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The effect of magnetic resonance imaging noise on cochlear function in dogs

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ABSTRACT

Noise produced by magnetic resonance imaging (MRI) scanners (which can peak at a sound pressure level of 131 dB) has been shown to cause noise-induced cochlear dysfunction in people. The aim of this study was to investigate whether noise produced during MRI had a deleterious effect on cochlear function in dogs, using distortion product otoacoustic emission (DPOAE) testing, which allows frequency specific, non-invasive assessment of cochlear function. DPOAE testing was performed before and after MRI in one or both ears under general anaesthesia at 14 frequency pairs (f_2 frequency ranging from 0.84 kHz to 8.0 kHz). A control group comprised dogs undergoing anaesthesia of a similar duration for quiet procedures. Thirty-six dogs (66 ears) and 17 dogs (28 ears) were included in the MRI and control groups respectively.

There was a reduction in DPOAE at all frequencies tested in the MRI group; a similar effect was not evident in the control group. This reduction in the MRI group was statistically significant in five of the 14 frequencies assessed ($P < 0.05$). These results demonstrate that exposure to MRI noise results in a significant reduction in frequency-specific cochlear function in dogs, although it is not known whether this is reversible or permanent. This suggests that all dogs undergoing MRI studies should be provided with ear protection as a routine precautionary measure.

Introduction

Magnetic resonance imaging (MRI) is an increasingly popular, non-invasive diagnostic imaging tool used in veterinary patients. MRI scanners do not produce harmful radiation and are generally considered safe. However MRI scanners do produce noise, with typical values between 65 and 95 dB sound pressure level (SPL; Kanal et al., 1990) and peaks between 120 and 131 dB SPL (Radomskij et al., 2002; Wagner et al., 2003). The MRI acoustic noise spectrum typically has a broad peak, with maximum intensity at approximately 1.5 kHz (Lauer et al., 2012). This has raised concerns of potential cochlear damage and noise-induced hearing loss in human patients (Brummett et al., 1988). Although cochlear impairment caused by MRI scanner noise in human patients appears to be temporary and reversible (Brummett et al., 1988), ear protection is recommended (Gangarosa et al., 1987).

It has been suggested that MRI scanners could produce noise at amplitudes that are also potentially damaging to hearing in dogs (Lauer et al., 2012). Hearing acuity is important in dogs, and those with impaired hearing are at greater risk of being involved in road traffic accidents (Luttgen, 1994) and of becoming lost and being startled, which might make them more inclined to become aggressive; moreover, dogs with congenital deafness are often difficult to home as they can be harder to train (Strain, 1996).

Noise-induced hearing loss occurs as a result of oxidative damage to sensory hair cells in the cochlea (Yamane et al., 1995) and also from mechanical disruption. It has been suggested that hair cells detecting high frequency sounds appear to be the most vulnerable to noise-induced hearing loss, and that one of the first signs of hearing damage is a reduction in sensitivity to high frequency sounds (Sjaastad et al., 2003). However, in practice this refers to frequencies around 4 kHz, which corresponds to those most involved with speech in people; these frequencies are not particularly high for canine hearing. Noise-induced hearing loss also depends on the frequency of the sound to which the ear is exposed, and exposure to narrow frequencies of sound tends to affect hair cells specific to that frequency (Emmerich et al., 2005). Noise-induced hearing loss has been observed in kennel housed dogs exposed to continuous noise with a mean of ≥100 dB SPL, and length of exposure and amplitude are both important (Scheifele et al., 2012).

Otoacoustic emission (OAE) testing specifically evaluates the outer hair cells of the cochlea (Rogers et al., 1995) and is effective for hearing evaluation in a variety of veterinary species, including dogs, cats and horses and for congenital sensorineural deafness

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screening in puppies (McBrearty and Penderis, 2011a, 2011b; Gonçalves et al., 2012; McBrearty et al., 2013). In distortion product OAE (DPOAE) testing, a non-invasive probe is placed in the external ear canal, producing simultaneous pairs of frequencies (denoted f_1 and f_2, where $f_2 > f_1$) which evoke detectable emissions by the cochlear hair cells at other frequencies. These emissions can then be recorded by the probe in the external ear canal (usually at the frequency $2f_1$-f_2), to give an indication of frequency-specific cochlear function (Gonçalves et al., 2012). The ratio of f_2 and f_1 is fixed, usually at 1.2:1, but the frequencies are varied to test the integrity of different regions of the cochlea.

The aim of this study was to investigate the effect of MRI scanner noise on cochlear function in dogs. Cochlear function was assessed before and after MRI by DPOAE testing. A control population of dogs undergoing anaesthesia for quiet procedures was assessed in an identical manner to control for any potential effect of anaesthesia.

Materials and methods

Animals

Ethical approval for the study was granted by the local ethics and welfare committee of the University of Glasgow (Reference 18a/12, approved 31 July 2012).

Data were collected over 7 weeks in the Small Animal Hospital, University of Glasgow. Dogs undergoing anaesthesia for an MRI scan were potential candidates for inclusion (MRI group). MRI was performed using a 1.5 Tesla MR imaging system (Magnetom, Siemens). The MRI studies comprised a variety of sequences, but in all cases T1-weighted (360–870/10–15; range TR/TE) and T2-weighted (2160–5890/86–130; range TR/TE) sequences were performed. Dogs undergoing anaesthesia for non-noisy procedures were screened as potential controls (control group). Dogs with previous hearing impairment or ear disease were excluded. Age, gender, breed and bodyweight and the drugs used for induction and maintenance of anaesthesia were recorded.

