**Slide One (Introduction)**

No disclosures, No conflicts of interest.

Limitations of this study:

Comprehensive literature review

Did NOT include any human subject research or trials of any kind.

Information collected and used in this study was accessible on the

Internet.

Purpose/aim of this study:

* **Review current practices and methods of already implemented hearing protection through academic literature review.**
* **Review current practices and methods of hearing protection at Valley Children’s Hospital.**
* **Review MRI regulatory hearing protection standards as they apply to occupational safety as well as to the general public.**
* **Create awareness for best practice by identifying areas of potential improvement**

**🡪 Offer suggestions for additional hearing protection options for**

**quality improvement**

Method:

* **Information regarding hearing, sound, hearing protection, shimming, gradient coil shape, protocol optimization and standard practice were collected.**
* **Current hearing protection at Valley Children’s Hospital was assessed through observation, interviews, examination and research.**
* **Alternative hearing protection was assessed for appropriateness, practicality, coverage, comfort, and ease of use.**

**Slide two**

* **\*MRI machines consist of a large cylindrical tunnel – bore – and a non-ferromagnetic couch or patient table.**
* **\*The magnet is ALWAYS on.**
* **\*Three-dimensional cross-sectional images of anatomy allow visualization of adjacent structures without superimposition, through the use of image weighting.**
* **Image weighting determines the contrast of an image. It is controlled through the parameters within each sequence.**
* **\*Although parameters can be adjusted by the technologist, it can affect image quality.**
* **\*Several Safety concerns exist in MRI.**

**Slide three**

* **Sound is one of the most preventable safety risks in MRI.**
* **During MRI Exams – patients within the bore or cylindrical tunnel of the machine experience several loud, repetitious sounds as the machine acquires images.**
* **Prolonged exposure to loud, repetitious sound can cause permanent threshold shifts and hearing loss. 3, 4**
* **Sources of sound exposure in MRI-**

**+Machine noise - ColdHead**

**+Gradient coil noise – rapid switching of gradients**

**+Sequence noise – Certain protocols exude louder**

**noise as the machine acquires images.**

**Slide four (regulatory oversight)**

1. OSHA

Requires employers to implement a hearing conservation program when noise exposure is at or above 85 decibels, averaged over 8 working hours, or an 8-hour time-weighted average

1. CALOsha

🡪Define noise as a sound wave generated when an object vibrates or compressed air is

suddenly allowed to expand, producing oscillations of air pressure.

🡪The intensity of those air pressure oscillations, typically measured as sound pressure

levels, is usually expressed as decibels

🡪How quickly the air pressure oscillations occur (frequency) is expressed as hertz (Hz),

the number of wave cycles per second.

🡪Permissible Exposure Limits (PEL) – 90 dBA for 8 hours.

1. FDA exposure limits for sound pressure levels.
   1. Occupational
   2. Patient exposure
   3. Maximum sound pressure levels of 140 dB - 99 dB with hearing protection
      1. Based on occupational noise exposure limits
      2. Intended to prevent other adverse effects associated with excessive noise levels
2. International Society for Magnetic Resonance Imaging in Medicine (ISMRM)– Safety Guidelines for Magnetic Resonance Imaging Equipment in clinical use
   1. Exposure to a loud noise can result in a reduction of the sensitivity of the hair cells in the organ of Corti and a shift in the threshold of hearing. This may be temporary if the cells can recover or permanent if the exposure is very loud (>140 dB(A)), prolonged or frequently repeated.
   2. Use of ear plugs, ear defenders or other means of hearing protection is highly recommended
3. CDC - National Institute for Occupational Safety and Health (NOISH)
   1. Established a recommended exposure limit (REL) of 85 dBA – averaged over an 8-hour work day.
      1. Additionally, workers who are exposed to noise at or above the NOISH REL are at risk for developing significant hearing loss over their working lifetime.
4. CDC Website on noise –

Loud noise can damage your hearing

Noise is considered hazardous based on

* 1. How loud the sound is
  2. How long the exposure lasts
  3. How often the exposure is repeated

**Slide five**

Some examples of normal sounds we experience in day to day life and their sound

Intensity

**Slide Six**

Some examples of sequences and sound pressure levels as recorded in literature

**Slide Seven**

Additional examples of MRI sequences and sound pressure levels – Most notably EPI

**Slide Eight**

What is sound Attenuation?

