## **Comments on Sonic Cannons**

Marshall Chasin, AuD., M.Sc., Reg. CASLPO, Aud(C),

**Doctor of Audiology,** 

Coordinator of Research,

**The Canadian Hearing Society** 

Three types of sonic cannons:

Sonic cannons have had three incarnations over the years. The first implementation uses very low frequency sounds (essentially in the octave below the lower note on a piano keyboard) that have a significant vibro-tactile, or "whole body" response. This has been well studied in the literature and can result in nausea, a feeling of fullness in the chest and even heart fluctuations. The literature indicates that the sound level and dose is below that which may cause hearing loss and this is understandable given the human ear's poor sensitivity to very low frequency sound. However, very low frequency (also called subsonic or infrasonic) intense sound is not practical because low frequency sound is non-directional. This means that the user of the very low frequency sound cannon is as much subject to the deleterious effects of the sound as the person or people that the cannon is aimed at. Simply stated, very low frequency sound cannot be "aimed".

The second implementation of sonic cannons is to use them to emit sound in the ultrasonic range (above the range of hearing of most healthy adults) and these intense, very high frequency sound sources are actually in wide spread use and is marketed under trade names such as the "Mosquito". They emit sounds that are above the hearing range of a typical adult but not above the range of a teenager with good hearing. Retailers at shopping malls and variety stores frequently use this to dissuade teenagers from hanging around the entrance to the store. The teenagers feeling discomfort move away while more mature consumers (with larger wallets) are not affected by this sound. They are also sold for use on vehicles in rural areas, in order to minimize the chances of a collision with moose and other large wildlife. Ultrasound has also been well studied in the literature and there is no known deleterious effect on hearing, and it is a rarely audible for most adults over the age of 25.

However, the third and most common implementation of a sound cannon, especially for crowd control and dispersion, is in the mid- to high- frequency region. These sounds are quite audible to a wide range of people of different ages and hearing abilities (essentially the right hand side of the piano keyboard). Unlike infrasound, this higher frequency intense sound is quite directional, and the directionality increases as a function of frequency. This makes such a high frequency sonic cannon a more effective choice for those who use it in the sense that the operator will receive a less intense level of the stimuli being emitted from the cannon. That is, the cannon can be aimed. However, these same intense frequencies can be damaging to the person or people "down wind" of the sonic cannon. At 1000 Hz and above, sound tends to become quite directional, but at

the same time, the sound pressure that reaches the human ear is more audible. (In the very low frequency region most of the sound energy hits the eardrum and bounces back, thereby not reaching the auditory system of the individual. This is not the case for the mid and higher frequency regions.)

If the sonic cannon hardware is to be used as a loudspeaker there is a very real risk of hearing loss for the operator because speech has significant low frequency sound energy (vowels and other sonorants) and the levels of his own voice may be extremely intense (because of the lack of directionality) at the level of his own ear. The operator should be cautioned to wear appropriate hearing protection and to limit the use of the sound cannon.

## Hearing and hearing loss:

The human ear is a complex organ that is made up of three distinct parts- the outer ear terminating at the eardrum, the middle ear (with the three tiny bones or ossicles), and the inner ear (made up of both the hearing sensory organ (cochlea) and the balance organ (the vestibular system)). Intense sounds can rupture the eardrum that mediates sound from the outer to the middle ears. This is quite rare but depending on the nature and physical makeup of the intense sound wave this is possible. More common however would be damage to the cochlea and its associated structures.

The cochlea is roughly the size of the tip of your baby finger and is filled with two distinct types of fluid. Immersed in the fluid are 15,000 nerve endings, or hair cells,

which transmit sound energy neurologically to the brain and also to receive feedback from the higher neurological structures. The chemistry of the cochlea is extremely complex and much of our hearing is accomplished based on microscopic flow of molecular ions such as potassium and sodium. (Chasin and Behar, 2010). Intense noise can disrupt the chemistry leading to hair cell death by processes called necrosis and apoptosis. Hearing loss from both necrosis and apoptosis may not show up immediately and may not be realized until years later. Intense noise has also been shown to disrupt the mechanics of the cochlea and again, this disruption may not show up until years later. (Gates et al., 2000; Kujawa and Liberman, 2006, 2010).

If a person were to be subjected to very intense noise, or even more moderate levels of noise (such as a dial tone) for a significant amount of time, permanent hearing loss would occur.

The tools that are used to assess hearing loss by an audiologist are admittedly blunt. The most ubiquitous of the measuring tools is called the audiogram. An audiogram is performed in a very quiet sound treated "audiometric room" and is a measure of the quietest sound that a person can hear across a wide range of test frequencies from about the middle of the piano keyboard (250 Hz) to an octave above the top note on the piano (8000 Hz). Reductions in the sensitivity of hearing in the audiogram are termed "hearing loss." However, recent research indicates that by the time that a hearing loss is measured on an audiogram, a significant amount of cochlear damage has already occurred.

Another clinical test that has been available since the late 1980s is called "otoacoustic"

emission testing" and this assessed the function of the cochlea (whereas the audiogram assesses the acuity). Reduced function of the cochlea typically shows up long before any loss observed on the audiogram. (Salvi, Lobarinas, and Sun, 2009).

Historically it was thought that once a person had been removed from a noisy location that had been implicated in hearing loss, such as a factory, there would be no more hearing loss associated with that prior environment. Indeed, many provincial Worker's Safety and Insurance Boards have that enshrined in their hearing loss prevention policies. However more recent research has indicated that hearing loss can continue to deteriorate due to the prior noise despite the fact that the individual is no longer exposed. Kujawa and Liberman (2006, p. 2115) state that "Data suggest that pathologic ... changes initiated by early noise exposure render the inner ears significantly more vulnerable to aging". This has also been shown in the central auditory system where inhibitory changes in the dorsal cochlear nucleus decreased neural function in older experimental mice as a result of exposure in juvenile mice. Caspar, Schatteman, and Hughes (2005). The cochlea, once subjected to a significant amount of noise or other ototoxic mechanism, is damaged and despite the fact that we do not yet fully understand the cochlear pathology of hearing loss from noise, it is known that the long term effects of noise do not cease upon removal from the noise source.

The important corollary is that if a person is subjected to an intense, potentially traumatic noise source and no hearing loss is measured initially on an audiogram, it does not follow that hearing loss resulting from this traumatic noise source will not rear its ugly head in

years to come. Kujawa and Liberman (2010) state "Results suggest that noise-induced damage to the ear has progressive consequences that are considerably more widespread than are revealed by conventional threshold testing. This primary neurodegeneration should add to difficulties hearing in noisy environments, and could contribute to tinnitus, hyperacusis, and other perceptual anomalies commonly associated with inner ear damage."

It is clear from the recent animal studies that significant noise exposure while young, may have significant cochlear and central auditory ramifications when older despite being exposed only when younger. Use of sonic cannons, as well as being in the proximity of other very intense noise sources can have a deleterious effect on the long term hearing status of exposed individuals. This potentially includes both the operator of the sonic cannon as well as those whom the noise is aimed towards.

## References:

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