Analysis Of an Arterial Pulse Using 1D KdV Model

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Abstract- In this study we developed a soliton model of an arterial pulse. The Korteweg-de Vries wave equation is our model of interest. It incorporates the aspect of modeling an arterial pulse which can potentially lead to development of better estimators of cardiac output. Accurate and continuous measurements of cardiac output are needed for severely ill COVID-19 patients but are often done using invasive methods. Another clinical importance is that the solitonic parameters inferred from the pulse could provide a better understanding of the physiology of cardiovascular disease and identify risk indicators in patients with hypertension. The results of this research may be helpful in the timely discovery of life-threatening cardiovascular conditions such as pulmonary embolism, stroke and heart attack in COVID-19 patients.

Indexed Terms- Arterial Pulse, Cardiovascular conditions, KdV equation, soliton

I. INTRODUCTION

This study proposes the use of arterial pulse analysis as a continuous and more efficient method to noninvasively measure cardiac output. This could be very useful during long surgeries and for patients in the intensive care units because changes in blood pressure could be caused by complications in the arterial system such as a burst artery. We use a simple KdV equation model for the pulse propagation. The advantage of using the soliton model is the ability to obtain a good approximation in amplitude change and the reduced computational cost.

II. MODEL MATCHING OF AN ARTERIAL PULSE

We study an oscillation amplitude curves to infer information on the diastolic, mean and systolic pressure. Blood pressure in artery is related to the stroke volume.

$$StrokeVolume = \frac{\int_{Ejection}\left[P_A(t) - P_D\right]dt}{Z}$$

$P_A(t)$ is arterial pressure at time t and P_D is arterial pressure at the end of the diastole. The area below the pulse is calculated using trapezoidal rule and it corresponds to stroke volume.

Extracting information from the pulse depends on a clean and noise free signal otherwise the results obtained may be inaccurate. Before using any algorithm, the noise is removed by filtering. The best filter is chosen using a simulation experiment. One pulse is selected and used as the representative pulse for the analysis.

Important features of each individual pulse are extracted such as;

i. Total pressure which is distance between the beginning and end of a pulse waveform.
ii. Systolic amplitude which is the maximum positive amplitude value.
iii. Diastolic amplitude is the minimum positive value of the curve.
iv. The mean arterial pressure is obtained when the x-axis value is zero.

The mean blood pressure should correspond to the standard pressure of the instruments used to measure pressure such as pulse monitors and pulmonary artery catheters. Cardiac output is the volume of blood per minute that is pumped from the left ventricle of the heart.

Cardiac output can be estimated from the relationship between the forward flow and the discrete spectrum of the pressure, that is;

$$Cardiac\,Output = Heart\,Rate \times Volumentric\,Flow$$

Cardiac output is measured in litres per minute. The heart rate is measured in hertz while stroke volume is expressed in millilitres. Cardiac output is a measure of how well the heart meets the oxygen demand of the body.

Several parameters such as cardiac output, systolic pressure, volumetric flow and heart rate are the estimated continuously and displayed as numerical values. This enables tracking changes in critical parameters whose implications can be intervened in a timely manner. Monitoring cardiac output assist in estimating oxygen delivery and understanding the causes of high blood pressure.

CONCLUSION

Simultaneous measurement of several hemodynamic parameters such as stroke volume, heart rate, systolic pressure and diastolic pressure is a practical way to improve noninvasive cardiac output estimates in future. We recommend inclusion of viscosity in the analysis of flow and arterial pulses. We also recommend the use of raw data in the wave fitting process.

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