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Monitoring cardiovascular changes due to local anesthesia during and after tooth extraction using pulse wave analysis

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ABSTRACT

A study was conducted to determine the ongoing short-term changes in pulse waveform and pulse transit time in patients during tooth extraction. The sympathetic stimulation produced during tooth extraction under local anesthesia (LA) utilizing 2% lignocaine with adrenaline is evaluated. The increase in pulse rate due to vasoconstriction in the peripheral blood vessels has been quantifying the sympathetic stimulation to the local anesthesia. The ECG and pulse signals were recorded from 16 non-medically compromised dental patients in resting condition (before local anesthesia), 2–3 min after injection of local anesthesia and 5–10 min after tooth extraction. The amplitudes and timings of pulse, width, slope, pulse rate interval and PTT were computed for every pulse. More than 25% increase in amplitude and slope of the forward wave and about 15% decrease in rise time and the width of the forward wave were observed after injection of local anesthesia (PostLA) as compared to pre-local anesthesia (PreLA) stages. Indices utilizing the variations on pulse amplitude can provide a window to detect volume of anesthetic and vascular stiffness. It is seen that the PTT decreases more than 5% after LA and increased about 5% after surgery as compared to resting conditions (PreLA). The result suggests that the contour analysis of pulse waveform and PTT can be used to quantify the sympathetic stimulation due to local anesthesia in healthy dental patients. The variations in amplitude shall be given more efforts and attention in order to ride the challenge in developing some means of pulse contour, which can be used to assist in the monitoring of the local anesthetic volume and duration.

1. Introduction

Anxiety, fear and pain play an important role in dental treatment and induce cardiovascular and hemodynamic changes [1]. The physiological and hemodynamic changes are influenced by many factors (both psychological and physical) like pain and stress. The increase in blood pressure (BP) is common even in healthy subjects. Research groups have studied the changes in blood pressure, body temperature, oxygen saturation level and heart rate in different stages of the dental surgery [1–3]. Gedik et al. [2] has reported the factors such as patient age, gender, education and volume of anesthetic drug used are strong determinants of the extent of changes in the heart rate, blood pressure and temperature before and after oral surgery. Liau et al. [1] reported that significant changes in the blood pressure, SpO_2 and heart rate in different conditions such as pre-injection, immediately after, after 5 min, after 10 min and after 15 min of the anesthesia. Few research groups reported that the responses of cardiac sympathetic and parasympathetic nervous systems assessed by the time domain and frequency domain analysis of heart rate variability (HRV) during oral surgery [4–7]. Most third molar tooth extractions are performed with the help of local anesthesia, which affects the BP and HR via changes in the cardiac autonomic nervous system and which maintains cardiovascular stability. The combination of dental stress and local anesthetics containing a vasoconstrictor can potentially produce significant and possibly senses complications in the patient with a compromised cardiovascular system. The administration of a vasoconstrictor in combination with a local anesthetic has evolved as a method for decreasing toxicity, increasing the duration of anesthesia and providing homeostasis during the oral surgical procedure. Every step that is performed in the dental treatment is capable of being viewed as frightening by the patient. Anxiety related to injection of an anesthetic is probably due to psychological responses. The anticipation of the injection of anesthetic produces more fear than

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the actual injection [8]. The injection of anesthetic agent propofol results in vasodilation, which can lead to lethal consequences in some critical patients for whom it may be intolerable [9]. Blood pressure and pulse rate monitoring essential during dental procedures, especially during molar tooth extraction and minor oral surgery. In some patients the pulse rate and blood pressure increase due to excessive cardiac work during dental treatment [10]. The cardiovascular and hemodynamic changes are indices of sympathovagal tone assessed by heart rate variability, contour analysis of pulse waveform and pulse transit time.

Examination of pulse wave provides valuable information about the cardiovascular and hemodynamic changes. Contour analysis of the pulse waveform was used to assess the vascular stiffness [11]. It has been reported that the changes in pulse parameters such as amplitude and its timing interval occurred during physical and mental activities. The contour analysis of the pulse wave is a promising method to obtain the information of arterial stiffness and hemodynamic of blood vessel. The pulse wave travels along with the elastic arterial walls. The physiological reason for the elastic nature of the arterial wall is to buffer the pulsatile ejection of blood from the heart and to provide constant flow in the capillary beds. The pulse wave velocity (PWV) can describe the state of the artery. The speed at which the arterial pressure wave travels is directly proportional to the blood pressure [12]. The pulse wave velocity is measured by measuring PTT, which is obtained by measuring the time between the R peak of ECG and systolic peak of the pulse [13,14]. The measurement of PTT is generally accepted as the simplest, noninvasive, rapid and reproducible method for assessing large artery stiffness. The PTT is a function of intravascular pressure and the physical characteristics of both the blood and blood vessel. An acute rise in BP causes vascular tone to increase and hence the arterial wall becomes stiffer which causes PTT to reduce. Kim et al. [15] have shown the increased PTT with reduced systolic blood pressure during anesthesia induction in hypertensive patients during kidney transplant surgery and also reported that PTT variability may show potential as a useful noninvasive index of SBP. The PTT has clinically significant association with systolic hypertension at a given time and also enables prediction of changes in BP over a short period [13].

