain. In the systematic review of normal values for short-term HRV by Nunan et al (64), a collection of short-term HRV studies including adults 18 years and older were analysed in both the time-domain and frequency-domain as seen in Table 3.

Table 3: Normal values for short-term HRV (64)

HRV Variable	Mean (SD)
mRR (ms)	926 (90)
SDNN (ms)	50 (16)
RMSSD (ms)	42 (15)
LF (nu)	52 (10)
HF (nu)	40 (10)
LF:HF ratio	2.8 (2.6)

1.6.3 Heart rate variability in health care workers pre and post call

Health care workers including doctors, nurses, physio- and occupational therapists to name a few, play a pivotal role in ensuring the delivery of care and services to the young, old, sick and ailing (73). However, not only do these health care workers have to deal with the daily stresses of life, they experience the stress of long working hours that may include night calls or shifts or both. HRV has been used to assess the role night calls or night shifts may have on the health of health care workers (54). In a 2019 pilot study in critical care units of a regional Department of Veterans Affairs Medical Center, in South Carolina (74), continuous HRV monitoring for 36-hours was measured in nurses doing night shift and compared the results to the HRV in nurses doing the day shift. The results suggested no apparent difference in HRV between the two shifts (74). Similar results were found in a 2013 Finnish study (75) involving nurses, where HRV measurements were recorded from a three-shift schedule. The study suggested no difference and attributed this to the nurses' ability to adapt to night shifts.

All medical disciplines experience their own unique stresses that are associated with the type of patients and illnesses they manage. In 2011 a Swedish study involving physicians working on night call (18), anaesthetists HRV was compared to the HRV of paediatricians and ear, nose and throat surgeons using a Holter ECG, during a 16-hour night call. The authors concluded that while on call, HRV was decreased in the anaesthetist group but post night call, there was no significant difference in HRV between the two groups and that overall HRV post call was unchanged across all groups. In a Danish surgical department study done in 2014 (76), including interns to specialist surgeon, HRV was measured during a 48-hour period and determined that night calls have a significant role in decreasing HRV. It was also reported that no difference in HRV was noted across the group. In a 2019 study of an orthopaedic department in Texas (77), involving the orthopaedic residents and their attendings, HRV was measured over a four-week period and included their leisure and on-duty time. The results demonstrated that orthopaedic surgeons have a poor resting heart rate and decreased HRV, likely attributable to the night calls they do. It also concluded that resting heart rate in the residents was higher than that of the attendings and that number of night calls

have a correlation with decreased HRV. Hulsegge (78) deduced that HRV only decreased among males doing shift work and that HRV in females showed little to no changes. This suggests that imbalances of the ANS may occur only in male shift workers and consequently, the associated sequelae.

1.7 Summary

HRV is a useful, non-invasive measurement tool used to investigate the balance between the SNS, PNS and ANS. These systems, along with the HPA axis are affected when the body is placed under stress. Although it is possible to ascertain an individual is under stress from them verbally, there are many subjective variables that will impact the findings and hence the results. In a meta-analysis (79) it was illustrated that HRV is impacted by psychological stress and hence can be reliably used as a marker of physiological health. In a study (73), a link between an organism's state of well-being (cardiovascular) and increased or decreased HRV was suggested. Studies (55,56) have illustrated the prognostic value of HRV in healthy and critically ill patients. With the acute and chronic stress and their sequelae experienced by the medical fraternity and the alarming rise in physician suicide rates, that being the highest globally among all professions (80) intervention is needed. In a study by Stellenbosch University (81), it was demonstrated that severe burnout among anaesthetists is three times the international average. It is therefore pertinent to the well-being of all anaesthetists, their families and their patients that investigations into work stress are explored and if night calls play a critical role in stress and its mental and psychological ramifications. With the ongoing and validated use of HRV used in various research fields, it being minimally invasive and accurate, a better understanding of stress and its effects experienced by anaesthetists during a night call may be elucidated.

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All articles should include an abstract. The structured abstract for an Original Research article should be between 200 and 230 words and should consist of four paragraphs labelled Background, Methods, Results, and Conclusions. It should briefly describe the problem or issue being addressed in the study, how the study was performed, the major results, and what the authors conclude from these results. The abstracts for other types of articles should be no longer than 230 words and need not follow the structured abstract format.

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1. Jun BC, Song SW, Park CS, Lee DH, Cho KJ, Cho JH. The analysis of maxillary sinus aeration according to aging process: volume assessment by 3-

dimensional reconstruction by high-resolutional CT scanning. Otolaryngol Head Neck Surg. 2005 Mar;132(3):429-34.

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11. Figure numbers: Arabic, table numbers: Roman

Section 3: Draft article

Heart rate variability of anaesthesiology registrars pre and post night call at a central hospital

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Key words: heart rate variability, night call, anaesthetist

Abstract

Background

Heart rate variability (HRV) is a tool used to measure the bio-psycho-social aspects of stress. Night call is associated with increased levels of stress and therefore decreased HRV. HRV in anaesthetists is currently unknown. The aim of this study was, therefore, to compare HRV pre and post night call in registrars in the Department of Anaesthesiology at Chris Hani Baragwanath Academic Hospital.

Methods

This was a cross-sectional study using convenience sampling. Pre and post night call HRV recordings were taken from 27 registrars using the Suunto® Smart Belt. The computer-based software Kubios® was used for data analysis. Time- and frequency-based analyses were done. The normal values from a systematic review for short-term HRV were used in this study.

Results

Overall HRV was low with no significant difference pre and post night call (Low frequency to high frequency ratio (LF:HF), 3.215 vs 3.473, p=0.719). There was no significant difference in overall HRV pre and post call between male and female registrars (LF:HF, 3.331 vs 3.090, p=0.805 and 4.128 vs 2.768, p=0.296). No significant differences in overall HRV pre and post call between junior and senior registrars (LF:HF, 3.094 vs 3.391, p=0.765 and 3.034 vs 4.113, p=0.417). However, there was a significant difference in post call overall HRV in time-domain variable, standard deviation of the normalised RR interval (SDNN) (54.2 vs 42.4, p=0.048). There was a positive, statistically significant correlation between number of night calls, SDNN (r=0.456, p=0.0017) and the square root of the mean squared differences of successive NN intervals (RMSSD) (r=0.502, p=0.008).

