Impedance audiometric measurements in clinically normal dogs

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Objective—To measure impedance audiometric values in clinically normal dogs that were sedated or anesthetized, evaluate effects of ear flushing on tympanometric measurements, and determine effects of performing acoustic reflex testing in a sound-attenuated room.

Animals—35 mixed-breed and purebred client-owned dogs and 21 laboratory-bred Beagles.

Procedures—Tympanometry and acoustic reflex testing were performed on 27 mixed-breed and purebred dogs under isoflurane anesthesia in a non–sound-attenuated room and 21 Beagles under sedation in a sound-attenuated room. Tympanometry was performed on 8 mixed-breed dogs under halothane anesthesia before and after ear canal flushing.

Results—Among impedance audiometric values, ear canal volume and compliance peak were smaller in Beagles than in mixed-breed dogs; differences among other values were not detected. Ear canal volume was dependent on body weight. Differences were not found for tympanometric values measured before and after ear canal flushing.

Conclusions and Clinical Relevance—Results of this study established reference range values for impedance audiometric measurements in clinically normal dogs under isoflurane anesthesia or sedation. Acoustic reflex testing does not need to be performed in a sound-attenuated room. The ear canals of normal dogs under isoflurane anesthesia or sedation can be flushed prior to performing tympanometry without altering the results. Impedance audiometry may be a useful noninvasive procedure for the diagnosis of otitis media in dogs. (Am J Vet Res 2000;61:442–445)

Impedance audiometry is a noninvasive objective means of evaluating the integrity of the middle ear and provides the basis for using tympanometry and acoustic reflex testing (ART). Excellent correlation exists between middle ear effusion caused by otitis media in children (detected by otoscopic examination) and abnormal tympanometric and acoustic reflex measurements.1,2 In dogs, however, otoscopic identification of abnormal tympanic membranes is difficult because of exudate, narrowing of the ear canal, and lack of patient cooperation. Therefore, tympanometry and ART may enhance determination of the effects of otitis media on auditory function in dogs.

Tympanometry is the measurement of changes in ear drum compliance (mobility) as pressure in the external ear is changed.3,4 This test provides an indirect measurement of the air pressure in the middle ear, the degree of compliance of the tympanic membrane, and an estimate of the external ear canal volume.5

The acoustic reflex is the involuntary action of middle ear muscles in response to a sound stimulus.6 When a loud noise is introduced into a normal ear, the muscles in the middle ear contract reflexively, decreasing the compliance of the tympanic membrane.7 The purpose of this reflex is protection of the inner ear from damaging levels of noise by attenuating high intensity sounds.8

Several factors can result in artifactual abnormal tympanometric measurements. The probe used to measure the sound pressure level may rest against the wall of the ear canal and cause an artifactually flat tympanogram.9 Because many animals with middle ear disease have otitis externa and exudate, cerumen, and debris in the external ear canal that will cause inaccurate tympanometric measurements,10 the ear canal must be cleaned prior to assessing the tympanic membrane and performing tympanometry. The effects of ear canal flushing must therefore be determined if tympanometry is to be used as a clinical diagnostic test in veterinary medicine.

The purposes of the study reported here were to determine impedance audiometry values in sedated or anesthetized clinically normal dogs, evaluate effects of ear flushing on tympanometric measurements, and determine whether acoustic reflex testing must be performed in a sound-attenuated room. It was hypothesized that there would be no differences in impedance audiometry values between sedated or anesthetized dogs, whether they were the same breed or mixed-breed dogs; that ear flushing would have no effect on tympanometric measurements, and that ART need not be performed in a sound-attenuated room.

Materials and Methods

Experiment design—Twenty-seven clinically normal mixed-breed and purebred dogs (15 female, 12 male; group 1) were selected from client-owned dogs admitted to The Ohio State University Veterinary Teaching Hospital for an elective procedure (spay, castration, or dental prophylaxis). Informed owner consent and hospital board approval was obtained for the study procedures. Dogs with a history of otitis or exudate in the horizontal ear canal on otoscopic examination were excluded from the study.

Breeds included Labrador Retriever (n = 3), Miniature Schnauzer (1), Standard Schnauzer (1), Golden Retriever (2), Shih Tzu (1), Rottweiler (1), Australian Shepherd (1), Norwegian Elkhound (1), Boxer (1), Keeshond (1), Spitz (1), and mixed-breed (13). Body weights ranged from 5.9 to 43 kg (mean, 19 kg), and ages ranged from 5 to 127 months (mean, 19.8 months). Dogs were sedated by administration of acepromazine (0.22 mg/kg of body weight, IM), anesthesia was induced with thiopental sodium (11 mg/kg, IV), dogs...
were endotracheally intubated, and anesthesia was maintained by administration of isoflurane gas (2% minimal alveolar concentration). An otoscopic examination was performed, using a hand-held otoscope and otoscopic cone to view the tympanic membrane and confirm that the tympanic membrane was intact and that exudate was not in the external ear canal.

