



Lessons Learned from the October Wars

HBO Latency | Blast vs Gunshot

Ivan GUR



At the moment of truth,
IDF MEDICAL CORPS.

Acute Acoustic Trauma (AAT)

Definition

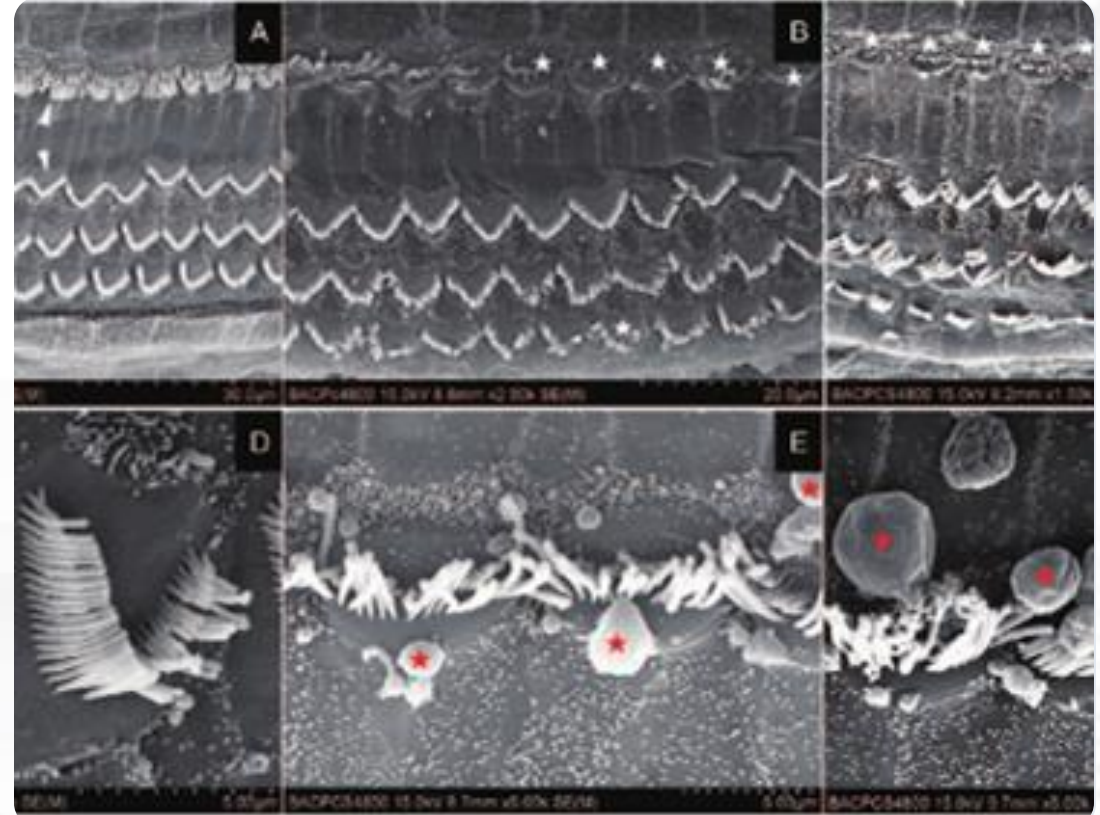
Sudden sensorineural hearing impairment resulting from **intense noise exposure**.

Key Impact & Prevalence

warning Primary cause of newly diagnosed hearing disability in military personnel.

trending_up High impact on readiness and longevity.

verified_user Preventable but frequently encountered in training and combat.



Mechanism of Injury

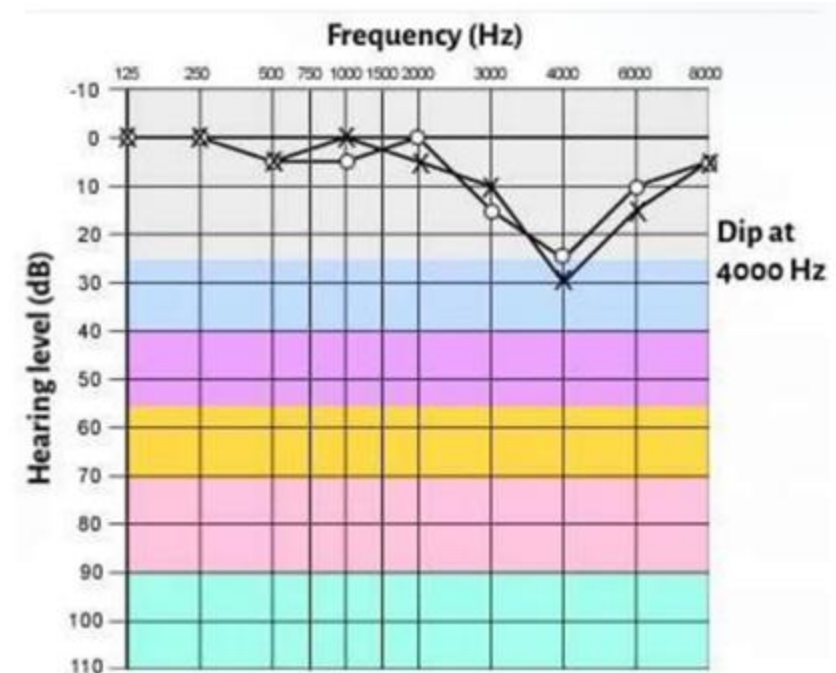
Primary Drivers of Cell Death

invert_colors_off1. Cochlear Ischemia

coronavirus2. Inflammatory Cascades

science3. Oxidative Stress

These lead to permanent cochlear hair cell loss and auditory synaptopathy.



Hyperbaric Oxygen Therapy

air1. Reverses Cochlear Hypoxia

The cochlea has high metabolic demands but limited collateral circulation. HBOT delivers high-pressure oxygen that diffuses into poorly perfused tissue independently of hemoglobin-bound transport, effectively raising inner ear oxygen tension.

healing2. Improves Microcirculation & Reduces Edema

By promoting the vasoconstriction of normal vessels while simultaneously maintaining oxygen delivery, HBOT reduces edema in injured tissue and improves relative perfusion to the damaged cochlea.

shield3. Modulates Inflammation & Free-Radicals

Acoustic trauma generates reactive oxygen species and inflammatory mediators that drive hair cell apoptosis; HBOT is proposed to attenuate this secondary injury cascade, supporting the recovery of hair cells and the stria vascularis.



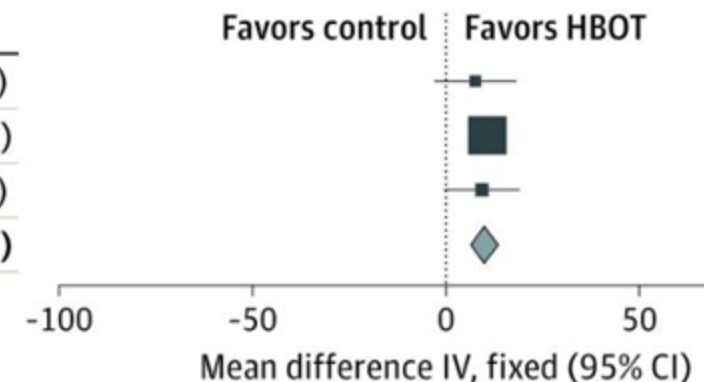
HBOT - SSNHL

A Fixed-effects model

Study or subgroup	HBOT group			Control group			Weight, %	Mean difference IV, fixed (95% CI)
	Mean	SD	Total	Mean	SD	Total		
Cho et al, ¹⁶ 2018	38.12	17.22	30	30.38	23.96	30	13.1	7.74 (-2.82 to 18.30)
Khater et al, ¹⁸ 2018	54.76	1.63	11	43.84	7.46	11	71.6	10.92 (6.41 to 15.43)
Krajčovičová et al, ¹⁷ 1998	18.20	20.60	47	8.8	18.2	21	15.3	9.40 (-0.36 to 19.16)
Total (95% CI)			88			62	100.0	10.27 (6.45 to 14.09)