Conclusion

In this study, registrars showed increased sympathetic nervous system dominance, with the associated decreased HRV both pre and post night call with no significant difference between these two time periods. The reasons for this decreased HRV may be multifactorial. There was no significant difference between HRV of male and female registrars or between junior and senior registrars.

Introduction

The health of workers encompasses physiological and psychosocial well-being, which is particularly pertinent to the medical fraternity. The high work stress profile of medicine has been associated with a concerning rise in physician burnout and suicide rates (1). Measures encompassing the bio-psycho-social well-being of doctors should be put in place to prevent complications such as macro and microvascular diseases associated with shift work (2).

Stress is a subjective phenomenon perceived and experienced by all living organisms. Heart rate variability (HRV) is one type of measurement used to assess stress, the balance between the sympathetic nervous system (SNS) and parasympathetic nervous system (PNS) and gives an impression of the overall health of the cardiovascular system (3).

According to the Basic Conditions of Employment Act, 1997 (4), night work is defined as being between 18:00 and 06:00 meaning, a 12-hour shift. However, within the medical fraternity, these hours worked vary in duration and in some cases, often exceed those stipulated by the Act. Multiple night calls are often done to address the patient load. Ferri et al (5) demonstrated that with greater stress loads, there was increased burnout. Night shift duty longer than 17 hours should be avoided, as suggested by the South African Society of Anaesthesiologists (6). There has been no defined amount of recovery time between night calls, and studies suggest a lack of recovery time negatively impacts the night worker's health (7).

Burnout is defined as a form of physical, emotional and mental fatigue due to extended periods of physiological and emotional stress and strain (8). Burnout has been shown to manifest pathologically through maladaptation of the cardiovascular, endocrine and nervous systems, among others as seen by raised blood pressure, diabetes and mood disorders, respectively (9). Burnout seen in the medical fraternity has far-reaching consequences affecting health care workers directly, their families, their patients and the health care system itself.

Maladaptive alterations of the autonomic nervous system and hypothalamic-pituitary-adrenal axis are seen when stress is experienced in the work-place over prolonged periods (10). McEwen (10) described the concepts of allostasis and the allostatic load theory where the body is able to maintain the balance of the autonomic nervous system and hypothalamic-pituitary-adrenal axis under acute stress (allostasis), while under chronic stress (allostatic load) there is an imbalance resulting in wear and tear and hence multisystem pathologies. The allostatic load theory explains the imbalance between the SNS and PNS and it is the over-stimulation of the SNS that is associated with disease progression as noted by the Framingham Heart Study (11).

Registrars working in the University of the Witwatersrand affiliated hospitals are required to work between 52 – 80 hours of overtime every month. However, due to increased patient load and resource demand exceeding supply, more night calls are needed, hence leading to increased overtime. HRV in orthopaedic (12) and general surgeons (13) was noted to be decreased and inversely correlated to the number of night calls and duration of night calls.

With ongoing stress, there is an unfavourable balance between the SNS and PNS, which results in undesirable sequelae. With the increasing rate of suicide, high levels of stress (14) and burnout (15) seen in anaesthetic registrars in South Africa, these factors contribute to the imbalance of the SNS and PNS as reflected by changes in HRV. HRV is currently not known in anaesthetic registrars. The aim of this study was to compare HRV in registrars in the Department of Anaesthesiology at Chris Hani Baragwanath Academic Hospital (CHBAH) pre and post night call using the Suunto® Smart Belt.

Methods

Approval to conduct this study was obtained from the Human Research Ethics Committee (Medical) (M191114) of the University of the Witwatersrand and other relevant authorities. A cross-sectional research design was followed.

The study population consisted of registrars, 29 – 39 years of age, working in the Department of Anaesthesiology at CHBAH. The sample size was determined in consultation with a biostatistician. A sample size of 27 registrars was calculated as

based on a standard deviation of 2 (16), a population corrected factor of 112, alpha of 5% and a power of 80%. A convenience sampling method was used. Registrars with known arrhythmias, taking beta-blockers or sympatholytic type drugs or both and those who did not have a post call HRV measurement were excluded from the study. First- and second-year registrars were classified as juniors and those ≥ 3 years were seniors.

Following an extensive literature review, a draft data collection sheet was compiled and was reviewed by one anaesthesiologist and two physiologists with an interest in HRV. Their recommendations were included in the final data collection sheet, that collected demographics, pre and post night call HRV measurements of registrars.

The Suunto® Smart Belt, a mobile device, was used to record HRV. It has been validated as a surrogate to a Holter monitor to measure HRV (17). The computer software, Kubios® (Department of Applied Physics, University of Cuopio, Finland) (18) was used to interpret the data. It has been validated for use in research and for other clinical applications (19).

Registrars were invited to participate by one author (TB) in advance and written consent was obtained. The pre night call data were collected between 07:00 and 11:00 any day before the scheduled night call. The demographic form was completed and the Suunto® Smart Belt was attached. The registrar sat quietly for five minutes before the recording of data started. HRV was then measured for 10 minutes. The data from the Suunto® Smart Belt was downloaded to Kubios® on a laptop. The data were checked to ensure successful transfer. In between recordings, the Suunto® Smart Belt was cleaned with an alcohol-based solution. The post night call data collection followed the same process as the pre call HRV as soon as possible at the end of the night call. Five Suunto® Smart Belt devices were available to record HRV, thus minimising the time registrars were asked to remain at the hospital post night call. Night call at CHBAH is from 16:00 – 08:00.

The following concepts were used in this study.