Meriam Websters definition of Attenuation = a lessening in the amount, force, magnitude, or

value of something, in this case, sound.

**Slide Nine**

**Some of the solutions that can help provide sound attenuation**

**during MRI exams are:**

**1. Gradient Coil Shape**

**2. Protocol Optimization**

**3. Hearing Protection**

**Slide Ten**

**Gradient coil shape** (geometry-based noise reduction)

🡪 According to an article by Paolo Leo and Annunziata D’Orazio, in an article titled Lorentz force and vibrations in transverse gradient coils in MRI, that appeared in the International Journal of Mechanical Sciences, in January of this year 288 (2025): Elliptical gradient coil shape =

#”Gradient coils – a set of loops of wire or thin conductive sheets that are

used to produce linearly variable magnetic fields which determine slight

variations in the main magnetic field necessary for the spatial encoding

of voxel position.”

- gradient coils are responsible for slice selection as well as

frequency and phase encoding during image acquisition

-thinner slices require steeper gradients.

-steeper gradients emit louder sound.

#”During the image acquisition, the coils are subjected to rapidly varying

current pulses which result in the generation of

intense Lorentz forces acting on the gradient coil... This

causes the supporting structure in which they are embedded to vibrate,

leading to the generation of …acoustic noise”

-Lorentz force from the encyclopedia Brittanica, is, “…the force

exerted on a charged particle…moving with velocity…through an

electric …and magnetic field...”

* + - * “a current represents a movement of charges in a wire, the Lorentz force acts on the moving charges. Because these charges are bound to the conductor, the magnetic forces on the moving charges are transferred to the wire with respect to the field.”

-<https://www.britannica.com/science/Lorentz-force>

- In the Journal of Magnetic Resonance Imaging, 12:37-45(2000),

author’s, Dr. Mark McJury, PhD and Dr. Frank G Shellock, PhD,

from the article, Auditory Noise Associated with MR Procedures:

A Review, write, “…noise occurs during the rapid alterations of

currents within the gradient coils. These currents, in the presence

of a strong static magnetic field of the MR system, produce

significant (Lorentz) forces that act upon the gradient coils.

Acoustic noise, manifested as loud tapping, knocking, or chirping

sounds, is produced when the forces cause motion or vibration of

the gradient coils as they impact against their mountings which, in

turn, also flex and vibrate.”

-From the journal, Magnetic Resonance in Medicine 73:1104-1109 (2015), Björn

Heismann, Siemens Healthcare, MRI, Martin Ott, Friedrich-Alexander-

University of Erlangen-Nuremberg, Pattern Recognition Lab, and David

Grodzki, Research Center Magnetic Resonance-Bavaria, wrote the article,

Sequence-Based Acoustic Noise Reduction of Clinical MRI Scans.

-Talks about how Lorentz forces act on a Trapezoidal gradient shape

-The article puts more emphasis on Sequence based acoustic noise

reduction as the title suggests.

-From the article, “Numerical design of transverse gradient coil with transformed

magnetic gradient field over an effective imaging area,” written by Chaoqun

Niu, College of Information and Communication Engineering, Hongyi Qu,

Institute of Electrical Engineering, which, appeared in Magnetic Resonance

Letters 5 (2025), the authors describe in more detail, several gradient coil

arrangements.

**Slide Eleven**

Protocol Optimization

Involves creating/organizing an order of sequences (protocol)

that are inherently sound attenuating.

`utilizing sequences that generally register lower sound

attenuation levels (by substituting inherently loud

sequences for quieter ones)

`ensuring image quality remains unchanged.