Heterogeneity: $\chi^2 = .33$; $df = 2$ ($P = .85$); $I^2 = 0\%$

Test for overall effect: $z = 5.27$ ($P < .001$)

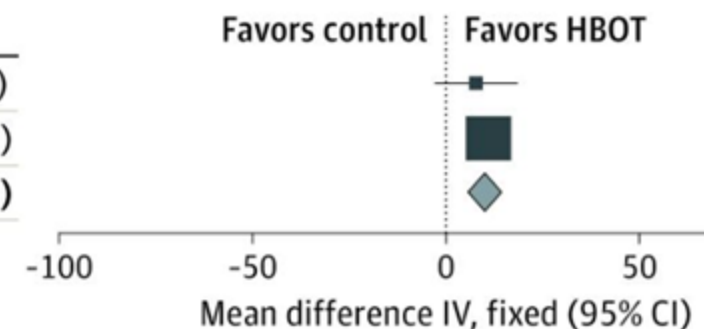


B Subgroup analysis

Study or subgroup	HBOT group			Control group			Weight, %	Mean difference IV, fixed (95% CI)
	Mean	SD	Total	Mean	SD	Total		
Cho et al, ¹⁶ 2018	38.12	17.22	30	30.38	23.96	30	15.4	7.74 (-2.82 to 18.30)
Khater et al, ¹⁸ 2018	54.76	1.63	11	43.84	7.46	11	84.6	10.92 (6.41 to 15.43)
Total (95% CI)			41			41	100.0	10.43 (6.28 to 14.58)

Heterogeneity: $\chi^2 = .29$; $df = 1$ ($P = .59$); $I^2 = 0\%$

Test for overall effect: $z = 4.93$ ($P < .001$)



HBOT - AAT

schedule

Time-Sensitive Efficacy

Retrospective cohorts of military populations exposed to impulse noise demonstrate that hearing improvement rates are highest when treatment is initiated within 24 hours to 7 days post-trauma.

(Holy et al., Int J Environ Res Public Health 2021;
Gutkovich et al., Eur Arch Otorhinolaryngol 2025)

medication

Works Best with Steroids

Combining HBOT with systemic corticosteroids appears to produce better outcomes than either alone, consistent with complementary anti-inflammatory and pro-perfusion effects.

(Joshua et al., JAMA Otolaryngol Head Neck Surg 2022; Alter et al., Laryngoscope 2025)



Who do we treat

history

Audiometry & Timing

Following exposure to intense military noise, audiometry must be **deferred to at least 48 hours** post-exposure.

This delay is critical to account for and exclude transient threshold shifts (TTS) before confirming permanent damage.

hearing

HBO Referral Thresholds

Initiation of Hyperbaric Oxygen Therapy requires meeting at least one of the following sensorineural hearing loss criteria:

45 dBin at least one frequency

40 dBin at least two frequencies

35 dBin at least three frequencies



Excluded

report_problem

Absolute Contraindications

Absolute contraindications to HBO, including the inability to equalize middle ear pressure or severe pulmonary pathology that risks pneumothorax.

event_busy

Protocol Non-Compliance

Inability to comply with the standard 14-day hyperbaric oxygen therapy (HBOT) treatment protocol.

hearing

Sudden Idiopathic HL

Presentation consistent with sudden idiopathic hearing loss, defined as diffuse sensorineural hearing loss with a discordant exposure history (treated all the same, but not included in this analysis).



Treatment protocol

medication

Systemic Corticosteroids

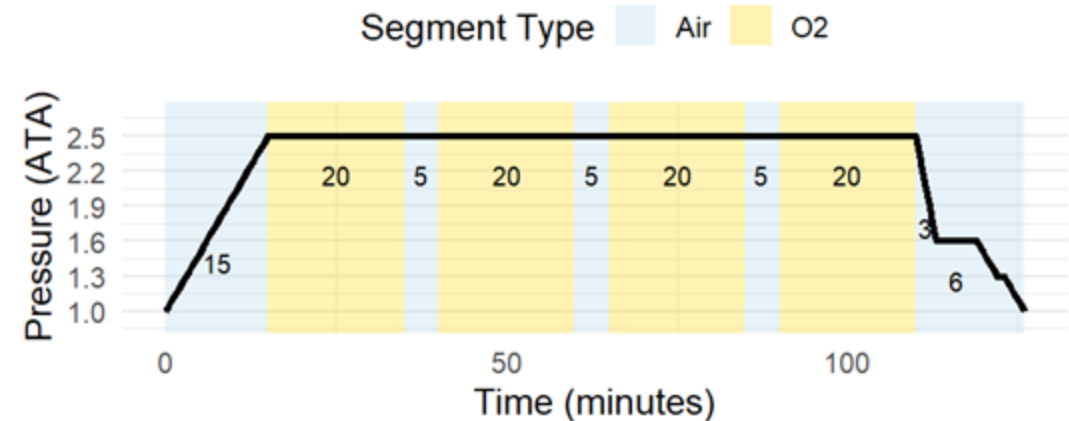
- Initiated prior to or concomitantly with HBO therapy.
- Regimen: Oral prednisone at 60 mg daily for 7 days, followed by a 7-day taper (40 mg for 3 days, 20 mg for 2 days, and 10 mg for 2 days).

timer

Hyperbaric Oxygen (HBO) Profile

- Administered at 2.5 atmospheres absolute (ATA) for 5 days a week.
- Patients undergo pure oxygen breathing for 90 minutes per session.
- To mitigate the risk of CNS oxygen toxicity with concurrent steroid use, the protocol incorporates frequent 5-minute air breaks between 20-minute oxygen intervals.

HBO15 Treatment Protocol



Outcomes

Therapy Endpoints: Continued until one endpoint is reached

equalizer

Audiometric Tracking

Comprehensive audiometry is performed at baseline and repeated precisely every five HBO sessions.

check_circle

Full Recovery

Hearing is restored to within normal limits, defined as $\leq 20\text{dB}$ across all tested pure-tone thresholds.

restore

Baseline Achieved

Hearing returns to the patient's documented pre-injury recorded thresholds.

trending_flat

Therapeutic Plateau

No clinically significant change ($<10\text{dB}$ improvement) is observed across any of the tested frequencies in two consecutive audiograms.





Timing & Latency

What happens beyond 7 days?
How long after the injury it
makes sense to treat?