The primary objective of this study is to evaluate the changes in pulse waveform, pulse rate interval and PTT of non-medically compromised patients undergoing tooth extraction under local anesthesia with 2% lignocaine with adrenaline. Also it is required to examine the response to hemodynamic changes through contour analysis of pulse waveform and to determine the contribution of the anesthesia effects on sympathetic and parasympathetic activities.

2. Methods

2.1. Subjects and data acquisition

In this study totally 16 non-medically compromised patients were selected out of which eight were male (26.50 ± 4.504 years) and eight were female (24.00 ± 4.071 years) patients, with an average age 25.45 ± 4.344 years. The patients had no history of cardiovascular disease, hypertension and diabetes. The details of the experimental protocol were explained to the subjects. Further, all patients gave written informed consent for collection of data. The protocol was cleared and approved by the Institutional Ethical Committee, SJM Dental College and Hospital, Chitradurga, Karnataka, India. The patients were rested on the dental chair for a period of 5 min prior to the study. The experiments were conducted in the minor oral surgical section, Department of Oral and Maxillofacial Surgery, SJM Dental College and Hospital, Chitradurga. The ECG and pulse signals were recorded under normal breathing

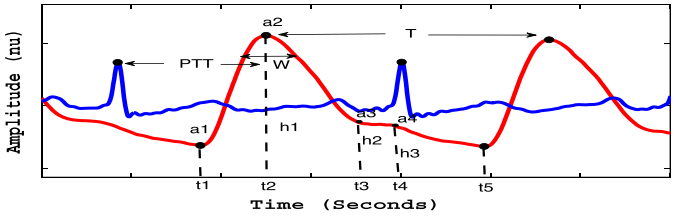

Fig. 1. Pulse characteristics derived from simultaneously recorded ECG and pulse signals.

condition using National Instruments' data acquisition card and signal express software from LabView. Sampling frequency of 500 Hz with a resolution of 14 bits per sample was used. The ECG and pulse were recorded in the minor oral surgical section before injection of local anesthesia (i.e. regional intra-oral nerve blocks), 2–3 min after injection and 5–10 min after tooth extraction. 1–1.5 ml of 2% lignox with dilution of 1:80,000 Adrenaline is given prior to oral surgery. The recorded ECG and pulse signals were extracted separately and preprocessed.

2.2. Data analysis

The characteristic features such as R wave peak of the ECG signal, diastolic (onset point) and systolic peak amplitude and corresponding timing intervals of each pulse were extracted to derive various parameters for analysis using the delineation algorithm [16]. The characteristics of pulse waveform are as shown in Fig. 1. The diastolic point (a_1) of the pulse is referred as baseline or foot point, the height of the systolic peak from onset point (amplitude $h_1 = a_2 - a_1$), elapsed time taken from onset point to the peak (rise time $T_1 = t_2 - t_1$), the ratio of amplitude to the rise time (slope h_1/T_1), the time taken to decline from systolic peak to onset of the next pulse (decay time $T_3 = t_5 - t_2$), the 70% of the peak of the forward wave (width W) and the inter beat interval between the successive peaks (T) are defined. In addition, the beat to beat changes in pulse transit time (PTT) were computed as the time delay between the R wave peak of ECGs and the systolic peak of the corresponding pulse signal. The ECG and pulse signals of two seconds duration were recorded during different stages and is shown in Fig. 2.

The averages of estimated parameters through 5 min of recording for all the patients during tooth extraction were as shown in Fig. 3. The mean parameters of all the patients before injection of local anesthesia, after injection of local anesthesia and after tooth extraction were analyzed. All the data were reported as mean ± SD.

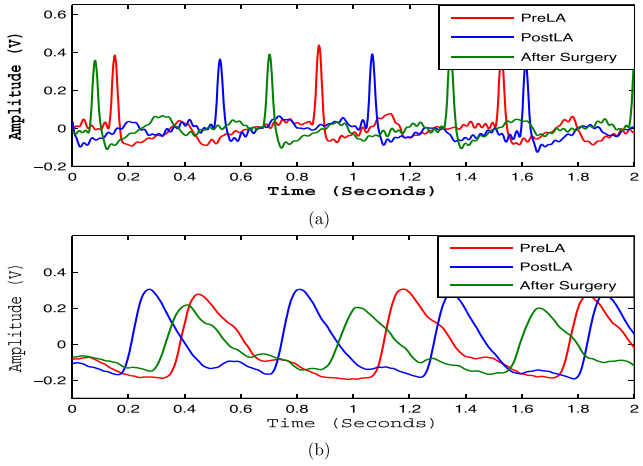

Fig. 2. ECG and pulse signals recorded during tooth extraction procedure.