Journal of Sound and Vibration (1998) **216**(3), 539–542
Article No. sv981755

INTRAUTERINE SOUNDS IN SHEEP

R. M. Abrams, K. J. Gerhardt, S. K. Griffiths, X. Huang and P. J. Antonelli
Departments of Obstetrics and Gynecology, Communication Sciences and Disorders, and Otolaryngology, University of Florida, Gainesville, FL 32610 *U.S.A.*

(*Received* 14 *May* 1998)

1. INTRODUCTION

Several studies in pregnant humans [1, 2] and in sheep [3, 4] indicate that the intrauterine sounds in these two species are rich and varied. When listening to recordings of these sounds, one is impressed with the sound pressure level (SPL) produced when pregnant women or sheep vocalize and also with the magnitude and quality of sounds transmitted from the environment. There is a relatively high intelligibility of externally generated speech recorded in the uterus [1, 5]. Fetal vibroacoustic stimulators, such as used by some obstetricians in prenatal examinations, produce especially intense sounds with many measureable overtones [6].

A listener to intrauterine sounds recorded with an underwater microphone (hydrophone) positioned by the fetal head of a pregnant subject also recognizes non-environmental sounds, that is, those originating from inside the maternal body. Intestinal gurgles, coughs, and very occasionally a pulsed sound linked to maternal or fetal heart beat are available. These internal sounds emerge from a "noise floor" comprised of continuous electrical noise related to the sensitivity and dynamic range of the measuring hydrophone, as well as more or less continuous acoustical noise in the examining room or laboratory. Spectral analyses of the intrauterine sounds measured in relatively quiet surroundings indicate a preponderance of low frequency SPLs rising above the noise floor [1, 4].

There remains some question concerning the origin of these low frequency sounds heard in intrauterine recordings. In the experiments of Querleu *et al*. [1], vascular and ambient noises were thought to be the source, although Benzaquen *et al*. [7] detected audible maternal cardiovascular sounds in only two of 10 patients in between uterine contractions (and in no patients during uterine contractions). Because of the absence of audible pulses in all other cases, the consistent low frequency component of the intrauterine background noise was assumed not to be due to maternal blood vessels, digestive system or vocalizations during which very different sound spectra were identified. In experiments with recently killed sheep, Peters *et al*. [8] found that building vibrations influenced the SPL at very low frequencies.

The present experiment was designed to examine in detail the contribution of sound and infrasound of maternal and environmental origin to the intrauterine

0022–460X/98/380539 + 04 $30.00/0

acoustic environment of the sheep fetus *in utero*. In order to accomplish this, studies were made in a sound-treated booth. Studies were completed on ewes that were to be euthanized as part of other protocols approved by the University of Florida Institutional Animal Care and Use Committee.

2. MATERIALS AND METHODS

Four near-term pregnant ewes were anesthetized with halothane by mask, intubated, and, placed supine on an operating table. These animals had been used for other experiments. The fetal head was delivered through a midline abdominal incision and a hysterotomy, care being taken to avoid losing any amniotic or allantoic fluid. A miniature hydrophone (Bruel & Kjaer Instruments, Inc., Marlborough, MA [B&K] Model 8103) previously calibrated with a piston phone (B&K Model 4223) was secured with sutures to the fetal skin in the temporal area. The hydrophone had a flat frequency response (+/−0·5 dB) from 0·1–20 kHz and had an omnidirectional sensitivity pattern. The fetal head was replaced in the uterus and maternal incisions were closed. A maternal intravenous line was placed, and the ewe was continued with sodium pentobarbital, as needed, to sustain a surgical level of anesthesia.

Ewes were carried on a stretcher to a sound-treated booth (IAC, Model GDL-1L, New York, NY), where measurements of intrauterine sound pressure were made. A bolus of euthanasia solution (Euthasol, 4 mg/kg) was administered, and within 5 min the measurement of SPLs was repeated. The animals remained supine during the experiment.