- HRV is the variability of intervals between QRS complexes generated by sinus node depolarisation in one continuous recording.

- RR interval is the distance between two consecutive R-waves of the QRS complex on an ECG.
- NN interval is the normalised RR interval.
- SDNN is the standard deviation of the NN interval and represents overall HRV in ms.
- RMSSD is the root mean square of successive RR intervals and represents the PNS in ms.
- LF represents the low-frequency modulation of the SNS and PNS and is measured in normalised units (nu).
- HF represents the high-frequency modulation of the PNS and measured in normalised units (nu).
- LF:HF ratio represents autonomic nervous system balance (20).

Data were analysed in consultation with a statistician using the statistical programs STATA (StataCorp, USA) 13.1 and Kubios® (Department of Applied Physics, University of Cuopio, Finland). Categorical variables (sex and rank of registrar) were described using frequencies and percentages. For the primary objective, the pre night call HRV was used as a control and the post night call HRV as a comparison. As data were normally distributed, continuous variables were summarised as means and standard deviations and compared using paired t-tests. The secondary objectives of comparing male and female and junior and senior registrars were done using independent t-tests. A p-value of 0.05 or less was considered statistically significant.

The frequency- and time-domain variables measured for HRV, the normal values (21) and the effect on the SNS and PNS are shown in Table 1. In the tables, SNS dominance is shown by blue shading, PNS dominance by green shading and values within the normal range remain unshaded.

Table 1: Heart rate variability variables and normal values (21)

Heart rate variability			
Domain		**Normal values**	
	SNS dominance		**PNS dominance**
	↑ Heart rate	60-100	↓ Heart rate
Time	↓ SDNN	50 (16)	↑ SDNN
	↓ RMSSD	42 (15)	↑ RMSSD
Frequency	↓ HF	40nu (15)	↑ HF
	↑ LF	52nu (52)	↓ LF
	↑ LF:HF ratio	2.8	↓ LF:HF ratio

Results

Twenty-eight registrars were invited to participate in this study. One registrar declined participation, resulting in a sample of 27 participants. The characteristics of the participants are shown in Table 2.

Table 2: Characteristics of participants

Characteristic	**Number**	**Percent**
Sex		
Male	14	51.9
Female	13	48.1
Registrar year		
Junior	16	59.3
Senior	11	40.7
	Mean	**SD**
Age (years)		
Male	33.0	3.2
Female	31.7	2.0
Number of calls (per month)		
Junior	5.3	0.7
Senior	4.7	0.6

The comparison between the participants' HRV variables pre and post call are shown in Table 3. There were no statistically significant differences between any of the variables pre and post call.

Table 3: Participants' pre and post call HRVs

HRV variable	Mean	SD	p-value
Time-domain			
Mean HR (bpm)			
Pre call	78.4	12.6	
Post call	75.0	11.4	0.146
SDNN (ms)			
Pre call	49.7	19.3	
Post call	49.4	16.9	0.940
RMSSD (ms)			
Pre call	41.6	20.5	
Post call	44.2	21.2	0.612
Frequency-domain			
LF (nu)			
Pre call	69.9	13.1	
Post call	69.6	14.7	0.934
HF (nu)			
Pre call	30.0	13.1	
Post call	30.3	14.6	0.934
LF:HF ratio			
Pre call	3.2	2.5	
Post call	3.5	3.3	0.719

The comparisons between the pre and post call HRV variables of males and females and between senior and junior participants are shown in Table 4 and Table 5, respectively. There were no significant differences between the pre call HRV of males and females or the post call HRV or between junior and senior participants.

Table 4: Male and female pre and post call HRVs

HRV variable	Pre call		Post call	
Time-domain	**Mean (SD)**	**p-value**	**Mean (SD)**	**p-value**
Mean HR (bpm)				
Male	74.7 (11.8)		71.1 (11.3)	
Female	82.4 (12.6)	0.110	79.1 (10.4)	0.066
SDNN (ms)				
Male	46.6 (14.1)		49.8 (16.7)	
Female	53.0 (23.9)	0.401	49.0 (17.9)	0.907
RMSSD (ms)				
Male	37.5 (16.4)		44.4 (23.9)	
Female	46.0 (24.1)	0.291	43.9 (18.9)	0.956
Frequency-domain				
LF (nu)				
Male	71.1 (13.6)		73.4 (12.4)	
Female	68.6 (12.9)	0.629	65.6 (16.2)	0.170
Hf (nu)				
Male	28.8 (13.6)		26.5(12.4)	
Female	31.3 (12.9)	0.623	34.3 (16.2)	0.172
LF HF ratio				
Male	3.3 (2.4)		4.1 (4.0)	
Female	3.1 (2.6)	0.805	2.8 (2.3)	0.296

Table 5: Junior and senior pre and post call HRVs

HRV parameter	Pre call		Post call	
Time-domain	**Mean (SD)**	**p-value**	**Mean (SD)**	**p-value**
Mean HR (bpm)				
Junior	78.2 (12.4)		71.7 (10.6)	
Senior	78.7 (13.5)	0.915	79.6 (11.4)	0.076
SDNN (ms)				
Junior	49.7 (20.2)		54.2 (19.1)	
Senior	49.7 (19.0)	0.999	42.4 (10.3)	**0.048**
RMSSD (ms)				
Junior	42.0 (23.8)		50.1 (23.7)	
Senior	41.0 (15.7)	0.908	35.5 (13.7)	0.080
Frequency-domain				
LF (nu)				
Junior	71.5 (10.4)		68.7 (14.8)	
Senior	67.7 (16.5)	0.470	80.0 (15.1)	0.701
Hf (nu)				
Junior	28.4 (10.4)		31.2 (14.7)	
Senior	32.3 (16.5)	0.466	28.9 (15.0)	0.466
LF HF ratio				
Junior	3.1 (1.958)		3.0 (2.2)	
Senior	3.4 (3.159)	0.765	4.1 (4.6)	0.417

The correlations for change in HRV variable with the number of calls per month are shown in Table 6. Within the time-domain variables, strong and moderate statistically significant positive correlations were found for the number of night calls per month and RMSSD and SDNN, respectively. This may suggest that with an increasing number of night calls, HRV and PNS dominance increase.