Exploring outcomes and optimal windows



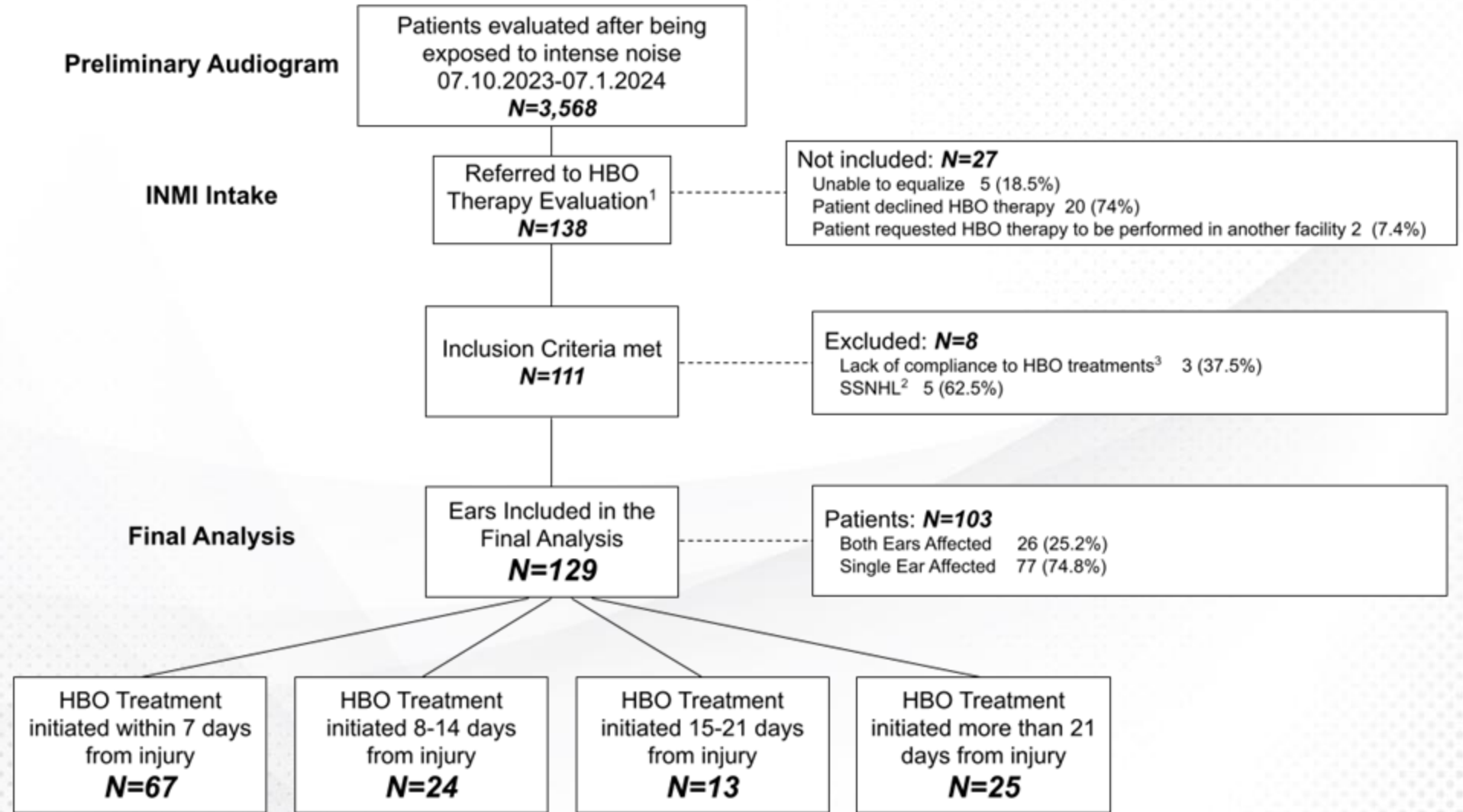
Beyond Pure Acoustic Trauma

What happens when the injury
mechanism is not “just” pure
acute acoustic trauma (impact
vs impulse)?