The output of the hydrophone was fed through a charge amplifier (B&K Model 2635). Spectral analyses were performed in 1/3 octave bands over a range of 6·3–20 000 Hz with a real time frequency analyzer (B&K Model 2123).

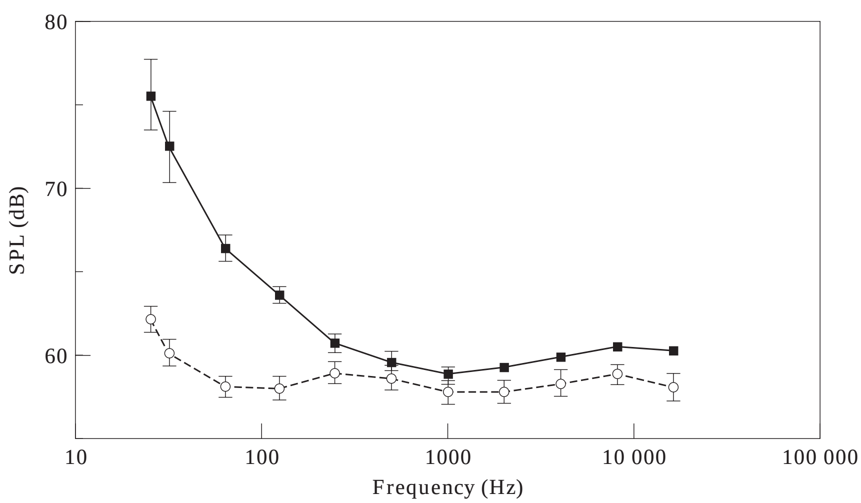

Figure 1. Average intrauterine sound pressure levels before (——) and after (----) death of ewe and fetus.

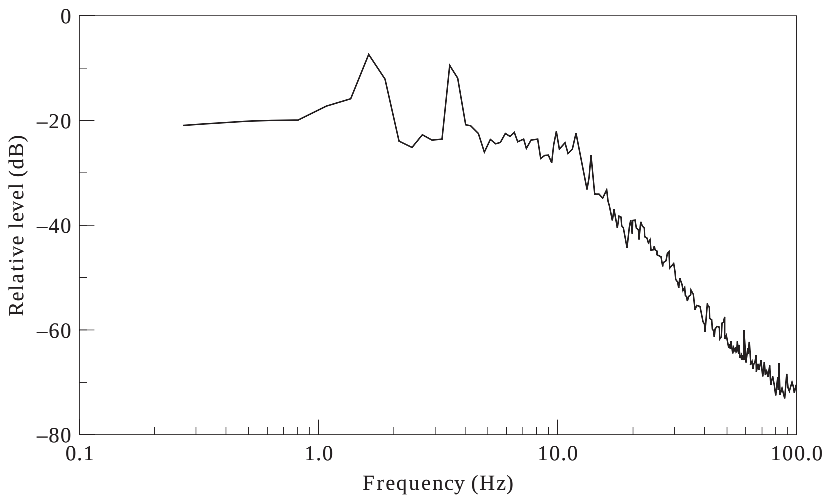

Figure 2. Fast Fourier transform of intraabdominal sound pressures from a 40 s sample in an anesthetized ewe.

3. RESULTS

Average spectra of intrauterine sound pressure levels both before and after death of the anesthetized ewes ($N = 4$) are given in Figure 1. Note that the average reduction in sound pressures after death approached 15 dB in the 1/3-octave band centered at 25 Hz. Two factor, repeated measures analysis of variance revealed significant interactions between the conditions of frequency and animal state (alive or dead) ($p < 0{\cdot}0001$). The Tukey Protected T-test was applied to the data and revealed that the spectrum levels in the alive animal for frequencies of 125 Hz and below were significantly higher than levels for the dead animals (alpha = 0·05). For levels at and above 160 Hz, no significant differences were noted.

