Digital Auscultation:
Challenges and Perspectives

Daniel Pereira
Instituto de Telecomunicações CINTESIS, University of Porto, Portugal

Ana Castro
University of Porto, Portugal

Pedro Gomes
Instituto de Telecomunicações, University of Porto, Portugal

José Carlos Neves Cunha Areias
Faculty of Medicine, University of Porto, Portugal

Zilma Silveira Nogueira Reis
Federal University of Minas Gerais, Brazil

Miguel Tavares Coimbra
Instituto de Telecomunicações, University of Porto, Portugal

Ricardo Cruz-Correia
CINTESIS, University of Porto, Portugal

1. INTRODUCTION

Ever since Laënnec invented the stethoscope in 1816 (Laennec, 1819) that auscultation is an essential component of clinical examination. It is both a powerful screening tool, providing a cheap and quick initial assessment of a patient's clinical condition, and a hard skill to master. A number of factors contribute to the difficulty of, for example, cardiac auscultation. Relevant pathological activity is often soft, short-lived and occurs in proximity to loud, normal activity: a typical murmur is 1000 times softer than normal heart sounds and can last for as little as thirty milliseconds (Luisada, 1955). The acoustic information is also inconsistent across the course of an examination, owing to natural variation and noise. These factors make it difficult to precisely pinpoint a sound in the audio signal, and to identify markers indicative of heart disease.

What if we have the ability to digitally record auscultation sounds? Could we create richer electronic health records for future reference? Would we make better diagnostics if we could ask an expert opinion from a remote specialist or from a local clinical decision support system? Could we radically improve the way we train our clinicians in the art of auscultation?

In this article, we will discuss the potential of digital auscultation for answering all these questions, showing how modern interactive technologies can help us improve both current healthcare practice and medical training, transforming an ephemeral sound into something that can be stored, transmitted, analyzed and studied. Reinforced by real case studies in a variety of scenarios, we will discuss how auscultation signals can be systematically recorded for adequate integration into electronic health records

(obstetrics cardiac auscultation, Belo Horizonte, Brazil), how digital auscultation can be used in both hospital and field telemedicine scenarios (pediatric cardiac auscultation, Pernambuco - Paraíba, Brazil), how real annotated datasets are boosting research on algorithms for clinical decision support systems (Pascal challenge, Porto-London, Portugal-UK), and how real heart sounds coupled with new interactive technologies are improving the way we teach auscultation to medical students (Sports Cardiology b-learning course, Porto, Portugal).

What is the future of one of medicine's oldest and possibly most iconic art? Can you imagine a world in which physicians do not have stethoscopes? Or will the digital revolution propel it for 200 more years of clinical practice?

The rest of this article is organized as follows. In Section 2, we review a state of the art of the auscultation procedure and the evolution of stethoscopes. We discuss the new challenges of digital auscultation, namely electronic health records, telemedicine and the clinical decision support systems Section 3. The state of the art of the teaching of auscultation is reviewed on Section 4, and novel perspective discussed, contextualized by one of our own case studies. A final discussion and conclusions are addressed in Sections 5 and 6, respectively.

2. BACKGROUND OF CLINICAL AUSCULTATION

2.1. The Importance of Auscultation: Lost Art, Difficulties (302 de 300)

The stethoscope is the oldest cardiovascular diagnostic instrument in clinical use. However, cardiac auscultation is in decline and the lack of ability to either hear or interpret a cardiac abnormality starts with medical students and continues through to physicians of different ages (Pelech, 2004).

By auscultating the heart we have an understanding of the heart rate and rhythm, the sound of the closing and, sometimes, the opening of valves, and anatomical abnormalities such as congenital or acquired defects. Heart sounds are caused by turbulent blood flow, while laminar flow is silent. Cardiac auscultation is a valuable and inexpensive tool. When used properly the stethoscope often enables physicians to make a rapid and an accurate diagnosis without any additional studies.

Why is the auscultation becoming a lost art? The reasons for the decline in physicians' cardiac examination skills are numerous. High reliance on ordering diagnostic tests (Simel, 2006), conducting teaching rounds away from the bedside (Collins, Cassie, & Daggett, 1978; LaCombe, 1997), time constraints during residency (Shankel & Mazzaferri, 1986; Simel, 2006), and declining cardiac examination skills of faculty members themselves (Vukanovic-Criley et al., 2006) all may contribute to the diminished cardiac examination skills of residents. Residents, who themselves identify abnormal heart sounds at alarmingly low rates, play an ever-increasing role in medical students' instruction (Mangione & Nieman, 1997; Vukanovic-Criley et al., 2006) exacerbating the problem (Criley, Keiner, Boker, Criley, & Warde, 2008).

Later, for physicians, more elaborate and expensive technological advances, the fear of a litigious environment during the practice of medicine, along with sophisticated noninvasive and invasive diagnostic tests, are all reasons for considering the cardiac auscultation a lost and difficult art. We see often that the stethoscope around the practitioner´s neck is more of a decorative ornament than a diagnostic tool, with a growing perception among some practitioners that cardiac auscultation is old-fashioned. However, despite the current emphasis on technology, the stethoscope, when used properly, remains a valuable and cost-effective clinical skill that often establishes the diagnosis and severity of heart dis-

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