`use built in pre-optimized sequences (manufacturer’s

protocols) when they exist and do not compromise the

integrity of the study through image quality or otherwise.

`periodically re-evaluating existing optimized protocols

(for quality control)

-durability of mechanics, availability of new

Technology, overuse/age, changes in the needs of

the department, required upgrades.

**Slide Twelve**

Hearing protection

-From the previously mentioned article, Lorentz force and vibrations in transverse gradient coils in MRI, Leo & Orazio (2025), “MRI acoustic noise is an issue of concern since it causes discomfort to patients and operators and sometimes can represent a health risk.” The authors go on to cite other articles that describe both temporary variations in hearing threshold following high levels of acoustic noise exposure in MRI scanners as well as the psychological stress, anxiety, and

fear experienced by pediatric…patients.

Currently available forms of hearing protection

\*Ear plugs  
 -one time use  
 -foam  
 -30 dB NRR  
 -one size  
  
\*Headphones  
 -adult sized  
 -rigid design, hard plastic   
 or super soft foam

**Slide 13**

*Proper Earplug Insertion*

**Slide 14**

Just for fun sound effects

**Slide 15**

Quality improvement suggestion

Dreamies/Dreamies T-M.

Prototypes were generated in 2015.

A pilot study was completed in fall of 2017.

2 different types.

DREAMIES (per their website:

https://www.neatcapmedical.com/faq/ )–

“...designed for continual, recurring use with a

single patient in the NICU or PICU and function

as a low-pass sound filter allowing some

beneficial human voice transmission to the patient

while blocking high-frequency noise such as

monitor alarms.”

DREAMIES T-M –

“…block noise across the full spectrum of

sound…with maximum sound blocking at

frequencies where MRI noise is the

loudest…intended for short use (up to 3 hours)

during…MRI exams on a single patient”

Let’s talk about fit. “…ear cups are contoured to match the

shape of an infant’s head and are held in place with a

unique flexible and adjustable headband. The headband

stretches only around the ear cups, to apply a uniform force

to form a good acoustic seal. The headband uses smooth

non-stretching silicone patches to gently grip the skin

across the back of the head and the forehead of the patient

without harm to the skin and head.”

\*5 sizes ranging from 23 cm to 48 cm

\*Overall mean rating of 27 dB of protection

\*Designed for kiddos from neonate (preemies over 26 weeks gestational age) through 2 years

of age.

\*Velcro closure

\*Single patient use

**Slide 16 - Conclusion**

\*MRI is a useful, effective diagnostic tool.  
\*The imaging team works diligently to ensure every patient receives the best, safest care

possible.  
\*Acoustic noise from MRI machines can produce loud, repetitious sounds that can make

our patients uncomfortable and can reach 138dB3.  
\*The most effective, available means of sound attenuation is hearing protection.  
\*Every patient is offered hearing protection every time.  
\*Currently available forms of hearing protection include coated, foam ear plugs that offer

30 dB of protection and   
 headphones that offer an additional 7 dB of protection.  
\*Newer solutions in hearing protection are becoming more widely utilized.  
\*DREAMIES are a hearing protection solution designed for children from neonate

through age two.   
\*Multiple sizes are available based on head size, and they are easy to apply.  
\*DREAMIES T-M offer 27 dB of hearing protection for our most sensitive patients.  
\*DREAMIES T-M would add an additional tool for technologists to use when providing

hearing protection.  
\*Used in conjunction with existing hearing protection options, our kiddos here at Valley

Children’s hospital would benefit from more than 50 decibels of protection while

undergoing diagnostic imaging exams.

**Future Direction**

Continue to communicate the importance of MRI Safety to create

Awareness and Imaging leaders as well as our Radiologists have been supportive of this effort.

Potentially request approval to obtain some of samples of Dreamies T-M

and see how they work with our population of kiddos.

Request feedback from our care teams and see if this would really be a

functional solution in hearing protection for our littlest patients.

**Questions?**