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Research paper

Hyperbaric oxygenation with corticoid in experimental acoustic trauma

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Abstract

Among possible therapies after acute acoustic trauma, hyperbaric oxygenation (HBO) combined with corticoid was found effective in several animal studies. Such evidence was obtained for moderate 20–25 dB losses. The aim of this study was to further assess this therapy for noise-induced hearing losses greater than previously examined. Sixty-five ears from thirty-six adult guinea pigs were used. Acoustically evoked responses from intracranial electrodes chronically implanted bilaterally into the ventral cochlear nucleus were used to assess acoustic sensitivity alterations. Trauma sound was a third-octave noise-band around 8 kHz presented bilaterally at 115 dB SPL for 45 min. One control group received no treatment, one group was treated with HBO only and another with corticoid only both starting within one day post-trauma, two groups were treated with both HBO and corticoid starting for one group within one day post-trauma, and for the second group at 6 days post-trauma. Acoustic thresholds were measured between the 6th and the 16th days after acoustic trauma. Animals treated with HBO alone or corticoid alone did not differ from controls. Combined HBO and corticoid therapy provided significant protection from noise-induced loss of auditory thresholds, especially when started one day post-exposure. Hearing loss reduction induced by HBO combined with corticoid was of similar magnitude (about 10–15 dB) as in previous studies although the induced hearing loss was considerably greater (about 40 dB instead of 20–25 dB).

Keywords: Acute acoustic trauma; Hearing loss; Hyperbaric oxygen; Corticoid; Guinea pigs

1. Introduction

Despite extensive educational measures and improved ear protection, acute acoustic trauma (AAT) still represents a major problem of public health. The hearing loss after AAT is due to several causes including: altered cochlear oxygenation, decreased cochlear blood flow, damage to cell membranes, metabolic effects of free radicals, altered neurotransmission and apoptosis (for an overview see Henderson et al., 2006). The succession of pathological events remains poorly understood and certainly varies with sound trauma parameters. However, altered oxygenation and decreased cochlear blood flow seem to occur first (Thorne and Nuttall, 1989; Lamm and Arnold, 1996) and induce free radical accumulation in the cochlea leading to cell dysfunction and death (Yamane et al., 1995; Yamashita et al., 2005).

For many years, various treatments of acoustic trauma have been aimed at reducing inflammation and at enhancing cochlear oxygenation. Corticoids are the most powerful anti-inflammatory drugs and are known to be involved in noise-induced hearing loss (Tahera et al., 2006). Exposure to noise trauma is associated with cochlear hypoxia and hyperbaric pressure is the most efficient way to greatly increase blood oxygen content (Thorne and Nuttall, 1989; Lamm and Arnold, 1996; Tibbles and Edelsberg, 1996). Corticoid therapies showed some benefits in animal

Abbreviations: HBO, hyperbaric oxygenation; AAT, acute acoustic trauma; VCNEP, ventral cochlear nucleus evoked potential

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experiments but only at very high doses (Takahashi et al., 1996; Lamm and Arnold, 1998) whereas more recent experimental data definitely established regulation of glucocorticoids in acoustic trauma (Tahera et al., 2006). Hyperbaric oxygenation (HBO) is the most efficient way of increasing oxygen levels and has several established medical applications (Tibbles and Edelsberg, 1996). As for acoustic trauma, studies are few but there is clear experimental evidence of successful HBO therapies (Lamm et al., 1982; Pilgramm, 1991; Lamm et al., 1998a; d'Aldin et al., 1999) and clinical studies also report significant success rates (Vavrina and Muller, 1995; Lamm et al., 1998b; Winiarski et al., 2005). The post-trauma delay always appears as a significant parameter. In several studies, both experimental and clinical, a combination of corticoid and HBO treatments was reported to bring greater benefits. The aim of this animal study was to further evaluate the ability of HBO and corticoid therapies alone or given in association either within one or six days post-AAT. Previous studies showed efficacy of combination of HBO and corticoid for noise traumas inducing approximately a 25 dB threshold shift. The present study aimed to test significantly higher sensitivity losses of about 40 dB.