The likelihood of a cardiac origin to these low frequency sounds is inferred from the results of a single experiment in an anesthetized non-pregnant ewe with a hydrophone placed near the geometric center of the abdominal cavity. A 40 s sample was recorded on an FM tape recorder (Bruel & Kjaer, Inc. Model 7005) and played back at 10 times the recording rate for FFT analysis. Results were scaled to reflect the original input frequencies and were plotted (Figure 2). Spectral peaks at 1·64 and 3·5 Hz occurred, corresponding to the rate of 106 beats per min as determined by auscultation.

4. DISCUSSION

The present experiment shows that sounds originating in the ewe and fetus contribute significantly to a rise above noise floor of sounds below 200 Hz. This conclusion is based on the use of a chamber in which external airborne sounds as well as building vibrations were minimized. Furthermore, the use of the Bruel and Kjaer hydrophone with its flat frequency responses provided a quantifiable signal without the application of correction factors to deal with loss of sensitivity at lower frequencies as were required in the study by Benzaquen *et al*. [7]. The use of 1/3-octave band analysis provided frequency resolutions at the lowest frequencies.

One assumes that the overall spectrum is heavily dominated by heart sounds whose fundamental frequencies of 1–2 Hz cannot be heard. Overtones are noted, however, some of which could fall into the audible region. The closure of the maternal heart valves cause vibrations to be set up in walls of the ventricles, aorta, and pulmonary arteries. As sound waves are transmitted through the thoracic and abdominal segments, these fundamental tones become progressively more distorted; and harmonics of the fundamental frequencies of the maternal heart rate become evident. Turbulence in the peripheral arterial vascular bed could contribute to the recorded SPL, but probably only in higher frequency bands. Depending on the sensitivity of the ear in the fetus (the developing cochlea initially responds more readily to lower frequency sounds [9]), some features of the cardiac sounds could be detected auditorily.

REFERENCES

1. D. Querleu, X. Renard, C. Boutteville and G. Crepen 1989 *Seminars in Perinatology* **13**, 409–420. Hearing by the human fetus?
2. J.-P. Lecanuet and B. Schaal 1996 *European Journal of Obstetrics and Gynecology and Reproductive Biology* **68**, 1–23. Fetal sensory competencies.
3. S. E. Armitage, B. A. Baldwin and M. A. Vince 1980 *Science* **208**, 1173–1174. The fetal sound environment.
4. K. J. Gerhardt, R. M. Abrams and C. C. Oliver 1990 *American Journal of Obstetrics and Gynecology* **162**, 282–287. Sound environment of the fetal sheep.
5. S. K. Griffiths, W. S. Brown, K. J. Gerhardt, R. M. Abrams and R. J. Morris 1994 *The Journal of the Acoustical Society of America* **96**, 2055–2063. The perception of speech sounds recorded within the uterus of a pregnant sheep.
6. R. M. Abrams and A. J. M. Peters 1995 *American Journal of Obstetrics and Gynecology* **173**, 1372–1376. Fetal acoustic stimulation test. Stimulus features of three artificial larynges.
7. S. Benzaquen, R. Gagnon, C. Hunse and J. Forman 1990 *American Journal of Obstetrics and Gynecology* **163**, 484–490. The intrauterine sound environment of the human fetus during labor.
8. A. J. M. Peters, R. M. Abrams, K. J. Gerhardt and D. J. Burchfield 1991 *Journal of Low Frequency Noise and Vibration* **10**, 92–99. Vibration of the abdomen in non-pregnant sheep: Effect of dynamic force and surface area of vibrator.
9. W. R. Lippe, B. M. Ryals and E. W. Rubel 1986 *Development of the Place Principle*. In: Advances in Neural and Behavioral Development, Volume 2. R. N. Aslin, Ed. Norwood, NJ: Ablex Publishing Company.