Table 6: Correlation of change in HRV parameters with number of night calls

HRV parameter	Post call (r)	p-value
Mean HR	-0.332	0.091
SDNN	0.456	**0.017**
RMSSD	0.502	**0.008**
LF nu	-0.267	0.179
HF nu	0.266	0.179
LF HF ratio	-0.192	0.337

Discussion

There is an SNS dominance as seen by a decreased HRV in this study with no statistically significant difference between pre and post call night. Similarly in a physician working on night call study (16) and a pilot study among critical care nurses (22), there were no differences in HRV noted in pre and post night call and post night shift. These findings were also found in a study done in a surgical department (13), where HRV was only decreased during the night call. In a study involving an orthopaedic department (12), HRV was measured over a four-week period and showed that HRV was decreased among participants. However, it must be noted that the methodologies of these studies differed from this study where 10-minute readings pre and post night call were done on registrars being their own controls. In the previously mentioned studies, continuous recordings were done for 36-hours (22) to four weeks (12). In the critical care nurses, recordings were taken in two separate groups, day shift and night shift (22).

Decreased HRV and SNS dominance may indicate chronic stress (23). The possible contributors to the decrease in HRV and SNS dominance, and no change between pre and post night call HRV in this study may be multifactorial. At CHBAH night calls are randomly assigned that may not allow registrars adequate time for recovery. Night call and stress should be followed by a process of recovery and where this recovery process is delayed or even deficient, the individual may be unable to attain the harmonious recovery state for optimal functioning (7). Registrar night calls are done in a milieu of high demand for service delivery, studying and personal commitments all of which contribute to chronic stress.

Furthermore, South Africa is rated 109th in the World Happiness Report (24) and according to Shi et al (25), emotional states of happiness and sadness have been shown to alter HRV. South Africans are exposed to the worries of uncontrolled crime rates, load-shedding, corruption and moral decline (26), all of which may have an impact on happiness, levels of stress and therefore HRV.

No difference in HRV was noted between female and male registrars pre or post call. This result is similar to a general population study in the Netherlands, where only a small difference in HRV between male and females was noted (27). This is in contrast to Hulsegge (28) who found a decrease in HRV among males doing shift work while no change was noted among female shift workers. No difference in HRV was found in junior registrars compared to senior registrars within the frequency-domain variables. However, a difference was noted in the time-domain variable SDNN. Having greater responsibilities such as supervising and managing night shifts, avoiding conflict with medical staff and attending to more critically ill patients may result in higher stress levels. A Taiwan study (29) also found junior staff to have a higher HRV, however, no difference in HRV were found between staff seniority in the orthopaedic (12) and surgical study (13).

The number of night calls showed a positive correlation to an increased overall HRV and PNS dominance within the time-domain variable of SDNN while no differences were seen in the frequency-domain variables. This may be attributed to randomly assigned night calls for the month. The night calls may also be clumped together early or later on in the month with an isolated call, weeks apart from the clumped night calls thus impacting the value of the pre HRV recording. This was found to be in contrast to the orthopaedic study (12) which found the number of overnight calls had the strongest correlation with worse HRV.

A limitation of this study is that it was a single contextual study only including registrars. Furthermore, the length of time from the last call was not ascertained and also only a snapshot of HRV recordings were obtained.

It is recommended that HRV be acquired in all anaesthetists in the department to determine if a low HRV is isolated in only anaesthetic registrars. Longer periods of

HRV recordings should be done to more accurately assess the impact of night call on HRV.

Conclusion

In this study, registrars had decreased HRV with SNS dominance in both pre and post night call and there was no significant difference between these two time periods. This is concerning as decreased HRV is associated with current health status, including stress levels and as the pre-call HRV was decreased this may indicate chronic stress in these registrars. The reasons for this decreased HRV may be multifactorial. There was no significant difference between HRV of male and female registrars however, post call there was a statistically significant difference in the HRV of senior and junior registrars with seniors having lower HRV than juniors.

Conflict of interest

The authors declare that we have no financial or personal relationships which may have inappropriately influenced us in writing this paper.

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Section 4: Proposal

Heart rate variability of anaesthesiology registrars pre and post night call at a central hospital

Trevor Martin Blumenthal

0404436Y

Supervisor	Juan Scribante Department of Anaesthesiology
Co-supervisor	Helen Perrie Department of Anaesthesiology
Clinical-supervisor	Tristan Leonard Department of Anaesthesiology

4.1 Introduction and problem statement

The health of workers encompasses physiological and psychosocial well-being, which is particularly pertinent to the medical fraternity. The high work stress profile of medicine has been associated with a concerning rise in physician burnout and suicide rates (1). Measures encompassing the bio-psycho-social well-being of doctors should be put in place to prevent complications such as macro and microvascular diseases associated with shift work (2).

Stress is a subjective phenomenon perceived and experienced by all living organisms. Heart rate variability (HRV) is one type of measurement used to assess stress, the balance between the sympathetic nervous system and parasympathetic nervous system, and gives an impression of the overall health of the cardiovascular system (3).

According to the Basic Conditions of Employment Act, 1997 (4), night work is defined as being between 18:00 and 06:00 meaning, a 12-hour shift. However, within the medical fraternity, these hours worked vary in duration and in some cases, often exceed those stipulated by the Act. Multiple night calls are often done to service the increasing patient load, which have been shown by Ferri et al (5) to result in greater stress loads and hence burnout. Night call duty longer than 17 hours should be avoided, as suggested by the South African Society of Anaesthesiologists (6). There has been no defined amount of recovery time between night calls, and studies suggest a lack of recovery time negatively impacts the health of the night worker (7).

