NON-CONTACT STETHOSCOPE FOR AUSCULTATION OF NEONATAL PATIENTS

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BACKGROUND

- Premature infants have to be monitored for signs of lung congestion and heart murmurs.
- Currently medical personnel use regular acoustic stethoscopes.
- The use of acoustic stethoscopes has undesirable side effects.

PURPOSE

To develop and test a non-contact stethoscope for use in neonatal cases.

ACOUSTIC STETHOSCOPES UNDESIRABLE SIDE EFFECTS

1. Neonates can have a stress response that often includes a withdrawal response, flinching, apnea, hypoxemia, and change in sleep state. This stress response affects heart and lung sounds so that the sound no longer reflects the baby’s baseline state. Warming the stethoscope does not help a lot in this regard.
2. Neonates thrive when outside interference is minimized. Accordingly nurses are reluctant to auscultate babies as often as clinically indicated. This can lead to missing early signs of disease.
3. Contamination is a big concern in the NICU. The larger the number of people auscultating the baby, the greater the chances of contamination.
4. NICU nurses and doctors often need to share sounds between each other during rounds or when a nurse detects a new murmur (new heart murmurs may appear several days after the birth). Currently clinicians take turns listening to the baby. This is highly undesirable since it stimulates the baby and increases chances of contamination. Since heart and lung sounds can change in short periods of time different physicians may hear different sounds leading to confusion.
5. Infants on ventilators whose endotracheal tube has to be suctioned deserve particular concern. The time of suctioning is determined among other things on the basis of auscultatory findings. The frequency of auscultation for this purpose remains arbitrary.

POSSIBLE ALTERNATIVES TO ACOUSTIC STETHOSCOPE

- Acoustic sensor in a mattress - problematic, since infants lie in a cradle on a soft blanket or a piece of fur. Sensors incorporated directly into the mattress are not able to pick up chest sounds through these very soft materials.
- Acoustic contact sensors on the skin - new set of concerns (see below).

PROBLEMS WITH CONTACT SENSORS

Bilirubin tends to accumulate in blood of prematurely born babies. Excess bilirubin can lead to brain damage. Light breaks down bilirubin in the skin. Accordingly, the amount of skin exposed to light has to be maximized. Contact acoustic sensors inevitably reduce the skin surface exposed to light. The skin of prematurely born babies is extremely delicate. No matter how thin acoustic sensors are made, they may leave a mark or break the skin when neonates are rotated in the cradle.

Wires from acoustic sensors to the amplifier can further complicate patient management. Auscultation has to be performed at multiple locations on the chest. It is generally believed that the minimum number of acoustic sensors is four. Multiple sensors exacerbate the problems associated with contact sensors.

NON-CONTACT ACOUSTIC TECHNOLOGIES

- The amplitude of chest vibrations is too small to create a detectable sound in the air surrounding the chest. Consequently, normal lung or heart sounds are not audible at a distance from the chest.
- Ultrasound is often used for distance measurements in nature (bats and industry (assembly line distance measurement devices)). Our calculations indicate that long wavelength ultrasound (frequencies 40 to 100kHz) lacks temporal resolution, while short wavelength ultrasound (frequency greater than 1MHz) decays very fast in the air and, therefore is not suitable for distance measurements.

METHODS - NON-CONTACT OPTICAL STETHOSCOPE

- Light has long been considered a perfect tool for measuring surface vibrations.
- One of the most precise methods of vibration measurement is based on two-beam interference - one being the beam reflected from the surface of interest and the other called the reference beam.
- The surface movements cause changes in the intensity of the reflected beam travels.
- The corresponding changes in the interference pattern in the two-beam interference can be detected as changes in the intensity of the detected light.

SKIN AS A SCATTERER OF LIGHT

- Traditionally, interferometer methods of vibration measurements were used for reflective surfaces only. The reflective surface reflects a narrow beam of light in one direction (like a sun beam reflected from a flat mirror).
- In recent years it has become clear that even scattering surfaces produce an interference pattern on detectors when scattered light is combined with a reference beam.
- Since skin scatters light, it is possible to develop a non-contact stethoscope working off bare skin by means of scattering surface interferometry.

FEATURES OF A FIBER OPTIC INTERFEROMETER

- High sensitivity
- Long range (up to 100 meters)
- Simplicity of assembly
- No need for component alignment
- Compact size (cigarette pack)
- Low weight
- Low cost
- Ease of incorporation of additional components (acoustic-optic modulator (AOM), probe beam fiber booster amplifier, object beam fiber amplifier, etc.).

TECHNICAL CHARACTERISTICS

- We utilized a commercially available fiber-pigtailed DBF laser diode as a coherent light source.
- The collimator focuses the probe beam on the target.
- The scattered light is collected by the same collimator.
- Interference between the reference beam and the scanned beam occurs at the 90/90 coupler with its two output ports delivering the signal to the Differential photodetector module.
- The output of the Differential photodetector module is then amplified in the RF amplifier module and then filtered in the FM demodulator module, producing audio output.
- The AOM is driven by the RF generator at 27.045 MHz followed by the RF driver amplifier, producing the greatest signal.
- The type of laser used is eye and skin safe.

CLINICAL RESULTS

Heart and lung sounds recorded with the fiber optic non-contact stethoscope were compared to those recorded with a contact sensor.

INTERFOMETER BLOCK DIAGRAM

- Blue arrows represent optical connection
- Black arrows represent electrical connection

INTERFOMETER PROTOTYPE

- The small suitcase on the left contains a battery-powered fiber-optic interferometer.
- The collimator is mounted on the tripod on the right.
- Light travels from the interferometer to the collimator via the yellow fiber optic cable.
- The collimator focuses the probe beam on the target.
- Light scattered by the target is captured by the collimator and the interferometer via the same yellow fiber optic cable.

CONCLUSIONS

1. We have built a non-contact stethoscope based on a novel fiber optic design with a frequency shifter (an Acousto-Optic Modulator). The prototype is battery operated and fits into a small suitcase.
2. We have integrated the non-contact stethoscope prototype with the FDA approved STG software for Heart and Lung Sounds analysis.
3. This non-contact stethoscope prototype was able to record high quality heart and lung sounds.
4. This non-contact stethoscope has the potential to improve the quality of care for neonatal patients and burn victims.