Tympanometry and ART were performed with a middle ear analyzer in a non–sound-attenuated room. For both tests, a probe with an ear tip (size range, 7 to 14 mm) was inserted into the horizontal ear canal. The ear tip was selected on the basis of the size of the horizontal ear canal. A 226-Hz probe tone was applied to the tympanic membrane at various pressures (−400 to +200 decaPascals [daPa]). A meter received output from the probe and compliance changes were recorded on an X-Y plotter. Measurements obtained from the tympanogram included external ear canal volume (ml), compliance peak (ml), and pressure (daPa) at maximum compliance. For the ipsilateral acoustic reflex, stimuli at 3 dB levels (80, 85, 90) were delivered through the probe to the tympanic membrane at a frequency of 2000 Hz. Reflexes were recorded at the ear canal pressure at which a peak was present in the tympanogram (ie, maximum compliance). At each stimulus, change in compliance (ml) was recorded. The maximum recordable change in compliance measurable by the middle ear analyzer was 0.8 ml.

Group-2 dogs included 21 clinically normal, sexually intact laboratory-bred Beagles (11 females, 10 males) housed according to the National Institutes of Health Guide on Laboratory Care and Use of Laboratory Animals. Body weights ranged from 6.2 to 9.6 kg (mean, 8.2 kg), and ages ranged from 8 to 12 months. Exclusion criteria as described for group-1 dogs were applied. Dogs were sedated by administration of ketamine hydrochloride (5 mg/kg, IM) and xylazine hydrochloride (2 mg/kg, IM). In a sound-attenuated room, tympanometry and acoustic reflex testing were performed as described for group 1. Noise dosimetry measurements yielded an 83% reduction of sound pressure level inside the testing chamber, compared with the value recorded outside the chamber.

Group-3 dogs were selected from client-owned dogs admitted to The Ohio State University Veterinary Teaching Hospital for an elective surgical procedure (spay or castration). Similar criteria for exclusion as described for group-1 dogs were applied. Group 3 consisted of 8 dogs (4 females, 4 males) and included Labrador Retrievers (n = 5), Boxers (2), and Greyhound (1). Body weights ranged from 27.2 to 34 kg (mean, 29.5 kg), and ages ranged from 12 to 28 months (mean, 17.6 months). Dogs were sedated by administration of acepromazine (0.22 mg/kg, IM), anesthesia was induced by administration of thiopental sodium (11 mg/kg, IV), dogs were endotracheally intubated, and anesthesia was maintained by administration of halothane. Because of time constraints, only tympanometry was performed as described for group 1. After recording the tympanogram, 5 ml of warmed sterile isotonic saline (0.9% NaCl) solution was placed into the horizontal ear canal. An open-end tom-cat catheter attached to a 12-ml syringe was passed through an otoscopic cone inserted into the horizontal ear canal to remove the saline solution from the ear canal. After removal of the saline solution, the tympanic membrane was viewed and a second tympanogram was performed.

**Statistical analyses**—To confirm a normal distribution, a normal probability plot was constructed from the data obtained from the left and right ears from all 3 groups of dogs. Data analysis for group 1 and group 2 were performed by use of 1-way ANOVA on data with a normal distribution and nonparametric Kruskal-Wallis test on data with a non-normal distribution. Data from right ears were compared with data from left ears; if significant differences were not detected, data from right ears were combined with data from left ears. Mean, SD, median, interquartile range, and 95% confidence intervals for the combined data were calculated. Combined data for ear canal volume from group 1 and group 2 were analyzed by use of simple linear regression, and a regression line was calculated that plotted volume (ml) versus weight (kg). For data from group 3, combined data were analyzed by use of a 2-tailed, paired t-test. A P value < 0.05 was considered significant for all tests. All data were computer analyzed.

**Results**

Tympanometric and acoustic reflex data from groups 1 and 2—A tympanogram was recorded from each dog (Fig 1). For group 1, ear canal volumes were recorded from 54 ears, compliance peaks from 52 ears, and pressures at maximum compliance from 52 ears (Table 1). Acoustic reflex data were obtained from 54 ears at 80 dB (mean ± SD, 0.05 ± 0.06 dB), 47 ears at

![Figure 1—Tympanogram recorded from a clinically normal dog. daPa = decaPascals.](image-url)

**Table 1—Tympanometric measurements of 27 clinically healthy purebred and mixed-breed dogs (group 1) and 21 healthy Beagles (group 2).**

<table>
<thead>
<tr>
<th>Pressure at maximum compliance (daPa)</th>
<th>Compliance peak (ml)</th>
<th>Ear canal volume (ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mean ± SD</strong></td>
<td><strong>95% CI</strong></td>
<td><strong>Median (iqr)</strong></td>
</tr>
<tr>
<td>Group 1</td>
<td>53.94 ± 55.26</td>
<td>0.47 ± 0.21</td>
</tr>
<tr>
<td>Group 2</td>
<td>65.61 ± 35.13</td>
<td>0.24 ± 0.08*</td>
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</tbody>
</table>

*Significantly (P < 0.001) different from group 1.

daPa = decaPascals. CI = Confidence interval. iqr = Interquartile range.