Burnout is defined as a form of physical, emotional and mental fatigue due to extended periods of physiological and emotional stress and strain (8). Burnout has been shown to manifest pathologically through maladaptation of the cardiovascular, endocrine and nervous systems among others as seen by raised blood pressure, diabetes and mood disorders, respectively (9). Burnout seen in the medical-fraternity has far-reaching consequences affecting health care workers directly, their families, their patients and the health care system itself.

Maladaptive alterations of the autonomic nervous system and hypothalamic-pituitary-adrenal axis are seen when stress is experienced in the work-place over prolonged periods (10). McEwen (10) described the concepts of allostasis and the allostatic load theory where the body is able to maintain the balance of the autonomic nervous system and hypothalamic-pituitary-adrenal axis under acute stress (allostasis), while under chronic stress (allostatic load) there is an imbalance resulting in wear and tear and hence multisystem pathologies.

The allostatic load theory explains the imbalance between the sympathetic nervous system and parasympathetic nervous system and it is the over-stimulation of the sympathetic nervous system that is associated with disease progression as noted by the Framingham Heart Study (11).

Registrars working in the University of the Witwatersrand (Wits) affiliated hospitals are required to work between 52 – 80 hours of overtime every month. However, the amount of overtime worked often exceeds these agreed hours leading to more night calls. HRV in orthopaedic (12) and general surgeons (13) was noted to be decreased and inversely correlated to the number of night calls and duration of night calls.

HRV represents the balance between the sympathetic and parasympathetic nervous systems. With ongoing stress, there is an unfavourable balance between these systems, which results in undesirable sequelae. With the increasing rate of suicide, high levels of stress (14) and burnout (15) seen in anaesthetic registrars in South Africa, these factors contribute to the imbalance of the sympathetic and parasympathetic systems as reflected by changes in HRV. HRV is currently not known in anaesthetic registrars.

4.2 Aim and objectives

4.2.1 Aim

The aim of this study is to compare HRV in registrars in the Department of Anaesthesiology at Chris Hani Baragwanath Academic Hospital (CHBAH) pre and post night call using the Suunto® Smart Belt.

4.2.2 Objectives

The primary objective of this study is to compare registrars' HRV pre and post night call.

The secondary objectives of this study are to:

- compare HRV between male and female registrars
- compare HRV between senior and junior registrars
- correlate the average number of night calls to HRV.

4.3 Research assumptions

The following definitions will be used in this study.

Registrar: is a qualified doctor who is registered with the Health Professions Council of South Africa as a trainee anaesthetist.

Night call: is a defined time period specific to after-hour work in the Department of Anaesthesiology. A night call at CHBAH is from 16:00 – 08:00.

Heart rate variability: "the variation over time of the period between consecutive heartbeats and is predominantly dependent on the extrinsic regulation of the heart rate" (16). HRV is measured using time-domain and frequency-domain analysis (17). From the HRV collected, multiple time-domain and frequency-domain variables are constructed and analysed. In this study, HRV will be measured with a Suunto® Smart Belt.

Pre night call measurement: will occur a day preceding the night call, preferably in the morning.

Post night call measurement: will occur in the morning at the end of the night call as soon as possible.

4.4 Demarcation of study field

The study will be conducted in the Department of Anaesthesiology at CHBAH, which is affiliated to the Faculty of Health Sciences of WITS. CHBAH is a central hospital with 2 888 beds, 25 theatres and on average 65 000 surgeries are done per annum. Forty-four anaesthetic registrars rotate at any one time through the department.

4.5 Ethical considerations

The study will be conducted in accordance with the Declaration of Helsinki (17) and the South African Good Clinical Practice Guideline (18). Approval to conduct the study will be obtained from the Human Research Ethics Committee (Medical) and the Graduate Studies Committee at Wits. Further approval will be obtained from the Medical Advisory Committee at CHBAH (Appendix 1). Permission to conduct the research was obtained from the Head of the Department of Anaesthesiology at CHBAH (Appendix 2).

Anaesthetic registrars will be approached, the study will be explained, and they will be invited to participate. The anaesthetic registrars who elect to participate in the study will in no way be subordinate to the researcher. Those who agree will be provided with an information letter (Appendix 3), whereafter they will be requested to sign a consent form (Appendix 4). The duration of the study will be approximately 15 minutes on a preceding day, preferably a morning, before their next night call, and 15 minutes post night call. The registrar will rest for five minutes before each test. The Suunto® Smart belt will be attached to the participants, secured for 10 minutes, and the registrars will be asked to supply demographic information pre night call (Appendix 5).

Each registrar will be allocated a study number and data will be collected anonymously. A separate list with the registrars' name and study number will be compiled and filed separately. Only the researcher and supervisors will have access to the raw data, thereby ensuring confidentiality.

The data collected will be stored electronically and password protected for six years after the completion of the study. Results will be made available to registrars on request after completion of the study. Should the results indicate a decreased HRV, the results of the study will be made available to the Head of Department and the Anaesthesiology Wellness Committee with a view to modify the current night call system. If necessary, the participant will be referred to a physician to aid in modifying their current health status.

4.6 Research methodology

4.6.1 Research design

A cross-sectional research design will be followed in this study.

A cross-sectional design “involves the collection of data once the phenomena under study are captured during a single period of data collection” (19).

4.6.2 Study population

The study population consists of registrars working in the Department of Anaesthesiology at CHBAH.

4.6.3 Study sample

Sample size

The sample size was determined in consultation with a biostatistician. The number of registrars included will be 27 as based on a standard deviation of 2 (20), a population corrected factor of 112, alpha of 5% and a power of 80%.

Sampling method

In this study, a convenience sampling method will be used. Convenience sampling is a non-probability sampling method whereby participants are enrolled according to their availability and accessibility (21).

Inclusion and exclusion criteria

The inclusion criteria for this study are:

- registrars who are between the age of 29 – 39 years
- who consent to take part in the study.

