CHAPTER 5

CONCLUSION

There is much interest in the area of determining the mechanism of lung damage caused by ultrasound. Currently research groups are in the process of determining the mechanism of lung damage. Some groups believe lung damage is not caused by inertial cavitation, but a mechanical force. Others believe that lung damage is caused by inertial cavitation. Because of this discrepancy, a simplified model of the lung damage was developed and studied in an attempt to evaluate the hypothesis that lung damage is not caused by inertial cavitation, but by a mechanical force. This experiment was performed not only to simplify the lung damage model, but as a side-study to the lung damage work being performed in our laboratory.

The purpose of this study is to determine the mechanism of water-breaking caused by ultrasound. The effects pulse repetition frequency, beamwidth, and carrier frequency had on the threshold water-breaking rarefactional pressure and threshold water-breaking radiation force were studied and analyzed (Chapter 4). This chapter will discuss the findings from this experiment.

The pulse repetition frequency affected the threshold water-breaking pressure. The threshold water-breaking peak compressional and peak rarefactional pressure for the continuous wave condition was much less than the peak compressional and peak rarefactional pressure for the higher pulse repetition frequency. The threshold water-breaking peak compressional and peak rarefactional pressure for the higher pulse repetition frequency was less than that for the lower pulse repetition frequency. Overall, the threshold water-breaking peak compressional and peak rarefactional pressure increased from the continuous wave, to the higher pulsed (larger pulse repetition frequency) wave to the lower pulsed (smaller pulse repetition frequency) wave. This trend was observed for all transducers.

This trend is similar to what was observed in a pulse repetition study [*O'Brien et al.,* 2001b]. For this study, the pulse repetition frequency varied (25, 50, 100, 250, and 500 Hz). This study was performed on mice and rats. The findings were that lung lesion development in the mouse was dependent upon the pulse repetition frequency. As the pulse repetition frequency increased, the percentage of lesions in mice increased. It was also found that the pulse repetition frequency affected lung lesion depth in the rat and mouse. As the pulse repetition frequency increased, the lesion depth increased.

The pulse repetition frequency also affected the threshold water-breaking radiation force. The threshold water-breaking radiation force for the continuous wave condition was greater than the threshold water-breaking radiation force for the higher pulse repetition frequency; and that threshold water-breaking radiation force was greater than the threshold water-breaking radiation force for the lower pulse repetition frequency. Overall, the threshold water-breaking radiation force decreased from the continuous wave, to the higher pulsed (larger pulse repetition frequency) wave to the lower pulsed (smaller pulse repetition frequency) wave. This trend was observed for all transducers, except for the yellow. The threshold water-breaking radiation force for the lowest pulse repetition frequency had a larger threshold water-breaking radiation force than the threshold water-breaking radiation force for the higher pulse repetition frequency. The trend for the threshold water-breaking radiation force was opposite that of the threshold water-breaking pressure, where the pressure increased from the continuous to the pulsed case.

The affects of beamwidth on the water-breaking pressure and radiation force were also studied. As the beamwidth increased, the water-breaking peak rarefactional pressure decreased.

For the water-breaking radiation force, the trend was the same. As the beamwidth increased, the threshold water-breaking radiation force decreased.

Another study performed in our laboratory tested the role of beamwidth [*O'Brien et al.,* 2001a]. In this beamwidth study, it was found that the lesion incidence, lesion depth, and surface area all showed a significant beamwidth effect. The beamwidth sizes used in this beamwidth study varied from 310-930 _m.

The third factor which was studied was the affect of the ultrasonic frequency on the threshold water-breaking pressure and radiation force. The overall trend for the ultrasonic frequency was that the water-breaking pressure increased with increasing frequency. However, in the same beamwidth study mentioned above [*O'Brien et al.,* 2001a], one of the findings was that ultrasonic frequency was not a significant factor over the range of the experiment. In another study [*Zachary et al.,* 2001], ultrasonic frequency was also found not to be significant. These findings are consistent with the findings of this experiment. The discrepancy in these results (this study compared to the *O'Brien et al*., 2001a and *Zachary et al*., 2001) are due to the dependency that beamwidth has on the ultrasonic frequency. At higher frequencies, the beamwidth is significantly smaller, given the f-number remains constant.

Pulse repetition frequency and beamwidth were factors found to affect the threshold water-breaking pressure and radiation force. Frequency was also found to affect the threshold water-breaking pressure and radiation force, but this is attributed to the relation between beamwidth and frequency.

The determination of the mechanism of threshold water-breaking is still not clear. Thus, the mechanism of lung damage is also not clear. There may be many factors besides radiation force that affect lung damage and additional studies need to be performed to come to a final conclusion of how water-breaking, and in effect lung damage occurs.