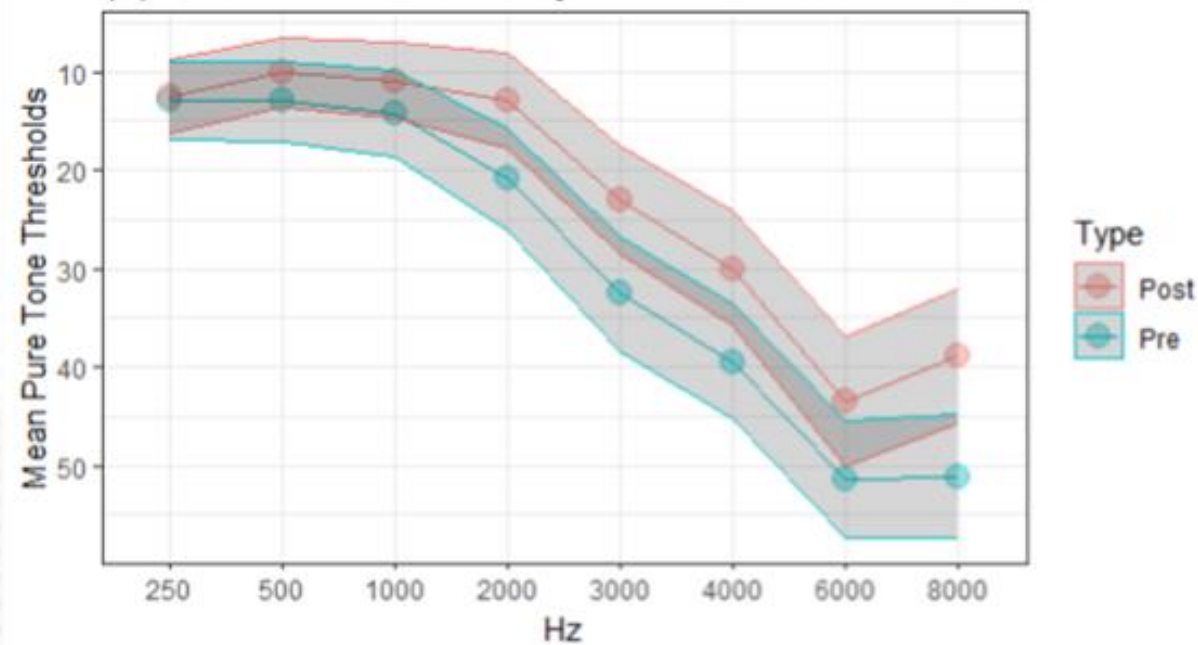
Investigating distinct pathophysiology



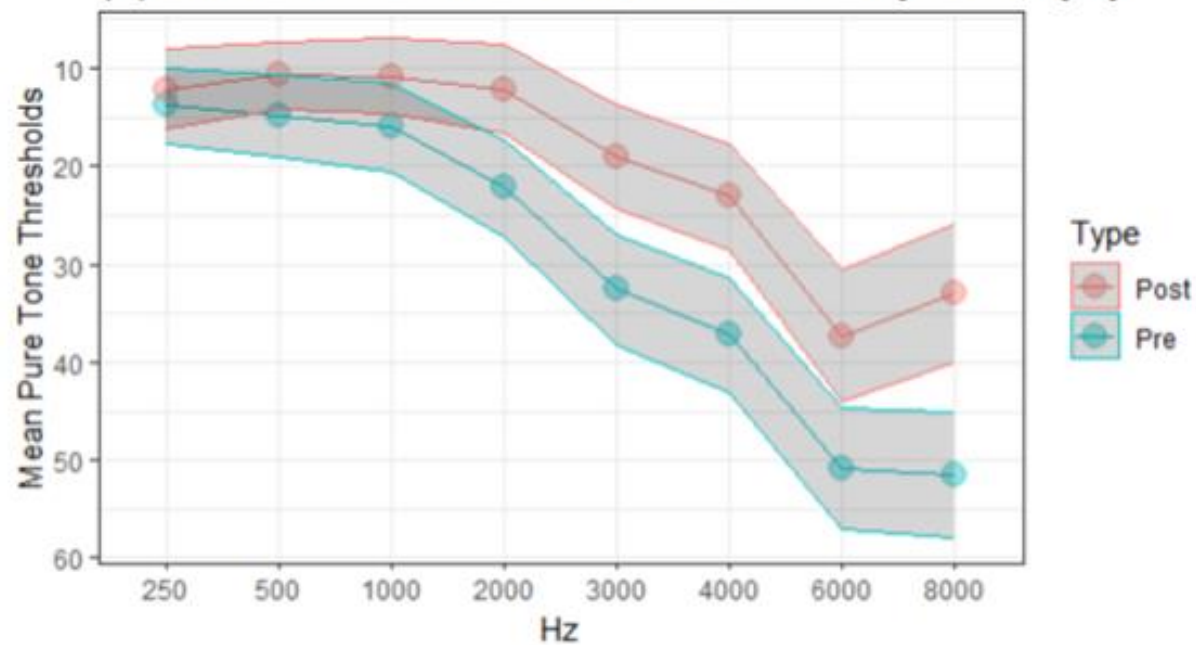
Treatment Latency



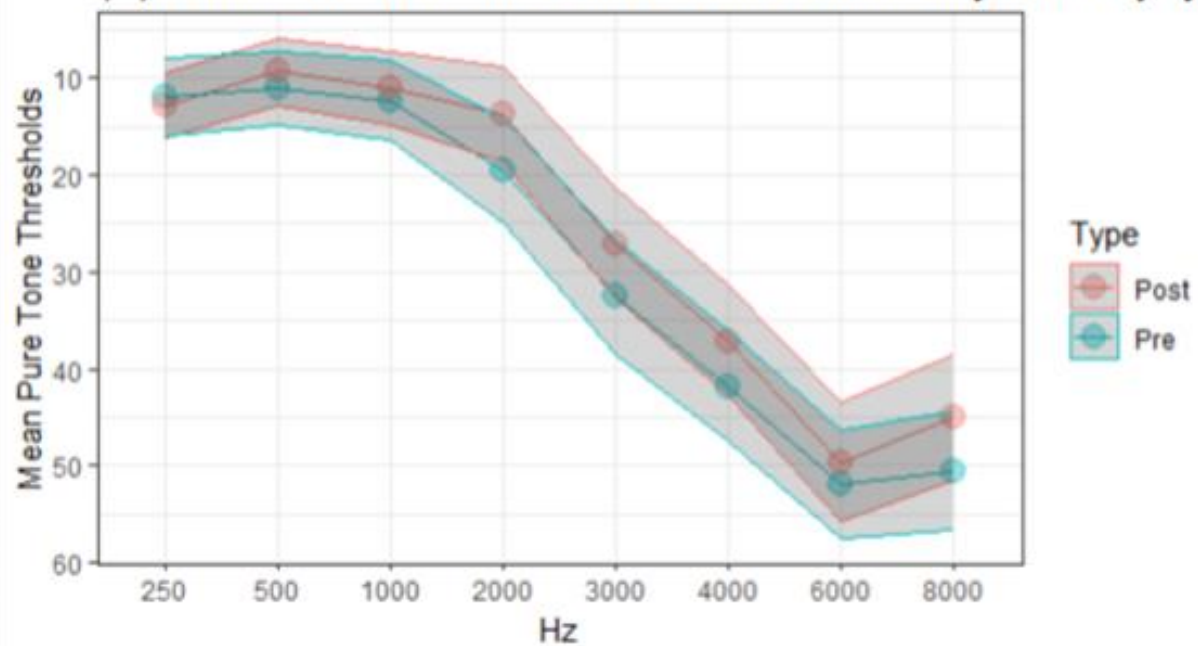
(A) - Pure Tone Audiometry Before and After Treatment



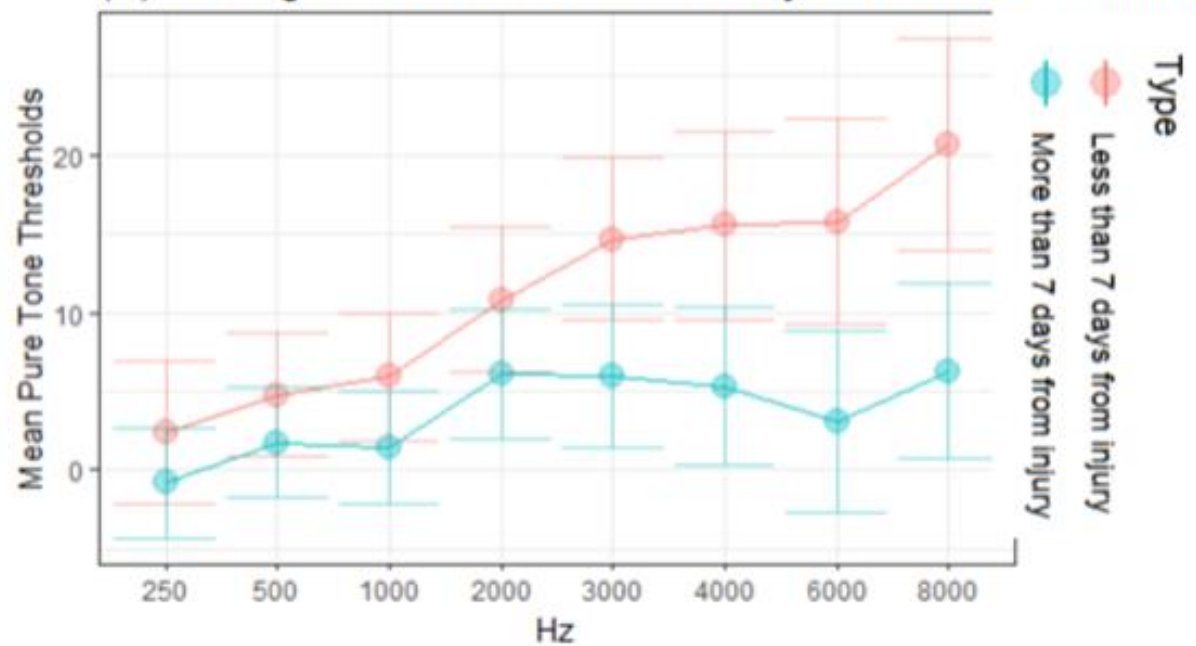
(B) - When Treatment was initiated within 7 days from injury



