BACKGROUND
The broad, long term objective of this research is to create an algorithm and then a device and medic training to detect pneumothorax (PTX) quickly and under a variety of battlefield conditions.

OBJECTIVE
The goal in this particular study was to investigate differences in the acoustic patterns of patients with pneumothoraces as compared to sound patterns in healthy controls.

MATERIALS AND METHODS
Using a Multichannel Lung Sound Analyzer (Stethographics STG16) we studied 2 patients with pneumothoraces and 16 patients who had undergone pneumonectomy. We considered pneumonectomy patients to have findings acoustically equivalent to patients with pneumothoraces. We examined 4 parameters in these 18 patients. These included:

A. RMS in the range from 80Hz to 180Hz.
B. RMS in the range from 10Hz to 80Hz.
C. R4 ratio. This is the ratio of sound energy at low frequencies (20Hz and 80Hz) to sound energy at high frequencies (80Hz and 900Hz).
D. Dynamic range of the sound amplitude envelope. This is the difference between the maximum envelope amplitude and the minimum envelope amplitude.

Based on observations of these parameters in these 18 patients we developed a PTX score and tested it in 125 healthy subjects and on 50 recordings of pneumonectomy patients.

RESULTS
Figure 1A shows STG recording from a patient with PTX during deeper than normal breathing. Waveforms are presented in a stacked mode. Channel number is indicated on the left. Microphone location on the chest is indicated on top left of each waveform. The green horizontal bar indicates inspiration; the blue horizontal bar indicates expiration. On examination of Figure 1A it is apparent that the normal lung is significantly louder than the collapsed lung. Thirty days after the spontaneous PTX the patient was reexamined (Figure 1B). The difference in amplitude between lungs was gone. Lung sounds were normal as was the chest x-ray.

Figure 2. The RMS in the range from 80Hz to 180Hz was greater in the normal lung than in collapsed lung.

Figure 3. The RMS in the range from 10Hz to 80Hz was greater in the collapsed lung than in normal lung.

Figure 4. The R4 ratio was increased in the PTX lung.

Figure 5. The dynamic range of the sound amplitude envelope was greater in the normal lung.

EFFECT OF FILTERING
Extraneous noises may be present when the acoustic PTX test was performed. Talking is one likely source of acoustic contamination. The frequency of human speech is normally above 180Hz. Accordingly we were interested if the signal from speech can be filtered out without reducing the RMS ratio. Figure 6A shows the RMS ratio in the interval between 80Hz and 180Hz. Compare that to the RMS ratio in the interval between 80Hz and 500Hz, Fig. 6B.

Figure 6A. RMS ratio between symmetrical microphones in the interval 80Hz to 180Hz as a function of breathing maneuver.

Breathing maneuver legend: 1=No breathing, 2=Very shallow breathing, 3=Normal breathing, 4=Deeper than normal breathing-long expiratory phase, 5=Deeper than normal breathing, 6=Pasting, 7=Vital capacity maneuver (very deep breathing).

Figure 6B. RMS ratio between symmetrical microphones in the interval 80Hz to 500Hz as a function of breathing maneuver.

Note that the data in Figure 6A are not significantly different from data in Figure 6B. We conclude that we can safely filter out the signal above 180Hz. This filtering will not have a significant effect on the RMS ratio but can eliminate talking artifact.

The PTX score based on the four parameters mentioned above was significantly different in patients with PTX as compared to normals as illustrated in Figure 7.

Figure 7. This PTX score had a sensitivity of 0.93, a specificity of 0.99 and a positive predictive power of 0.98.

CONCLUSION
These results demonstrate the possibility of developing an automated PTX detector based on acoustic differences between collapsed and normal lung.