Current imaging technologies, such as conventional radiology and computerised tomography (CT), are limited in their capability to diagnose many lung pathologies. Furthermore, ultrasound has been found unsuitable to be used as a diagnostic tool for the lungs.

Vibration Response Imaging (VRI) is a novel, non-invasive and radiation-free technique that uses the vibrations of the lungs to produce dynamic imaging.

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Visualising the energy of tissue vibrations

The VRI device (Figure 1) was designed to be used as a diagnostic tool for the assessment of lung disease and disorders by visualising vibration energy emitted during the respiration cycle. Airflow in the lungs during the respiratory cycle creates vibrations that propagate throughout the lung tissue. These vibrations are affected by the structural and functional properties of the lungs and can exhibit responses that may vary in space, time, frequency and intensity. Thus, the VRI creates an immediate dynamic image that can simultaneously identify and locate both structural and functional abnormalities throughout the lungs.

The development of the first VRI system for the lungs was based on the finding that lung vibration energy directly correlates to the ventilation. In order to capture the image of the lung, the VRI device records the energy generated by the vibrations of the lungs during both inspiratory and expiratory phases of breathing. The system uses an algorithm that combines the output signals from a bank of band-pass filters sliced over regular time intervals to produce a sequence of images that reflect the vibration properties.

Any change in space, time, intensity and frequency of the airflow affects the lung vibrations and is thus reflected in the recorded image. These modifications of airflow vibrations enable the VRI system to detect anomalies of the lung, such as bronchial obstruction, space-occupying lesions (cancer, foreign bodies), pneumonia, asthma and pleural effusion. Furthermore, the VRI device is able to perform quantitative measurements of lung function, such as spirometry and regional assessment of the lung.

Figure 2: A patient undergoing a VRI procedure with the sensor matrix adhered to his back

In the clinical context

Full coverage of the human lungs is needed to accumulate the VRI energy of the lungs. This is done by attaching 20 specially designed piezo electric pressure sensors over each side of the back (Figure 2).

In order to address the issue of applying 40 sensors with a specific pressure and defined location, yet accommodating individual human anatomical variability, the two arrays of VRI sensors are attached by a low vacuum, computer-controlled method in which the vacuum pressure is maintained constant, ensuring ease of attachment. With this active-controlled vacuum system, the force of application and exact location of each sensor on the chest wall is recognised by the VRI software, thus controlling the energy accumulation level. The use of an array of sensors at defined distances enhances the image resolution.

The VRI graphic representation generates a grey-level-coded spatial representation of the lung vibrations. High data values, in which lung vibration energy is greatest, are depicted as dark colours (black) and low data values are shown as light colours (light grey); the minimum is defined as ‘white’. This representation enables the following of the course of the dynamic development of the lung in the image. Furthermore, VRI technology allows the image to be viewed dynamically or frame by frame and the maximal energy frame is distinguished from all other frames. Figures 3 to 6 show examples of images of human lungs acquired by Vibration Response Imaging compared to standard...
An additional advantage of VRI is that it also detects and records adventitious (i.e. abnormal) lung sounds much like a stethoscope. However, information gathered by VRI is different from a stethoscope because VRI can display a dynamic image for visual examination of the recorded data. Each channel can be examined by the VRI algorithm for crackles (i.e. discontinuous abnormal lung sounds), wheezes (i.e. continuous abnormal lung sounds), and automatic breathing cycle selection. Crackles and wheezes that are identified by the algorithm are presented in the display as coloured dots on the lung image (Figure 5).

Clinical investigation of the VRI device was carried out in leading medical centres located in Europe, the USA and Israel. These trials were conducted on a cohort of human subjects, both healthy and with various lung pathologies. Dynamic lung images from the VRI were compared to existing, so-called ‘gold standard’ imaging technologies, such as chest radiographs and chest CT scanning. Lung abnormalities were identified by VRI patterns with a degree of sensitivity comparable to ‘gold standard’ imaging technologies. In September 2005 the system received the CE mark, allowing Deep Breeze Ltd to market the technology to physicians in European Union countries.

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Figure 7. A flow-volume loop derived from a VRI image of a normal subject during tidal volume breathing. Vibration energy is plotted as a function of its integral over time for both lungs (left panel) and for each lung separately (central panel, left lung; right panel, right lung).