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Lung Assessment & Monitoring in the ICU Using Vibration Response Imaging

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Lung imaging and monitoring in critically ill patients is challenging. In the intensive care unit (ICU), the most common bedside methods for assessing the lungs are portable chest radiography and auscultation. Chest radiography is associated with some radiation exposure and is not practical for frequent serial assessment of lung pathophysiology in an ICU setting. Auscultation is simple and useful but suffers from its subjective nature. Other imaging modalities such as computerised tomography (CT) or ventilation perfusion scanning typically require patient transport and associated risks with critically ill patients. A new technology, vibration response imaging (VRI), provides a visual display of distribution of lung vibrations created by air movement in and out of the lungs and may offer utility in diagnosis and monitoring in ICU patients.

Vibration Response Imaging Technology

Vibration response imaging (VRI) is a computer assisted acoustic-based technology that measures the vibration energy generated in the lungs and transmitted to the surface of the chest during respiration or mechanical ventilation. Vibration response imaging creates a functional, two-dimensional video depicting distribution of vibration within the lung. Turbulent air and vibrations within the airways generate lung sounds. The vibrations are affected by the structural and functional properties of the lungs and can exhibit responses that vary in frequency, intensity, space and time. Pathologic processes affecting the lungs such as pneumonia, heart failure, and acute respiratory distress syndrome are expected to alter these transmitted sounds.

The VRI device is a portable, stand-alone device with thirty-six piezoelectric contact sensors spatially assembled on two planar arrays placed posterior under each lung of the patient (Figure 1). Recordings may be performed in both supine and sitting positions. In the sitting position, the arrays are attached to the back using low computer-controlled suction. Dorsal attachment is used as the area of sound transmission between the lung and the sensors is more uniform between patients (particularly females) and interferes less with routine patient or nursing care. The sensors' signals undergo several stages of filtering that reduces interference generated by chest-wall movement and heart sounds.

Data collected by the sensors during a 20 second recording is processed and a greyscale video depicting the relative geographical distribution of respiratory sound is created. The process and algorithm used in creating the image has been described in detail (Dellinger et al. 2007). A sequential dynamic display of images (each from 0.17 seconds of data) is displayed 60 seconds after the start of the recording, generating a movie that shows changes occurring in the distribution of vibration energy across lung regions over time. The maximal energy frame (MEF) is the frame in the video sequence that usually provides the most information on the distribution of lung vibration and usually approximates peak inspiratory vibration. A larger MEF image indicates a more homogeneous distribution of vibration intensity throughout the lung and a smaller MEF image indicates regional inequity of vibration intensity.

When imaging a mechanically ventilated patient, a flow sensor is placed in the tubing between the patient and the ventilator, allowing flow and pressure waveforms to be synchronised with the VRI image and displayed (Figure 1C). The VRI faceplate also displays the percentage contribution of lung regions (left, right and upper, middle, lower) to the total vibration signal (Figure 1C).

Potential Advantages of VRI

- Non-invasive and radiation free: The VRI passively detects vibration reaching the skin surface without introducing radiation to the patient. Although this technology will not replace conventional imaging techniques such as portable chest radiographs or CT since these technologies show anatomy, it may reduce their number and frequency.
- Bedside assessment with immediate results: Compared to chest radiograph, which requires processing time and CT and ventilation/perfusion (V/Q) scan requiring transportation with its inherent risk. Unlike CT and V/Q scanning, VRI provides near-real time lung imaging results at the bedside.
- Objective: Unlike auscultation, VRI does not depend on the auditory acuity of the clinician. The recording and accompanying data are stored for later viewing and for comparison with subsequent recordings.
- Monitoring and serial imaging possible (practical):

The non-invasive and radiation-free nature of the VRI allow for its use as a lung-monitoring tool where recordings can be obtained in rapid succession or hourly/daily. Recruitment manoeuvres and adjusting PEEP settings are good examples where rapid serial studies might be beneficial in matching optimal settings with distribution of lung vibrations.

Potential Role of VRI in the Management of ICU Patients

- Assessment of endotracheal tube placement and detection of inadvertent oesophageal or endobronchial intubation. VRI may assist in differentiation of endotracheal vs. oesophageal vs. endobronchial position of the endotracheal tube as each of these different placements would be expected to produce a different distribution of sounds created during air movement.
- Lung assessment in ICU patients: The lungs of ICU patients are not homogeneous. The VRI technique makes it possible to detect changes in function of different regions and it might impact treatment possibilities. Diagnosis of lung pathologies may be facilitated or may be identified sooner with use of this technology (Dellinger et al. (2007) have shown that the distribution of vibration energy differs with the mode of ventilation. With more studies, VRI may offer the potential as a real time non-invasive method of adjusting ventilator therapy in intensive care units.
- Assessment of the effectiveness of therapy: Differences in the VRI image have been demonstrated in ICU patients before and following therapy for pulmonary diseases. These diseases include pleural effusion before and after thoracentesis as well as acute congestive heart failure with pulmonary oedema before and after clinical improvement. These characteristic changes after therapy could be used to titrate therapy and to assess changes in airflow induced vibration.

Conclusion

In ICU patients who frequently have acute pulmonary pathology, determining differences in regional vibration for diagnostic and management purposes could be advantageous. This novel imaging technique may offer the potential to use vibration intensity as a surrogate of regional lung function. There is currently no direct lung monitoring technique at the bedside. Further studies will help determine how this technique might be integrated ICU care.

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