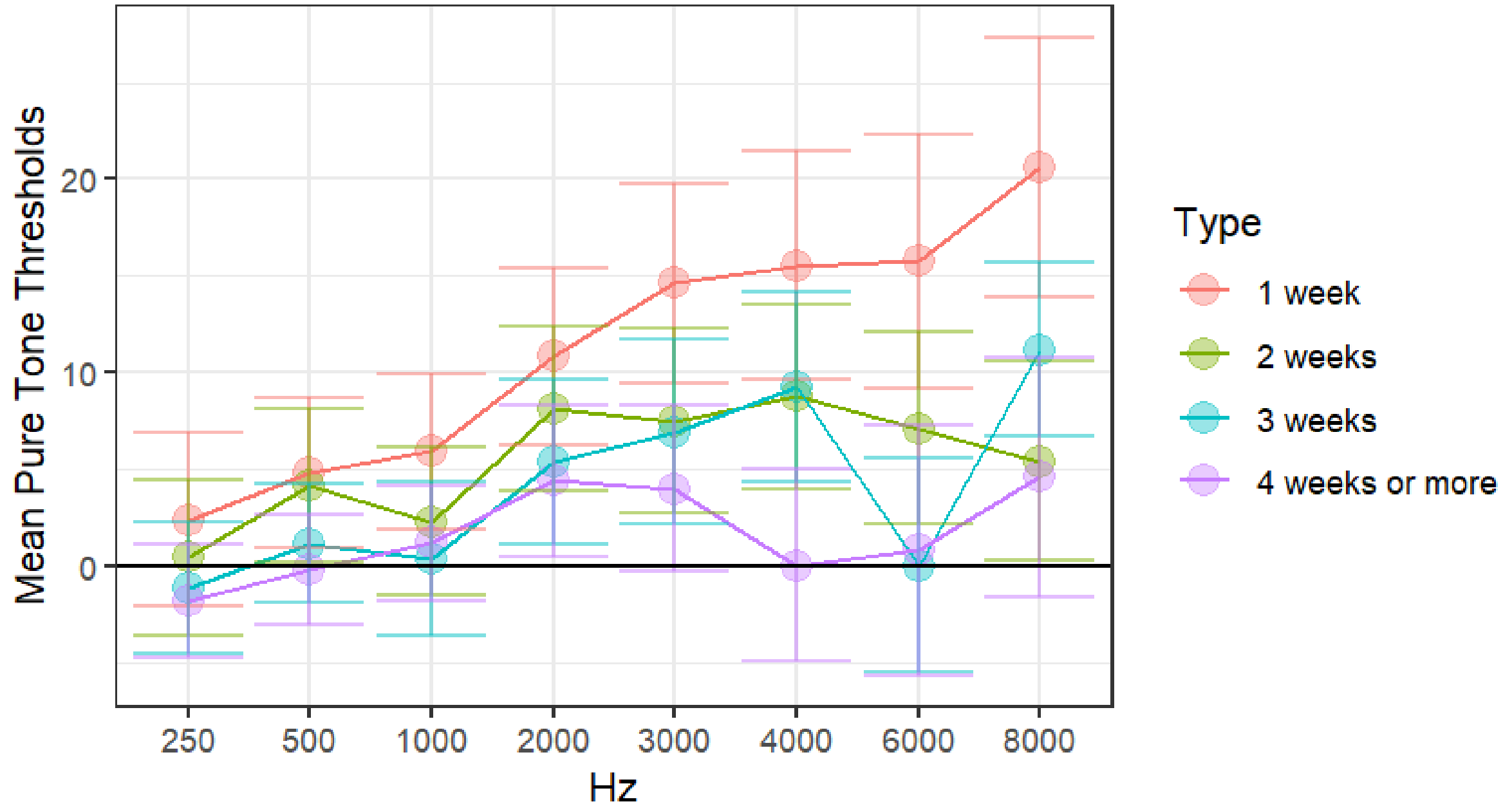
(C) - When Treatment was initiated more than 7 days from injury



(D) - Change in Pure Tone thresholds by time to HBOT initiation



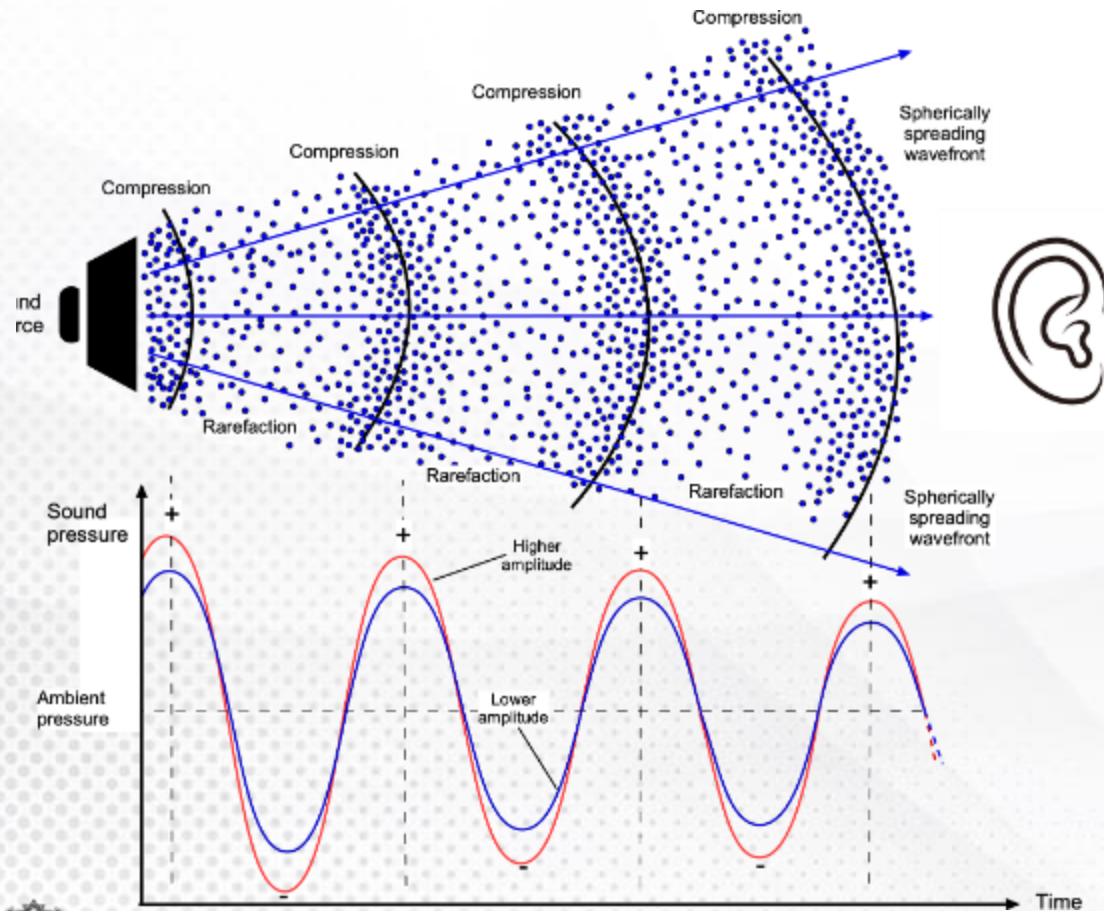
Change in Pure Tone Thresholds by week of HBOT initiation



	Minimal Response		Combat Readiness Restored		ΔHPTS	
Characteristic	RR (95% CI) ¹	p-value	RR (95% CI) ¹	p-value	RR (95% CI) ¹	p-value
<i>HBOT² latency and age only</i>						
Age	-0.01 (-0.02 to 0.00)	0.033	-0.02 (-0.03 to -0.01)	<0.001	-2.4 (-3.5 to -1.3)	<0.001
Days From Injury to HBOT ² Initiation	-0.01 (-0.02 to -0.01)	<0.001	-0.01 (-0.02 to -0.01)	<0.001	-2.0 (-3.0 to -1.0)	<0.001
<i>Steroid latency and age only</i>						
Age	-0.01 (-0.02 to 0.00)	0.064	-0.02 (-0.03 to -0.01)	<0.001	-2.2 (-3.3 to -1.0)	<0.001
Days From Injury to Steroid Initiation	-0.01 (-0.02 to 0.00)	0.004	-0.01 (-0.02 to 0.00)	0.004	-2.2 (-3.3 to -1.2)	<0.001
<i>HBO latency, Steroid latency, and age</i>						
Age	-0.01 (-0.02 to 0.00)	0.026	-0.02 (-0.03 to -0.01)	<0.001	-2.3 (-3.4 to -1.1)	<0.001
Days From Injury to Steroid Initiation	0.01 (-0.02 to 0.03)	0.51	-0.01 (-0.04 to 0.02)	0.44	-1.3 (-4.3 to 1.6)	0.37
Days From Injury to HBOT ² Initiation	-0.02 (-0.03 to 0.00)	0.033	-0.02 (-0.04 to 0.00)	0.028	-1.1 (-3.2 to 0.98)	0.29
¹ CI = Confidence Interval; ² HBOT - Hyperbaric Oxygen Therapy; ³ ΔHPTS average - difference in the high pure tone sum average;						



What's special about blast



Blast injury represents a distinct, multifaceted trauma due to unique physical signatures.

Primary Blast

Supersonic shockwave overpressure.

