Available online at www.sciencedirect.com
ScienceDirect
Progress in Biophysics and Molecular Biology 93 (2007) 399–410
Progress in Biophysics & Molecular Biology
www.elsevier.com/locate/pbiomolbio

Review

Cardiac imaging: The biological effects of diagnostic cardiac ultrasound

Maria Grazia Andreassi*, Lucia Venneri, Eugenio Picano

CNR Institute of Clinical Physiology, Pisa, Italy

Available online 7 August 2006

Abstract

Diagnostic cardiac ultrasounds are an environment-friendly and non-ionising imaging technology. However, ultrasounds are not biologically inert, and their use might have profound clinical impact. This paper summarizes the known effects of cardiac ultrasound—compared to other major imaging techniques—to exposed patients and to clinically exposed physicians practising ultrasound imaging. Furthermore, this review also provides an overview of the evidences on the biological effects of diagnostic ultrasound—which suggest that ultrasound with frequency, intensity and duration fully in the diagnostic range have significant molecular, cellular and organ effects.

A better understanding of these effects may improve our understanding of the complex interactions between ultrasound and biological tissues and may open new avenues to therapeutic applications based on the ultrasound-modulated cell functions, such as membrane transduction, apoptosis, cell permeability and thrombolysis.

Keywords: Diagnostic cardiac ultrasound; Biological effects; Clinical risks

Contents

*Corresponding author. Tel.: +39 0585 493646; fax: +39 0585 493601.
E-mail address: andreas@ifc.cnr.it (M. Grazia Andreassi).

0079-6107/$ - see front matter
doi:10.1016/j.pbiomolbio.2006.07.020

1. Introduction

A Renaissance of medical imaging occurred in the recent years, and the modern practise of the medicine heavily relies on imaging techniques. Every year, about 5 billion imaging exams are performed worldwide, and about 1 out of 3 are made with ultrasound (Roelandt et al., 1989) Most infants now born in the western countries were exposed to ultrasound before birth (NCRP, 2002). New medical imaging technologies allow the description of anatomy, function, perfusion, and metabolism in a polycrome, three-dimensional, overwhelming fashion, not without costs, however, and not without risks. We will briefly review the known effects of cardiac ultrasound—compared to other major imaging techniques—to exposed patients and to clinically exposed physicians practising ultrasound imaging. We will then review evidences on the biological effects of diagnostic ultrasound—which may be a conceptual link to a targeted use of ultrasound for therapeutics applications.

2. The ultrasound energy spectrum in clinical approaches

The role of imaging techniques in defining the presence and the causes of heart disease is essential. Medical imaging began on 8 November 1895, when Professor Wilhelm Conrad Roentgen of the University of Würzburg discovered X-rays. There have been numerous refinements of X-ray techniques over the past 100 years with development of invasive radiology and computed tomography. In addition, entire new modalities have appeared including nuclear medicine, ultrasonography, magnetic resonance imaging (RP118, 2001). The "4 sisters" of cardiac imaging have very different biological and technological basis. It is important to operate a distinction, which is also relevant for the legal regulations of medical imaging between "ionising" and "non-ionising" techniques. Ionising techniques use high-frequency electromagnetic waves, such as X-rays (radiology) and γ-rays (nuclear medicine). Ionising radiations are only one part of the electromagnetic spectrum (Fig. 1). There are numerous other radiations (e.g., visible light, infra-red waves, radiofrequency electromagnetic waves) that do not posses the ability to ionise atoms of the absorbing matter. According to the general equation $E = hv$ radiation energy (E) is directly proportional to frequency (v). Higher energies can be toxic to the cell through the production of free radicals. Obviously, the use of high energies has also several advantages, including the possibility to go inside the body without obstacles represented by bone and air. However, the use of ionising testing is associated to environmental impact and definite biorisks for the patient and the operator (Cormack et al., 1998; ICRP, 2001).

As always in medicine, a responsible use of these technologies clearly outweighs the risk (Picano 2004). Other technologies employed in cardiac imaging pose no environmental burden or known risk to the patient

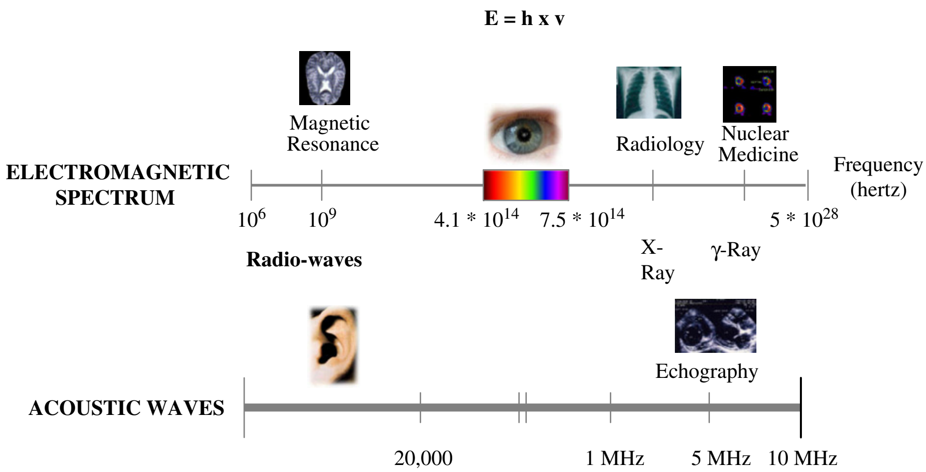

Fig. 1. Electromagnetic and acoustic spectrum. Only high-energy electromagnetic waves (used in radiology and nuclear medicine) are ionising.