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Low-frequency ultrasound permeates the human thorax and lung: a novel approach to non-invasive monitoring.

[Article in English, German]

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Abstract

PURPOSE: Conventional sonography at 2 - 10 MHz cannot permeate the chest because ultrasound at this frequency is strongly scattered and reflected by air inclusions in the lungs. Therefore, sonography is considered impracticable for thoracic imaging. However, human thoraxes and lungs in situ were never rigorously probed with ultrasound at frequencies below 1 MHz. In addition, ultrasound is commonly applied as echo imaging rather than sound transmission.

MATERIALS AND METHODS: Human subjects were studied with a transducer detector pair or an elastic thorax belt equipped with 12 sensors 5 cm apart that was wrapped around the thorax and a single pulse transmitter attached to the sternum. We focused on fast ultrasound transmission from 1 kHz to 1 MHz, coupled over thoracic sonotrodes.

RESULTS: Between 1 Hz to 1 MHz, sound transmission through thorax and lungs shows three distinct bands: < 1 kHz sound is transmitted at 30 - 50 m/sec, between 1 - 10 kHz sound transmission is absent and > 10 kHz sound is transmitted with a speed of 1500 m/sec. We demonstrate that low-frequency ultrasound (10 - 750 kHz) can permeate the thorax and permits monitoring of the air and water content of human lungs. In healthy subjects at 15 kHz, the difference in sound transmission through thorax and lungs between inspiration and expiration was dynamic and spanned several decades. Sound transmission during expiration was strongly decreased in patients suffering from pulmonary emphysema or pneumothorax, but increased in patients with pleural effusions.

CONCLUSION: Sound transmission in the lungs is characterized by three distinct frequency bands. Low frequency ultrasound is transmitted through the lungs and may offer a novel non-invasive approach to real time diagnostics.

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