Secondary / Tertiary

Debris impact and whole-body translation.

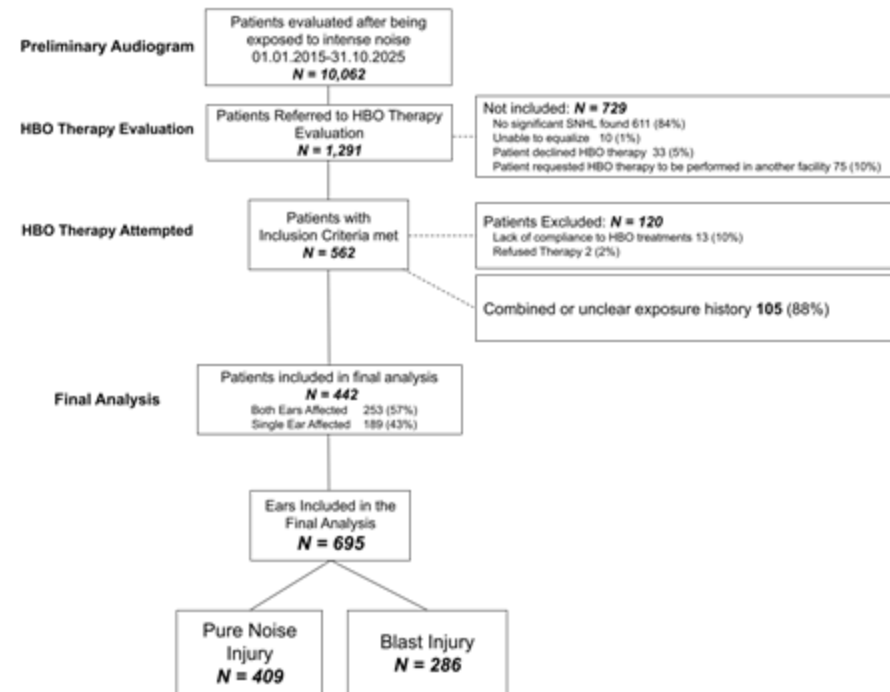
Acoustic

Diffuse energy distribution compared to focal gunfire pulses.



Patient selection

Selection Flowchart



442

FINAL PATIENT COHORT

Representing **695** Affected Ears
253 patients had bilateral involvement

Patient Funnel Metrics

1,291 patients referred for initial evaluation

562 met criteria for HBO therapy

15 excluded for non-compliance

105 excluded due to combined/uncertain exposure

Session Quantity Distribution

Treatment Insights

10 SESSIONS (MEDIAN TREATMENT)

The vast majority of patients across both exposure groups were treated with a standard course of 10 HBO sessions.

6% REQUIRED EXTENDED THERAPY

Only a small fraction of patients (approx. 6%) in both cohorts required 20 or more sessions, showing no significant difference between groups ($p = 0.8$).

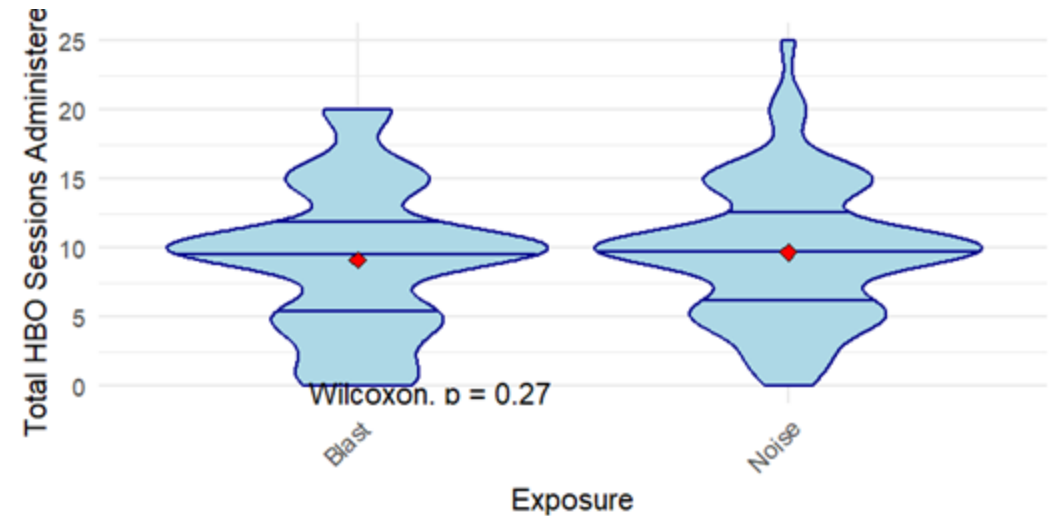


Figure: Distribution of HBO Therapy Sessions Administered

Comparison between Blast Injury and Noise Exposure groups (Wilcoxon, $p = 0.27$)

Baseline

Group Similarity

Baseline characteristics were largely similar between groups. No significant differences in:

- Gender and Age
- Timing of treatment initiation
- Length of therapy & ear proportion (one vs. both)

Otoscopic Findings

Normal exam rate was significantly lower in the **blast group** compared to noise (**68% vs. 88%**, $p < 0.001$).

Other findings (perforations, hemotympanum) were infrequent and similar across groups.

Hearing Thresholds & SRT

- **Blast group** thresholds were significantly worse from 250 Hz to 4000 Hz ($p < 0.027$).
- No significant difference at high frequencies ($p > 0.1$).
- **Pre-treatment SRT** significantly higher in blast group (Mean 16 ± 13 vs. 10 ± 7 dB, $p < 0.001$).

Otologic Symptoms (Blast vs. Noise)

Broadly similar prevalence across groups:

- Tinnitus: **55% vs. 57%**
- Subjective Hearing Loss: **65% vs. 58%**
- Hyperacusis: **44% vs. 39%**
- Auricular Pain: **27% vs. 18%** (n.s.)
- Vertigo: **16% vs. 10%**