The exclusion criteria in this study are:

- registrars with known arrhythmias
- registrars taking beta-blockers or sympatholytic type drugs or both
- registrars who do not have a post call HRV measurement.

4.6.4 Data collection

Data collection

Data collection sheet

Following an extensive literature review, a draft data collection sheet was compiled. The draft data collection sheet was reviewed by one anaesthesiologist and two physiologists with an interest in HRV. Their recommendations were included in the final data collection sheet.

The final data collection sheet (Appendix 5) will collect the following data:

- demographics
- pre night call HRV measurements
- post night call HRV measurements.

Equipment

The Suunto® Smart Belt is a mobile device that will be used to record HRV in this study. It has been validated as a surrogate to a Holter monitor to measure HRV (22). Kubios® is the computer software that will be used to interpret the data from the Suunto® Smart Belt. It has been validated for use in research and for other clinical applications (23).

Data collection process

Once ethics approval has been received, the researcher will invite the registrars in advance. The participating registrar will not be subordinate to the researcher. The

pre night call data collection will start between 07:00 and 11:00 any day before their scheduled night call. The demographic form will be completed and the Suunto® Smart Belt will be attached. The registrar will then sit quietly for five minutes before the recording of data starts. HRV will then be measured for 10 minutes. The data from the Suunto® Smart Belt will then be downloaded to Kubios® on a laptop. The data will be checked to ensure it was successfully transferred across, and if not, the readings will be repeated. In between registrar recordings, the Suunto® Smart Belt will be cleaned with an alcohol-based solution.

The post night call data collection will follow the same collection process as the pre call HRV. Five Suunto® Smart Belt devices will be available to record HRV, thus minimising the time registrars will be asked to stay post night call.

4.6.5 Data analysis

A Microsoft Excel spreadsheet will be used to capture data. Data will be analysed in consultation with a biostatistician using the statistical programs STATA (StataCorp, USA) 13.1 and Kubios®. Kubios® software analysis HRV into multiple variables as seen in table Categorical variables will be described using frequencies and percentages for sex and rank of registrar. For the primary objective, the pre night call HRV variables will be used as a control and the post night call HRV variables will be used for comparison. Due to HRV involving multiple variables, each variable will be analysed independently and compared. Continuous variables will be summarised as means and standard deviations or medians and inter-quartile ranges. Should the data follow a normal distribution, a paired t-test will be used. A Wilcoxon signed-rank test will be used should the data not follow a normal distribution. The secondary objectives of male and female comparison and junior and senior comparison, depending on the distribution, will be done with either the independent t-test or Mann-Whitney test. A p-value of 0.05 or less will be considered statistically significant. A correlation of 0 signifies no relationship at all. A correlational value near − 1 signifies a strong negative relationship, and a value near + 1 signifies a strong positive relationship (19).

4.7 Significance of the study

Night calls have been associated with an increase in complications such as macro and microvascular disease (2) and damage to DNA (24). Associated with night calls and concurrent day shifts is the decreased time for recovery, thus resulting in burnout. Burnout has far-reaching consequences, including cardiovascular disease, substance abuse and increased rate of suicide (25) to name a few. It has been documented that burnout among South African anaesthetists is three times the international average (26).

The results of the study will give insight into the HRV of anaesthesiology registrars. If the HRV is shown to be decreased, the current night call system can be modified, this may then contribute to an improved recovery period, increased HRV, less stress and less burnout in the department. Should any abnormal results be collected, the participant will be notified and given the appropriate channels of support.

4.8 Validity and reliability of the study

Bothma et al (27) refer to the validity of a study as “the degree to which a measurement represents a true value” and reliability as “the consistency of the measure achieved”.

The validity and reliability of the study will be ensured by:

- using an appropriate research design
- an appropriate sample size determined in consultation with a biostatistician
- use of the validated Suunto® Smart Belt on all registrars
- use of the validated processing software Kubios®
- data collection will be done by one researcher
- data analysed in consultation with a biostatistician.

4.9 Project outline

4.9.1 Time frame

Activity	Sept 2019	Dec 2019	Jan 2020	Feb 2020	Mar 2020	Apr 2020	May 2020	Jun 2020	Jul 2020	Aug 2020
Proposal preparation										
Literature review										
Proposal submission										
Ethics approval										
Post graduate approval										
Data collection										
Data analysis										
Draft article										
Submission										

4.9.2 Budget

Item	Price per page/item	Number of pages/items	Copies	Total
Proposal	R 1	15	6	R 150
Post graduate form	R 1	2	6	R 12
Information letter	R 1	1	30	R 30
Consent forms	R 1	1	30	R 30
Complete report	R 1	100	4	R 400
Suunto® Smart Belt	R 125	5	-	R 500
Kubios® software	R 3 500	1	-	R 3 500
Grand total				**R 4 662**

Five Suunto® Smart belts and Kubios ® software were purchased at the cost to the researcher. The Wits Department of Anaesthesiology will incur the costs of paper and printing of the post graduate application, information letters, consent forms and data collection sheets.

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4.11 Appendices

Appendix 1: Letter to the Medical Advisory Committee

Dr Trevor Martin Blumenthal
Department of Anaesthesiology
University of Witwatersrand
7 October 2019

Attention: Medical Advisory Committee

Medical Advisory Committee

Re: Pre and post night call heart rate variability of registrars in the department of anaesthesiology

Burnout, stress and suicide rate are factors that influence the lives of anaesthetic registrars. I will be conducting an M Med research study where I aim to compare the pre and post night call heart rate variabilities of registrars in the Department of Anaesthesiology. A Suunto® Smart Belt will be attached to the registrar for 10 minutes on the morning a day before the scheduled night call and for 10 minutes post their night call. A 5-minute rest period will be given prior to the collection of data both pre and post call. The pre and post measurements are done to determine their baseline heart rate variability and then to see whether night call duty has an impact on their heart rate variability respectively. Decreased heart rate variability is associated with multisystem diseases typically cardiovascular disease.