Measurements were recorded during anesthesia (group 1) or sedation (group 2).
Diagnosis of otitis media in dogs is difficult and may require otoscopy, endoscopy, radiography of the bulla, and myringotomy. In addition, these procedures may require general anesthesia to be performed adequately. Therefore, tympanometry and the acoustic reflex may be valuable techniques to assess the effects of otitis media on auditory function in dogs. The values established in the study reported here may be used as reference values for studies that evaluated sedated or anesthetized dogs for suspected otitis media.

In the study reported here, differences between group-1 and group-2 dogs for ear canal volume may be explained by differences in body weight, because group 1 consisted mainly of large dogs, whereas group 2 consisted of Beagles; mean body weight of group 1 was twice that of group 2. A linear increase in ear canal volume in dogs weighing 4 kg to 10 kg has been reported; however, dogs weighing >10 kg did not have the expected volume increase with weight. In that study, the same size probe ear tip was used in all dogs regardless of body weight; in large dogs, the ear tip would be passed down the ear canal farther than in small dogs and a smaller percentage of the ear canal would be measured. In the group-1 dogs reported here, probe ear tips of various sizes were used and size was based on the largest tip that could be placed into the horizontal ear canal; therefore, a larger volume of the ear canal was measured. Results of simple linear regression analysis of ear canal volume versus body weight were significant for group 1 when probe ear tips of various sizes were used, indicating that accurate measurement of ear canal volume requires the use of probe ear tips of appropriate size for each dog.

Differences between groups for compliance peak resulted from anesthesia of group-1 dogs versus sedation of group-2 dogs; a larger compliance peak was measured for group 1, compared with group 2. Our data, like that of Kitzman et al, revealed a larger compliance peak that may be related to the effects of isoflurane anesthesia. During anesthesia, the middle ear becomes a closed cavity, because swallowing is prevented, which may result in increases in middle ear pressure that cause alterations in tympanometric data. Results of studies evaluating the effects of halothane and halothane and nitrous oxide on middle ear pressure in humans revealed an increase in middle ear pressure during anesthesia. In the study reported by Kitzman et al, an increase in pressure at maximum compliance and compliance peak were obtained for dogs anesthetized with halothane and halothane and nitrous oxide combined, compared with preanesthetic values. Sedatives, such as acepromazine, oxymorphone, xylazine, and ketamine have been used without causing alterations in tympanograms or the acoustic reflex.

A different study reported amplitude (change in compliance [cm³]) for the acoustic reflex in sedated dogs. The analyzer used in that study manually measured the compliance change on a meter, resulting in mean amplitudes of 0.80 and 1.79 cm³ for the ipsilateral acoustic reflex at 80 and 90 dB, respectively, at a 2000 Hz frequency. The analyzer in the study reported here used a computer to measure the change in compliance, resulting in mean amplitudes of 0.05, 0.05, and 0.08 ml at 80, 85, and 90 dB, respectively, for group 1, and 0.05, 0.06, and 0.06 ml at 80, 85, and 90 dB for the ipsilateral acoustic reflex at a 2000 Hz frequency for group 2. It is not possible to compare results between these studies, because of differences in equipment. Therefore, in order to use the normative data obtained in our study, it is recommended that the analyzer be used.

When performing acoustic reflex testing, extraneous noises in the room may be sufficient stimulus to elicit contractions of the intra-aural muscles and falsely decrease compliance in the ears prior to stimulating the ipsilateral ear. In the study reported here, differences in the acoustic reflexes measured at 80, 85, and

**Discussion**

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90 dB were not detected between group 1 and group 2. Therefore, it is not necessary to perform acoustic reflex testing in a sound-attenuated room. To the authors’ knowledge, studies evaluating the effects of gas anesthesia on the acoustic reflex have not been published.

Differences between the sedated Beagles (group 2) and the isoflurane-anesthetized dogs (group 1) were not found for pressure at maximum compliance, suggesting that gas anesthesia is an appropriate alternative to sedation for this procedure. The effects of endotracheal intubation on impedance audiometric values have not yet been reported.

In group 3, tympanometry was performed under halothane anesthesia before and after flushing the ear canal with a saline solution, to evaluate the effects of ear flushing on tympanometric measurements. In the study by Kitzman et al,9 an increase in pressure at maximum compliance and compliance peak were obtained for dogs anesthetized with halothane, compared with preanesthetized dogs. However, in our study, any increase in compliance peak or pressure at maximum compliance detected on the initial tympanogram would be taken into account on the final tympanogram; differences were not detected. Therefore, accurate tympanometric measurements may be obtained after flushing the ear canal in healthy ears. This finding illustrates that the ear flush procedure is not responsible for abnormal tympanograms.

Results of a recent study indicate that 82.6% of dogs with chronic otitis externa have concurrent otitis media, and 71.1% have an intact tympanic membrane, as determined by myringotomy.14 Impedance audiometry may prove to be a useful noninvasive technique for diagnosis of otitis media. Results of the study reported here provide impedance audiometry values for clinically normal sedated or anesthetized dogs that may serve as reference ranges for evaluation of dogs for otitis media.

References