Δ HPTA

Gunshot Noise Group

6.2 dB Improvement

Blast Injury Group

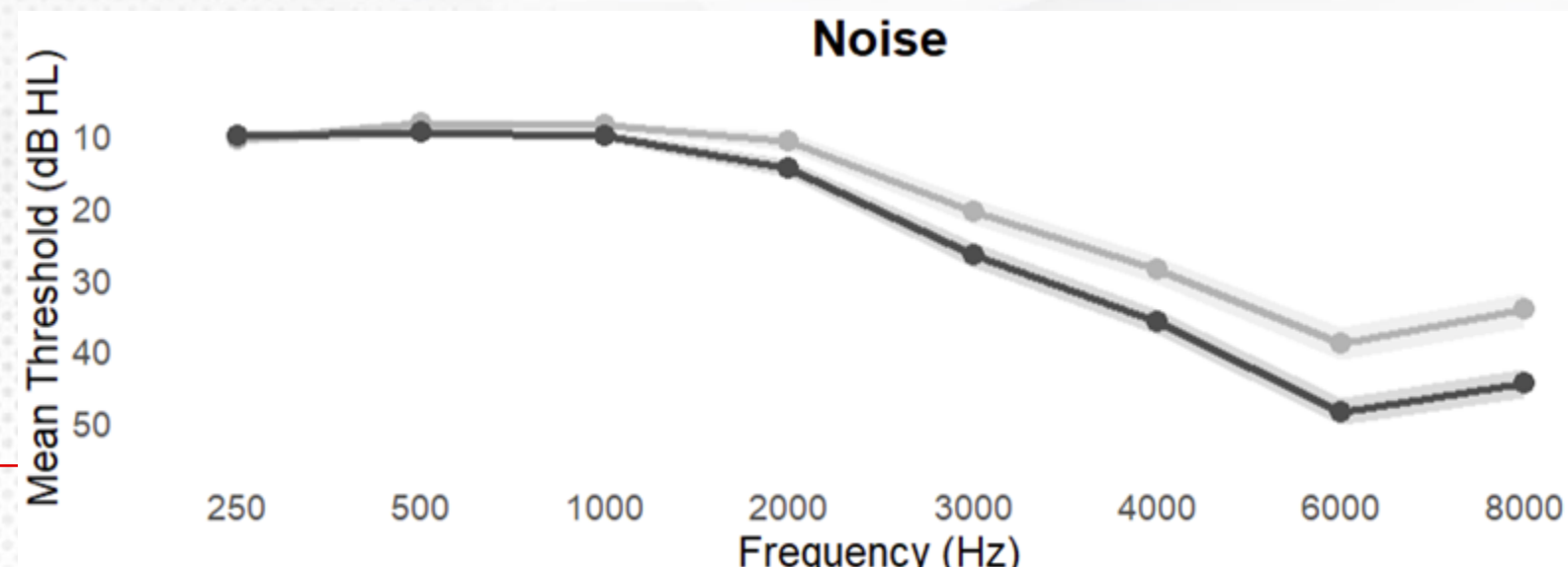
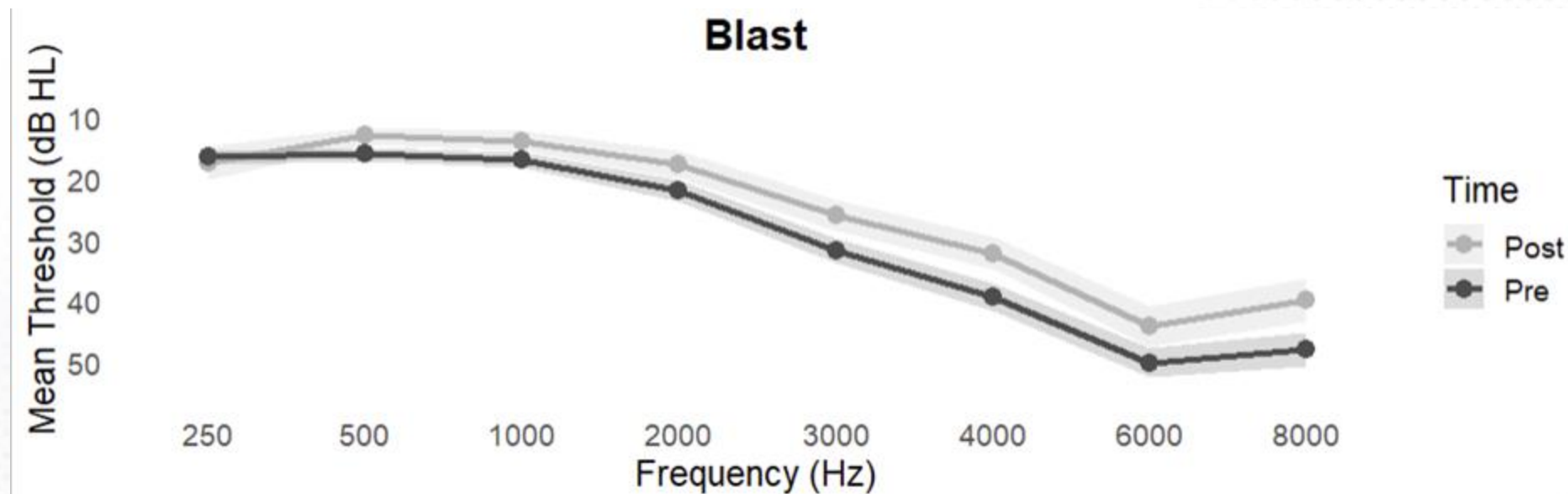
3.8 dB Improvement

Finding: Gunshot noise group demonstrated superior recovery in High-Frequency Pure-Tone Average (3000-8000Hz). $p = 0.019$

Extensive mechanical disruption in blast injury may limit hair cell regeneration/survival in basal turns.



Pure tone Analysis



Speech Reception & Subjective Gain

If you start low...

Despite worse high-frequency recovery, blast patients showed significantly greater improvement in Speech Reception Thresholds (SRT).

- **Blast SRT Gain:** 2.3 dB (net MD improvement)
- **Noise SRT Gain:** 0.5 dB (net MD improvement)
- **Clinical Significance:** Higher functional improvement in speech intelligibility for blast cohorts.



Between-Group analysis

Hearing Thresholds (PTA & HPTA)

Blast group demonstrated significantly worse thresholds at both pre- and post-treatment assessments. Degree of auditory injury was consistently more severe in blast-related trauma.

Improvement Magnitude

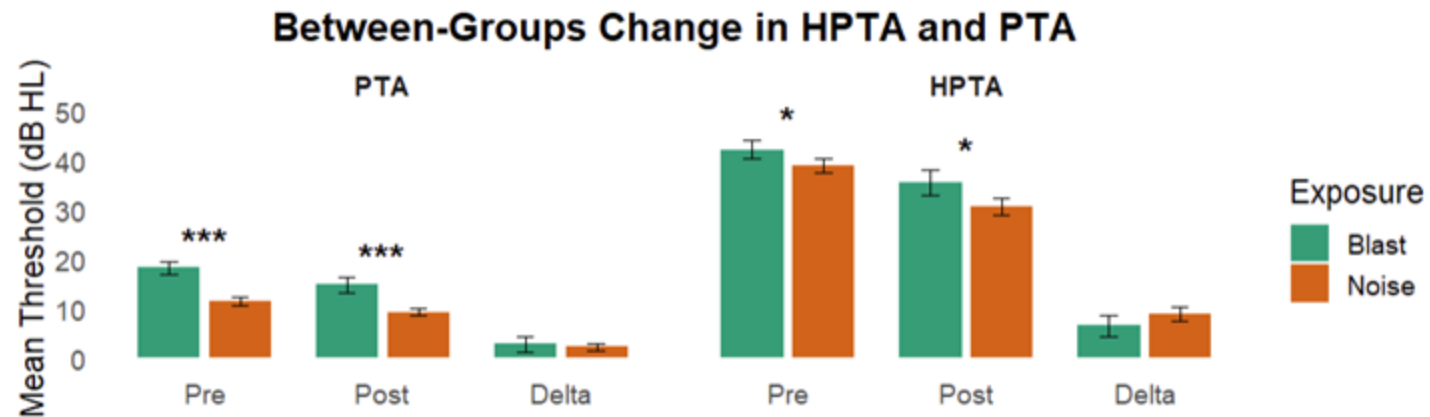
Improvement was less significant in higher frequencies (Δ HPTA $p=0.197$) compared to lower frequencies (Δ PTA $p=0.061$).

Speech Reception (SRT)

- Blast group had higher (worse) values pre/post treatment ($p < 0.001$).
- Notably greater improvement following HBO therapy (Md 2.3 dB, $p < 0.001$).

Speech Discrimination

Only baseline differences observed (blast group performed slightly worse). Post-treatment scores showed no significant difference or differential treatment effect.



Detailed data presented in Table 2

Within-Group analysis

Hearing Thresholds (PTA & HPTA)

Significant post-treatment improvement in both PTA and HPTA for each exposure group.

- **Noise Group:** Greater improvement in high frequencies (Δ HPTA 8.92, $p < 0.001$).
- **Blast Group:** Δ HPTA 6.55 ($p < 0.001$).