Only my supervisors and I will have access to the results thus ensuring confidentiality. A copy of the final report will be made available to you and the participating registrars after the completion of my data collection. My research done at Chris Hani Baragwanath Academic Hospital will not involve any cost to the hospital or Department of Anaesthesiology.

Yours sincerely,



Trevor Martin Blumenthal (071 361 5180)

Appendix 2: Approval of Head of department of anaesthesiology CHBAH

Dr Trevor Martin Blumenthal

Department of Anaesthesiology

University of Witwatersrand

7 October 2019

Attention: The Head of Department of Anaesthesiology

Dear Dr Lines

Re: Pre and post night call heart rate variability of registrars in the department of anaesthesiology

I will be conducting an M Med research study where I aim to compare the pre and post night call heart rate variabilities of registrars in the Department of Anaesthesiology. I will be using the Suunto® Smart Belt which will be attached to the registrar for 10 minutes on the morning a day before the scheduled night call and for 10 minutes post their night call. The pre and post measurements are done to determine their baseline heart rate variability and then to see whether night call duty has an impact on their heart rate variability respectively. Decreased heart rate variability is associated with multisystem diseases typically cardiovascular disease.

Only my supervisors and I will have access to the results thus ensuring confidentiality. A copy of the final report will be made available to you and the participating registrar after the completion of my data collection. My research done at Chris Hani Baragwanath Academic Hospital will not involve any cost to the hospital or Department of Anaesthesiology.

Yours sincerely,

T M. Blumenthal

Trevor Martin Blumenthal (071 361 5180)

Permission granted 08/10/2019

DR. D. LINES.

Appendix 3: Information letter

Pre and post night call heart rate variability of registrars in the department of anaesthesiology.

Dear Colleague,

Good day, my name is Trevor Martin Blumenthal. I am a registrar in the Department of Anaesthesiology and am currently busy with my M Med. I would like to invite you to participate in my research. The aim of my research is to determine the baseline heart rate variability of registrars in the Department of Anaesthesiology and compare it to the post night call heart rate variability.

The study will require you to be available for two mornings between 07:00 and 08:00, one morning pre night call, preferably the day before your scheduled night call and one morning post your night call. The test will take approximately 15 minutes. You will be asked to provide your demographics before attaching a Suunto® Smart Belt "hygienically cleaned" to your chest. No identifying information will be displayed and you will be given a study number. The data captured from the Suunto® Smart Belt will be uploaded to a secured database that is password protected. Only my supervisors and I will have access to the data. On completion of the study, you may request access to your data.

Participation is voluntary and you will be required to sign a consent form. You may, at any time, withdraw without explanation and will in no way be discriminated against.

Participation in this study does require you to stay up to 15 minutes after a night call but the value of the data may provide insight into the health of registrars and the impact night duties have on their health.

This study has been approved by the Human Research Ethics Committee (Medical) and the Graduate Studies Committee of Wits. Should you require any more information or wish to contact me regarding this study, my number is 071 361 5180. You may also contact:

- Professor CB Penny, Chairperson of the Human Research Ethics Committee (Medical) at the University of the Witwatersrand, on telephone: 011 717 2301, e-mail: Clement.Penny@wits.ac.za
- Committee Secretariat: Ms Z Ndlovu or Mr Rhulani Mkansi, telephone: 011 717 2700/1234, or e-mail: Zanele.Ndlovu@wits.ac.za or Rhulani.Mkansi@wits.ac.za or Charmaine.khumalo@wits.ac.za or josh.ndkingumandla@wits.ac.za

Thank you for your time

Yours Sincerely,

Trevor Blumenthal

Appendix 4: Consent

Pre and post night call heart rate variability of registrars in a department of anaesthesiology

1. I …… agree to participate in this research project. The research has been explained to me and I understand what my participation will involve.

2. I was given time to ask questions and found any answers given to me to be reasonable and satisfactory.

3. I understand that there will be no immediate benefit to me, should I agree to participate, nor will I receive any payment.

4. Participation will not cost me anything but my time.

5. I understand that even if I initially consent to take part in the study, I may withdraw at any time and would not be required to give reasons. If that happened, any data collected about me for the purposes of the study would immediately be destroyed, unless I give consent for it to be retained.

6. If I require further information, I have been given contact details, listed below.

…… (signature)

…… (date)

Contact details:

TM Blumenthal, cell phone: 071 361 5180 or by e-mail: 0404436Y@students.wits.ac.za

Professor CB Penny, Chairperson of the Human Research Ethics Committee (Medical) at the University of Witwatersrand, on telephone: 011 717 2301, or my e-mail: Clement.Penny@wits.ac.za

Committee Secretariats: Ms. Z Ndlovu or Mr. Rhulani Mkansi, telephone: 011 717 2700/1234, or e-mail at: Zanele.Ndlovu@wits.ac.za or Rhulani.Mkansi@wits.ac.za or Charmaine.khumalo@wits.ac.za or josh.ndkingumandla@wits.ac.za.

Appendix 5: Data collection sheet

Study Number	Age	Sex	Registrar year	Average number of night calls	Average number of days between calls	Pre call HRV		Post call HRV	
						SDNN		SDNN	
						RMSSD		RMSSD	
						PNS INDex		PNS Index	
						SNS INDEX		SNS Index	
Study Number	**Age**	**Sex**	**Registrar year**	**Average number of night calls**	**Average number of days between calls**	**Pre call HRV**		**Post call HRV**	
						SDNN		SDNN	
						RMSSD		RMSSD	
						PNS INDex		PNS Index	
						SNS INDEX		SNS Index	
Study Number	**Age**	**Sex**	**Registrar year**	**Average number of night calls**	**Average number of days between calls**	**Pre call HRV**		**Post call HRV**	
						SDNN		SDNN	
						RMSSD		RMSSD	
						PNS INDex		PNS Index	
						SNS INDEX		SNS Index	

Code:

SSDN- standard deviation of NN intervals.