Descriptive statistics were reported as mean, median and range. Cochlear function was determined immediately after induction of anaesthesia prior to MRI (MRI group) or quiet procedures (control group) and again immediately following MRI (MRI group) or towards the end of anaesthesia (control group). OAE testing did not increase anaesthesia length and all dogs were undergoing MRI or other procedures as part of an unrelated clinical investigation.

OAE testing

All OAE testing was performed by a single investigator using the Echoport ILO-288 USB-II system with v6-software (Otodynamics) on a laptop computer. At the start of each day, the OAE probe (UGD-DPOAE probe, Otodynamics) was calibrated. After induction of anaesthesia, otoscopic examination of the external ear canal was performed. Any cerumen or debris was removed using a dry swab. A clean OAE probe tip of an appropriate size was used for each dog. The probe position in the external ear canal was adjusted to achieve the best possible fit, using the OAE machine's Checkfit function. Good probe fit was indicated by a short positive and then negative waveform deflection and a smooth frequency spectrum curve.

DPOAE testing was performed with 14 frequency pairs (Figs. 1 and 2). The frequencies ratio of the two stimuli was 1.21 ($f_2 > f_1$) and the intensity level of both was 55 dB SPL. Each frequency pair was delivered for 1.5 s and the evoked emissions were recorded at a third frequency ($2f_1$-f_2) and at the background noise level. The 14 frequency pairs were played in sequence from highest to lowest three times, requiring a total test time of 63 s per ear, defined as a 'run'. All tests were performed in a clinical environment. A noise-reducing ear cover (Ear Muff EP-101; Parkson Safety Industrial) was placed over the test ear throughout DPOAE testing to reduce environmental noise.

After each test, the probe was removed from the ear and the coupling tubes checked for blockage by debris. If blocked, the couplings were replaced, the result was discarded and the test was repeated. The test was then performed on the second ear, time permitting. After completion of the MRI or quiet clinical procedure, the DPOAE testing was repeated during recovery from anaesthesia. The duration of MRI study, the time between the end of the MRI and the post-MRI test, the length of time between pre- and post-procedure tests and the reason for the MRI study or procedure were recorded.

Data analysis

The OAE testing software automatically rejected data for a frequency pair during any time that the background noise exceeded a pre-defined threshold. If this occurred all three times that that frequency pair was presented, then that frequency was excluded from the analysis for that ear. If a run had more than six frequency pairs with no data, the run was excluded. For each frequency, the difference (dB SPL) in absolute DPOAE between the post- and pre-procedure tests was calculated. The difference was expressed as the mean change in absolute DPOAE (±standard error of the mean, SEM) for that frequency, with significance calculated using the Mann–Whitney *U* test. For all statistical tests, significance was defined as the two-tailed $P < 0.05$. The change in absolute DPOAE between the post- and pre-procedure tests for each ear at each frequency was also classified as decreased or not decreased. When examining the change in absolute DPOAE, random sample distribution would have predicted a distribution of 50% of ears demonstrating a decrease and 50% demonstrating no decrease in absolute DPOAE (an identical value is very unlikely). The

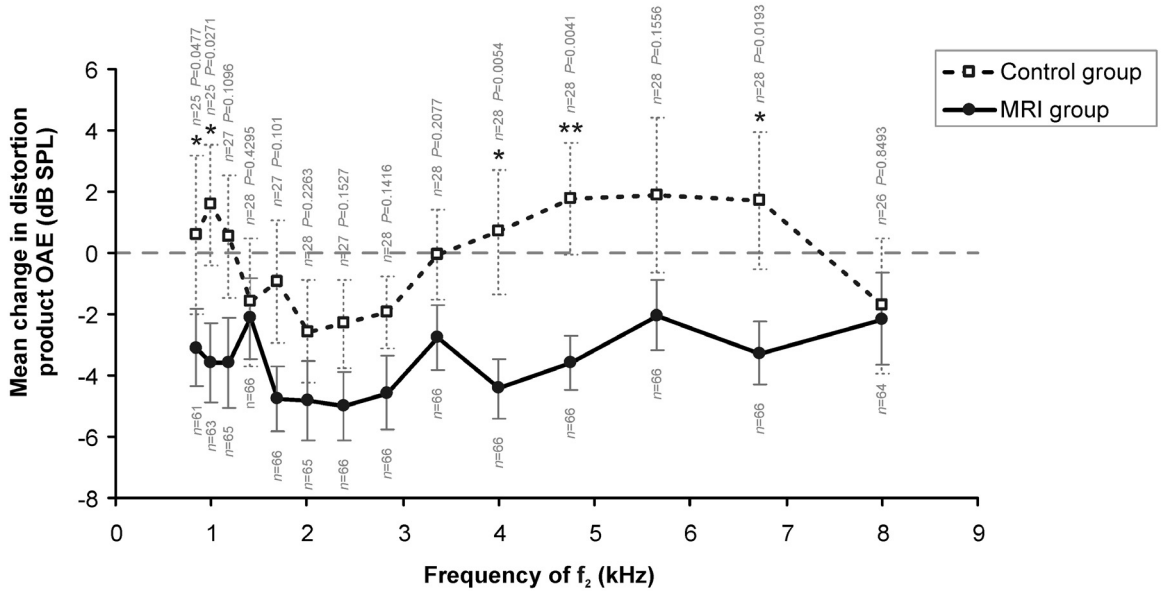

Fig. 1. Mean (±standard error) change in the distortion product otoacoustic emission (DPOAE) after either exposure to MRI noise or a quiet procedure at each of the 14 frequency pairs tested. Magnetic resonance imaging noise resulted in a substantial reduction in cochlear function across all the frequencies tested compared to a control group undergoing quiet procedures under general anaesthesia of similar length. $^{*}P < 0.05$; $^{**}P < 0.005$.