Speech Reception (SRT)

Significant improvement in both groups:

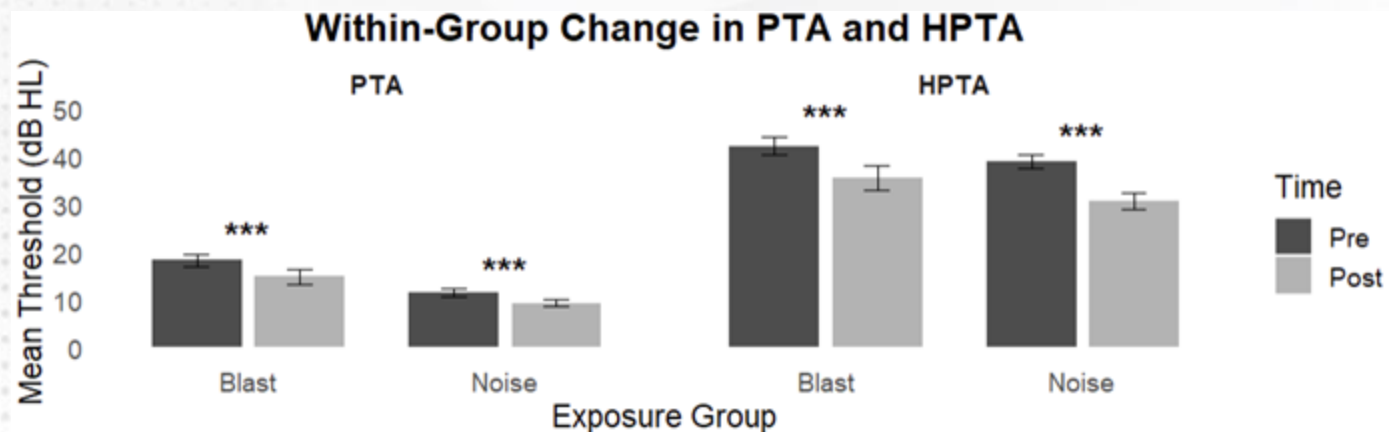
- **Blast Group:** More pronounced (5.51, $p < 0.001$).
- **Noise Group:** (2.46, $p < 0.001$).

Speech Discrimination

Scores showed similar trends but only *bordered statistical significance*.

Subgroup: Initial Pathological Otoscopy

No significant difference found in any outcome measures for patients with initial pathological findings.



Detailed findings presented in Table 3 and Supplementary Table 1



Patient Reported Outcomes

Blast injured patients showed a **twofold rate** of subjective symptom improvement ($p < 0.036$).



Hearing Loss

35.7%

Resolution (Blast Group)



Tinnitus

31.5%

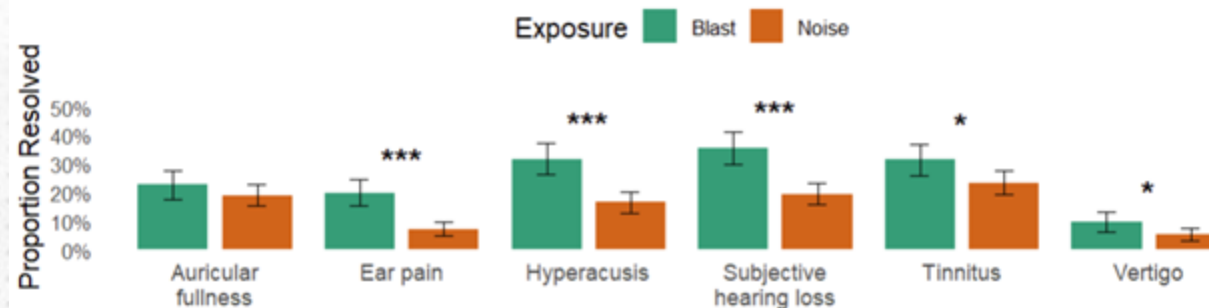
Resolution (Blast Group)



Hyperacusis

31.8%

Resolution (Blast Group)

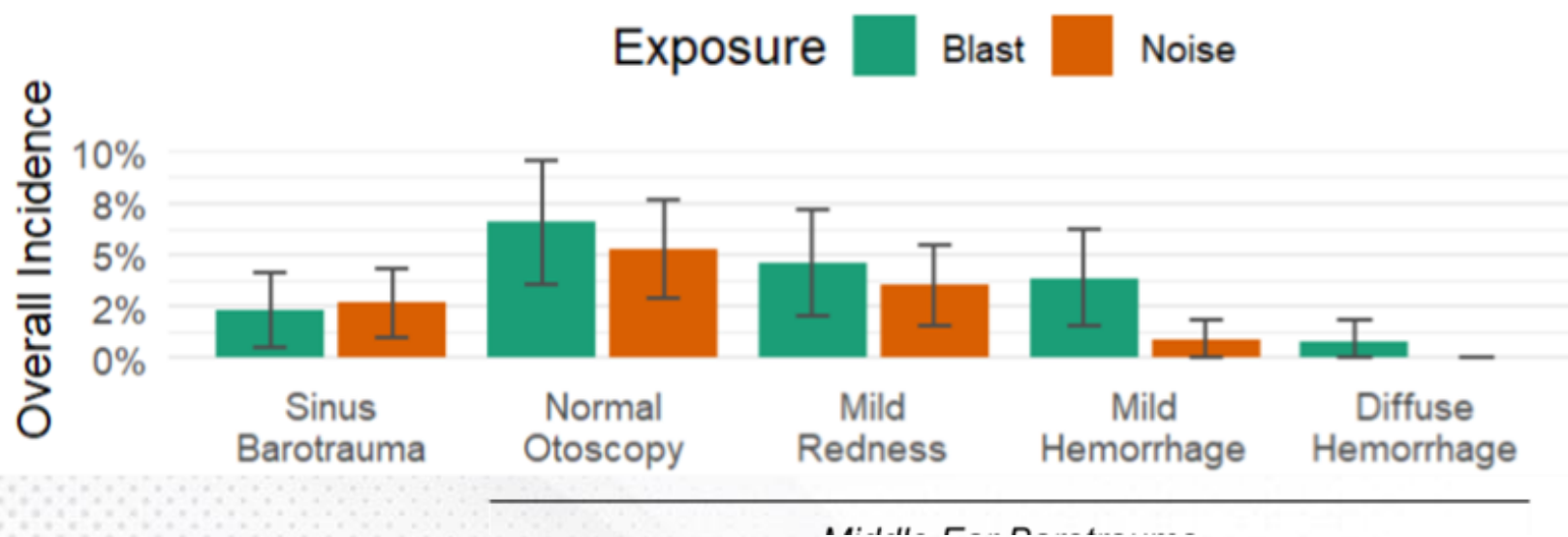


Adverse Events

Minimal Safety Concerns

Only a few, very mild and pressure-related adverse events were reported:

- **Specific Events:** Barosinusitis and minimal to mild (TEEDO-3) middle ear barotrauma.
- **Group Comparison:** The incidence of these events was **similar in both groups**.



Take Home

7-Day Window

Time is tissue. Maximizing high-frequency auditory recovery and returning personnel to combat readiness requires initiating therapy within 7 days of acoustic insult.

Delaying intervention beyond three weeks yields significantly diminished clinical returns.

Treating Blast Injuries

While HPTA gains are overall more diminished, the therapy-induced **improvement in lower frequencies** may be even more vital for long-term hearing preservation and overall disability prevention.

Resource Optimization

Implementing a strict, data-driven framework is vital for sustainability.

Deferring audiometry to 48 hours rules out transient threshold shifts, and **monitoring every 5 sessions** ensures treatment stops at the plateau.





israeliaeromedicalunit@mail.idf.il
israeliaeromedicalunit@gmail.com
ostyly@gmail.com
+972-542-555655

THANK YOU



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