RMSSD- the square root of the mean of the squares of the successive differences between adjacent NNs

PNS Index- Kubios® HRV software computed PNS value based on Mean RR (ms), RMSSD (ms) and SD1 (%)

SNS Index- Kubios® HRV software computed SNS value based on Mean HR (bpm), Baevsky's stress index and SD2 (%)

*A PNS (or SNS) index value of zero means that the parameters reflecting parasympathetic (or sympathetic) activity are on average equal to the normal population average.

Average number of calls in a 3 month period

(circle calls on the calendars below)

2020

January

S	M	T	W	T	F	S
29	30	31	1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	1
2	3	4	5	6	7	8

February

S	M	T	W	T	F	S
26	27	28	29	30	31	1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
1	2	3	4	5	6	7

March

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31	1	2	3	4
5	6	7	8	9	10	11

Section 5: Annexures

5.1 Ethics approval

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

R14/49 Dr TN Blumenthal

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)
CLEARANCE CERTIFICATE NO. M191114

NAME: (Principal Investigator)	Dr TN Blumenthal
DEPARTMENT:	School of Clinical Medicine Department of Anaesthesiology Charlotte Maxeke Johannesburg Academic Hospital
PROJECT TITLE:	Heart rate variability of anaesthesiology registrars pre- and post- night call at a central hospital
DATE CONSIDERED:	2019/11/29
DECISION:	Approved unconditionally
CONDITIONS:	
SUPERVISOR:	Prof J Scribante; Ms H Perrie; Dr T Leonard
APPROVED BY:	Dr CB Penny, Chairperson, HREC (Medical)
DATE OF APPROVAL:	2020/02/18

This clearance certificate is valid for 5 years from date of approval. Extension may be applied for.

DECLARATION OF INVESTIGATORS

To be completed in duplicate and **ONE COPY** returned to the Research Office Secretary on the 3rd Floor, Phillip Tobias Building, Parktown, University of the Witwatersrand, Johannesburg.
I/we fully understand the conditions under which I am/we are authorized to carry out the above-mentioned research and I/we undertake to ensure compliance with these conditions. Should any departure be contemplated, from the research protocol as approved, I/we undertake to submit details to the Committee. **I agree to submit a yearly progress report**. When a funder requires annual re-certification, the application date will be one year after the date when the study was initially reviewed. In this case, the study was initially reviewed in **November** and will therefore reports and re-certification will be due early in the month of **November** each year. Unreported changes to the application may invalidate the clearance given by the HREC (Medical).

Principal Investigator Signature

2020/02/18
Date

PLEASE QUOTE THE CLEARANCE CERTIFICATE NUMBER IN ALL ENQUIRIES

5.2 Graduate studies approval

UNIVERSITY OF THE
WITWATERSRAND,
JOHANNESBURG

Private Bag 3 Wits, 2050
Fax: 027117172119
Tel: 02711 7172076

Reference: Mrs Sandra Benn
E-mail: sandra.benn@wits.ac.za

11 December 2019
Person No: 0404436Y
PAG

Dr TM Blumenthal
P O Box 3719
Edenvale
1610
South Africa

Dear Dr Trevor Blumenthal

Master of Medicine in Anaesthesia: Approval of Title

We have pleasure in advising that your proposal entitled *Heart rate variability of anaesthesiology registrars pre and post night call at a central hospital* has been approved. Please note that any amendments to this title have to be endorsed by the Faculty's higher degrees committee and formally approved.

Yours sincerely

Mrs Sandra Benn
Faculty Registrar
Faculty of Health Sciences

5.3 Medical advisory committee

GAUTENG PROVINCE
HEALTH
REPUBLIC OF SOUTH AFRICA

MEDICAL ADVISORY COMMITTEE

CHRIS HANI BARAGWANATH ACADEMIC HOSPITAL

PERMISSION TO CONDUCT RESEARCH

Date: 3 February 2020

TITLE OF PROJECT:

Pre and post night shift HRV of registrars in the department of anaesthesiology

UNIVERSITY: Witwatersrand

Principal Investigator: TM Blumenthal

Department: Anaesthesiology

Supervisor/s : J Scribante, H Perrie

Permission Head Department (where research conducted): Yes

The Medical Advisory Committee recommends that the said research be conducted at Chris Hani Baragwanath Academic Hospital. The CEO / management of Chris Hani Baragwanath Academic Hospital is accordingly informed and the study is subject to:-

- Permission having been granted by the Committee for Research on Human Subjects of the University of the Witwatersrand.
- The Hospital will not incur extra costs as a result of the research being conducted on its patients within the hospital
- The MAC will be informed of any serious adverse events as soon as they occur
- Permission is granted for the duration of the Ethics Committee Approval.

Recommended
(On behalf of the MAC)
2020/02/03

Approved/~~Not Approved~~
Hospital ManagementDate:
Date: 04/02/2020

5.4 Turnitin report

0404436y:ref.docx

ORIGINALITY REPORT

14%	12%	11%	5%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

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5	Submitted to City University Student Paper	<1%
6	academic.oup.com Internet Source	<1%
7	link.springer.com Internet Source	<1%
8	F Desai, J Scribante, H Perrie, M Fourtounas. "Contamination of pulse oximeter probes before and after decontamination in two intensive care units", Southern African Journal of Critical Care,	<1%

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG | FACULTY OF HEALTH SCIENCES

12 February 2021

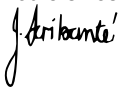
The Chairperson
Graduate Studies Committee
Faculty of Health Sciences
University of the Witwatersrand

Dear Professor Papathanasopoulos

Re: M Med: **Heart rate variability of anaesthesiology registrars pre and post night call at a central hospital**

Dr Trevor Blumenthal, student number: 0404436Y, has submitted his research report to Turnitin, which revealed a similarity index of 14%. These similarities appear not to be plagiarism but mainly the use of common terminology and phrases specific to the research topic.

Yours sincerely,



Juan Scribante
Supervisor