2. Materials and methods

2.1. Animals and implantation

Thirty-six adult albino guinea pigs (Dunkin Hartley breed from Charles River Laboratories) weighing between 400 and 500 g at the beginning of the experiments were used in this study. At the time of arrival, and for at least one week, all animals were checked for the bilateral pinna reflex in response to a weak high frequency hissing sound. Each animal underwent surgery for chronic bilateral electrode implantation. Anaesthesia consisted of a mixture of xylazine at 10 mg/kg mixed with ketamine at 50 mg/kg. The skin of the top of the skull was incised and the bone was scraped and dried visualizing the frontal, parietal and occipital bone junctions. Two electrodes made of teflon-coated platinium wire of 0.2 mm diameter (Medwire Corp., NY) were stereotaxically implanted in the ventral cochlear nucleus through small holes drilled in the skull. The presence of a click-evoked response was checked during descent of the electrode. When maximal responses were obtained, electrodes were fixed in place with acrylic cement. Then two holes were drilled about 5 mm anterior to the fronto-parietal junction, one on each side of the sagittal line. Brass screws fixed in these holes served as reference and ground electrodes. The four electrodes were then soldered to the pins of a small connector fixed to the skull by acrylic cement and the skin was sutured. All animals were given at least one week recovery after the operation, then the ventral cochlear nucleus evoked potential audiogram (VCNEP audiogram) was checked for normality. A final total of 36 animals presenting 65 ears with normal audiograms were used in this study. Experimental protocols followed the guidelines of the Centre National de la Recherche Scientifique (CNRS) and the French and European laws on the laboratory animals care and use.

2.2. Evoked potential audiograms

Inside a double-wall silent booth, animals were placed in a holding box with their head gently maintained in a fixed position by a neck and a nose ring. An earphone was placed at 1 cm in front of the entrance to the external acoustic meatus. Acoustic levels were measured by replacing the head of the animal by a 0.5 inch condenser microphone. Levels were measured in dB SPL (dB peak equivalent SPL for transient stimuli). Tone pips were generated by gating a sine wave of adjustable frequency with a linear rise/fall time of 2 ms and no plateau. Tone pips were chosen at octave intervals from 500 Hz to 2 kHz and at third octave intervals from 2 to 32 kHz to more precisely assess audiogram losses at high frequencies. At each frequency VCNEP audiogram thresholds were determined by averaging up to 300 responses and visual detection was used to determine the presence of a response. This way threshold measures were reproducible within about 3 dB.

2.3. Acoustic trauma

The animals were exposed to noise at least one week after the electrode implantation. First, a pre-exposure VCNEP audiogram was performed. Then the animals were bilaterally exposed for 45 min to a one third-octave band of noise with a center frequency of 8 kHz at 115 dB SPL. In many cases 3 h following the acoustic trauma, another VCNEP audiogram was performed to assess short-term threshold shifts.

2.4. Treatments

A group of 10 animals (15 ears) did not receive any treatment and was used as a control. A second group of 4 animals (8 ears) received corticoid therapy alone (10 mg/kg/day of methylprednisolone hemisuccinate by intramuscular injection). A third group of 7 animals (14 ears) was treated with HBO therapy alone (see below). A fourth group of 10 animals (19 ears) was treated with HBO in association with corticoid with treatment starting within one day after acoustic trauma. A fifth group of 5 animals (9 ears) was treated as the fourth group but their treatment started on the 6th day after acoustic trauma. All treatments lasted for 10 days.

2.5. Hyperbaric chamber

The hyperbaric chamber (Bethlehem 1836 HP) was a horizontal cylinder with a volume of 1367 liters. Each animal was placed in an individual cage. Twenty animals could be exposed together. The inside temperature was