Effects of Impulse Noise on the Hearing of Fetal Sheep in Utero

Kenneth J. Gerhardt*, Xinyan Huang*, Scott K. Griffiths* and Robert M. Abrams†

*Department of Communication Sciences and Disorders and †Department of Obstetrics and Gynecology, University of Florida, Gainesville, Florida 32611

Abstract: Knowledge of the transmission of exogenous sounds into the uterus and the effects that these sounds have on fetal hearing is incomplete. The purposes of this study were to measure the transmission of impulse noise into the uterine environment and to evaluate the effects of impulse noise exposure delivered to pregnant sheep on the hearing of the fetus in utero. A shock tube produced impulses that averaged 169.7 dB peak sound pressure level in air. In the uterus, the peak levels varied as a function of fetal head location. Slight elevations of evoked potential thresholds were noted but only for low-frequency stimuli. Scanning electron microscopy revealed damage to hair cells in the middle and apical turns of the cochlea.

PURPOSE

Significant numbers of American women of childbearing age are noise exposed. Safe maternal exposure levels have yet to be determined. The purposes of this study were to measure the transmission of impulse noise into the uterine environment and to evaluate the effects of impulse noise exposure delivered to pregnant sheep on the hearing of the fetus.

The following hypotheses were addressed: 1) low-frequency components of impulse noises will be transmitted into the uterus with little loss in sound pressure, whereas the high-frequency components will be greatly attenuated; 2) impulse noise exposures will produce elevations in fetal auditory evoked potential thresholds that are dependent upon the frequency content of the eliciting signal; and 3) histology of inner ear tissue will reveal significant hair cell damage in the middle and apical turn of the fetal cochlea.

METHODS

During sterile surgery, the instrumentation for chronic recording of the evoked potentials was implanted in fetal sheep at 127 days gestational age (Term is 145 days) (N=11). The fetus was exteriorized and the fetal head prepared for evoked potential recordings. A hydrophone was sutured near the fetal pinna. The purpose of the hydrophone was to record acoustic levels in the intrauterine environment during the impulse noise exposure.

The shock tube (10 feet long with a 4 inch bore) was directed into a sound-treated booth through an exponential horn which was designed to match the impedance of air in the tube to the air in the sound-treated booth. Using compressed nitrogen (70 p.s.i.) released into the tube suddenly, a peak sound pressure level (pSPL) of about 170 dB was achieved at a distance of four feet.

Two days after surgery the ewe was placed in the sound-treated booth and fetal evoked potential thresholds were assessed. After pre-exposure testing, ewes were exposed to 20 noise impulses produced during a 30-minute period. A second hydrophone connected to one channel of a spectrum analyzer and positioned close to the maternal flank recorded the pressure-time history generated by the shock tube. In addition, a simultaneous recording (channel 2) from the hydrophone in utero was obtained, thus yielding transmission characteristics for the impulse. The post-exposure evoked potentials were followed for 10 days. At 137 days gestational age, the ewes and fetuses were sacrificed and cochleae removed and prepared for scanning electron microscopy.

Stimuli for the auditory brain stem response (ABR) were clicks and 4.0, 2.0, 1.0, and 0.5 kHz tone bursts. Stimuli for the amplitude modulation following response (AMFR) were amplitude-modulated tones at 1.0, 0.5 and 0.25 kHz. Activity at the recording electrodes was band-pass filtered, differentially amplified, digitized and averaged. Two responses were obtained at each stimulus level beginning at 70 dB and descending in 10 dB steps until no
replicable response could be determined. The stimulus was then raised in 5 dB steps until a response was detected. Thresholds for the AMFR were interpreted from fast Fourier transform and defined as the lowest level at which the spectrum level at the modulation frequency (50 Hz) was greater than the average spectrum level at the four largest peaks in the spectrum below 100 Hz.

RESULTS AND DISCUSSION

Evaluation of 200 impulses recorded in air, both with and without the presence of a ewe, averaged 169.7 dB pSPL with a standard deviation of less than 1 dB. The pSPL measured at other locations in the room varied by no more than 4 dB.

Peak levels recorded in the uterus averaged 9.52 dB less than those recorded in air. Spectral analysis in one-third octave-bands revealed peak levels in air at 315 Hz compared to 160 Hz when recorded from the uterus. High-frequency sound pressures were attenuated by the tissues and fluids of the ewe by up to 25 dB, as predicted from earlier studies (Gerhardt et al., 1990; Peters et al., 1993).

The position of the hydrophone within the uterus influenced both pSPL as well as spectral distribution. When the hydrophone was near the abdominal surface, peak levels were approximately 2 dB less than the peak levels recorded in air. When the hydrophone was deep within the uterus, the morphology of the waveform changed and peak levels were up to 20 dB less than those recorded in air.

Electrophysiologic thresholds were examined over time. Small elevations in the mean thresholds for the 0.5 kHz stimuli (ABR) were noted in the post-exposure measures. Thresholds improved in recordings over the next 10 days. No similar elevations were noted for the higher-frequency tone bursts or clicks, or for the AMFR. Similarly, continuous, intense broadband noise exposures delivered to fetal sheep resulted in temporary post-exposure threshold elevations for low-frequency tone bursts (Griffiths et al., 1994).

Cochleae from 11 fetuses were examined using scanning electron microscopy. Hair cells from noise-exposed fetuses appeared different from control fetuses in a number of respects. Damage to both inner and outer hair cells was noted primarily in the apical and middle turns of the cochlea. Abnormalities included bent and/or missing stereocilia, giant stereocilia and phalangeal scarring. The damage found in fetal sheep inner ears is consistent with reports following noise exposures in other species (Saunders et al., 1985). Inner hair cells were more severely affected than outer hair cells in the apical region between 5 and 20% of the total distance from helicotrema. These findings are quite different than would be predicted based upon knowledge of adult noise-induced hearing loss that affects the basal region of the cochlea.

The findings that noise exposure to the fetus in utero affects auditory evoked potentials and inner ear histology apply only to fetal sheep. There are no compelling data that demonstrate human fetuses have the same susceptibility to noise as sheep or that human fetuses are at risk to inner ear damage produced by noise levels to which pregnant women might normally be exposed.

ACKNOWLEDGEMENTS

This research was funded through a grant from the United State Army Medical Research and Materiel Command and from the NIH (HD20084).

REFERENCES