Chapter 8
Heart Sound Analysis for Blood Pressure Estimation

Rui Guedes
Faculdade de Medicina da Universidade do Porto, Portugal

Henrique Cyrne Carvalho
Serviço de Cardiologia, Hospital de Santo António, Centro Hospitalar do Porto, Portugal

Ana Castro
Universidade do Porto, Portugal

ABSTRACT

This chapter aims to give a perspective on how the study of the heart sound relation with blood pressure has evolved. The use of heart sound as a surrogate of the BP has been used with more emphasis on the detection of pulmonary hypertension patients, considering the frequency content, amplitude, and split the second heart sound and its subcomponents, which arise following the closure of the corresponding heart valves. Estimation of BP using the analysis of heart sound is characterized by the simplicity of the equipment used to obtain data, which after analysis allows to achieve promising results that until now were only obtained with techniques requiring far more complex and expensive equipment. The main objective of this chapter is to understand how heart sound analysis may be used to estimate blood pressure and which methods are employed to detect pulmonary hypertension.

INTRODUCTION

Heart disease is one of the main causes of death globally. Some heart diseases may be diagnosed by measuring the pulmonary arterial pressure (PAP), which may be increased due to heart and pulmonary diseases. An increase in the pressure of the pulmonary artery could be an indication of pulmonary arterial hypertension, and may be defined as a mean PAP superior to 25 mmHg (Galie et al., 2009) and outside the 15-30 mmHg range for the systolic PAP (Edwards Lifesciences LLC, 2009).

For diagnostic purposes, most patients undergo an electrocardiogram (ECG), a chest X-ray, an echocardiogram, a computerized tomography scan of the chest, and a cardiac catheterization. The last one,

DOI: 10.4018/978-1-5225-7489-7.ch008

the invasive arterial blood pressure (BP) monitoring, is considered the gold standard for BP assessment, providing accurate information, however it is also the most expensive (Chung, Chen, Alexander, & Cannesson, 2013). During a cardiac catheterization, a small flexible tube is inserted into a blood vessel in the arm or the groin, with a contrast dye that makes it possible to see under X-ray and obtain images of the heart structure and vessels. The catheter with a pressure sensor allows measurement of pressures in the vessels and heart chambers, which provide clues to a pulmonary hypertension diagnosis. Despite the catheterization procedure being performed with the patient awake, and bring little or no pain, the patient may still feel pain in the blood vessel where the catheter is inserted. There is a mandatory rest time after the procedure. Also financial costs and risk discourage patients to undergo right heart catheterization procedure and from seeking potentially life-saving diagnosis and treatment of elevated PAP. Elevated PAP can be an indicator of pulmonary hypertension, a condition that may worsen over time, although treatments can relief symptoms and give patients a better quality of life. The diagnostic we want to focus in pulmonary hypertension is the pulmonary arterial hypertension (PAH) that is a type of high BP that occurs in the right side of the heart and in the pulmonary arteries. PAH occurs when the pulmonary arteries thicken or grow rigid, this makes blood flow more difficult. The right side of the heart has to work harder to push blood through the arteries, and the arteries are not able to carry adequate blood to oxygenate in the lungs. It is difficult to continuously assess pulmonary arterial hypertension evolution, which motivates the search for accurate noninvasive PAP measurement devices.

BACKGROUND

A noninvasive estimation of the PAP is already in clinical use, the Doppler echocardiography; it uses ultrasound technology to measure PAP by analyzing the speed of blood flowing through the heart. Doppler is widely used by cardiologists, it requires specific equipment, a specialized and trained doctor, and therefore it is difficult to be used for continuous monitoring, or in places without specialized healthcare professionals. Also some patients are not candidates for Doppler due to physiological constraints or poor signal-to-noise ratio: PAP cannot be estimated in 34 to 76% of patients with chronic obstructive pulmonary disease, 10 to 20% of patients with elevated PAP, and the most important in approximately half of patients with normal PAP (Xu, Durand, & Pibarot, 2003); also the Doppler estimations present an average error of 30% compared to right heart catheterization (Smith & Ventura, 2013).

Another method proposed for PAP noninvasive estimation is the heart sound analysis. Phonocardiography is a technique that generates a record of sounds produced by the contracting heart, resulting from valves and associated vessels vibration, the phonocardiogram (PCG), as we can see in Figure 1.

The sound is collected with a stethoscope over the main auscultations points on the chest; for the detection of pulmonary hypertension, usually the second heart sound exhibits an hyperphonesis of the pulmonary component, more audible over the pulmonary auscultation site (Young, 2001). Recent rebirth of the stethoscope, with electronic record of the PCG, has led to the search of automatic signal processing techniques to detect this clinical sign, and few studies have addressed this issue in the literature (J Xu et al., 2002; Lim, Shin, Park, & Bae, 2013; Nigam & Priemer, 2004). Phonocardiography has been used to estimate PAP from noninvasively recorded heart sounds using models for how these sounds correlate with PAP. There are however several research questions that need to be answered in the PCG study, namely the robust segmentation of heart sounds, and modeling of the heart components that allow the