Determining the Recovery Rate of Hearing Thresholds Across Audiometric Frequencies with Use of Hyperbaric Oxygen Treatment

Christopher E. Niemczak, Au.D., Ph.D., Nicole P. Harlan, M.D., Catherine C. Rieke, AuD., Abigail M. Fellows, M.A., Devin R. Cowan, B.S., Jiang Gui, Ph.D., Samantha M. Leigh, B.S., Allyson Schiller, B.S., Judith A. Kertis, B.S.N., R.N., Pamela M. Hannigan, R.N., Jay C. Buckey, M.D.

Dartmouth-Hitchcock

Dartmouth GEISEL SCHOOL OF MEDICINE

Introduction

- Hyperbaric oxygen treatment (HBOT) was first reported to improve auditory outcomes following sudden sensorineural hearing loss (SSHL) in the early 1970s. The mechanism of action is unknown but is thought to involve improved cochlear oxygenation. But despite more than 40 years of interest in HBOT for SSNL, the frequency specific recovery has not been fully described.
- Further investigation of frequency specific results of HBOT for SSHL may provide a better understanding of the therapeutic mechanism. This study seeks to investigate amount of recovery (in dB) across tested audiometric frequencies (250 – 8000 Hz) before and after HBOT.
- The goal of this study was to analyze patient outcomes retrospectively to understand how HBOT affects specific frequency regions. This work will aid in the understanding of the recovery rate (in dB) of audiometric thresholds with HBOT and provide future directions for HBOT therapy for SSHL

Methods

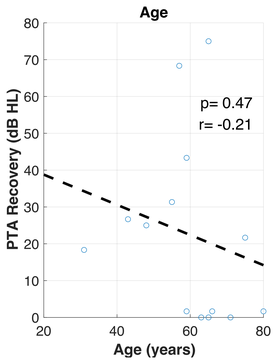
Study Design:
- Retrospective analysis

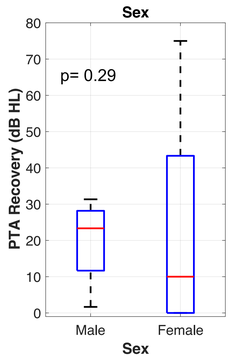
Participants:
- 14 Dartmouth Hitchcock Medical Center (DHMC) patients treated with HBO for SSHL
- Inclusion criteria were adults (age range 31-80) with SSHL and seen for HBOT
- All subjects were given oral steroids in conjunction with HBOT. Some also received intratympanic steroid injections.

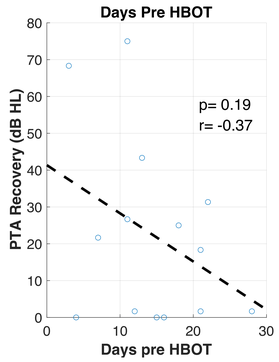
Audiologic Tests
- Pure tone air conduction audiometry (with masking as needed) performed by an audiologist

Statistical Analysis:
- Primary outcome variables were audiometric thresholds from 250-8000 Hz before and after HBOT
- Analysis included audiometric thresholds across frequencies as response variables in linear mixed effect models with fixed effects including age, and time between onset of symptoms and first HBOT session (Time pre HBOT)
- Pre SSHL audiograms were not available for 13/14 participants so recovery back to baseline hearing could not be assessed

Results

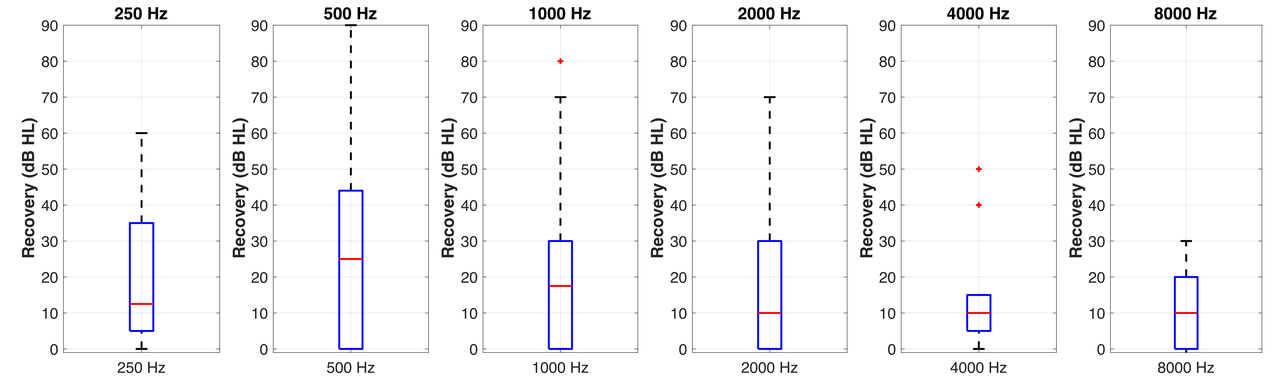


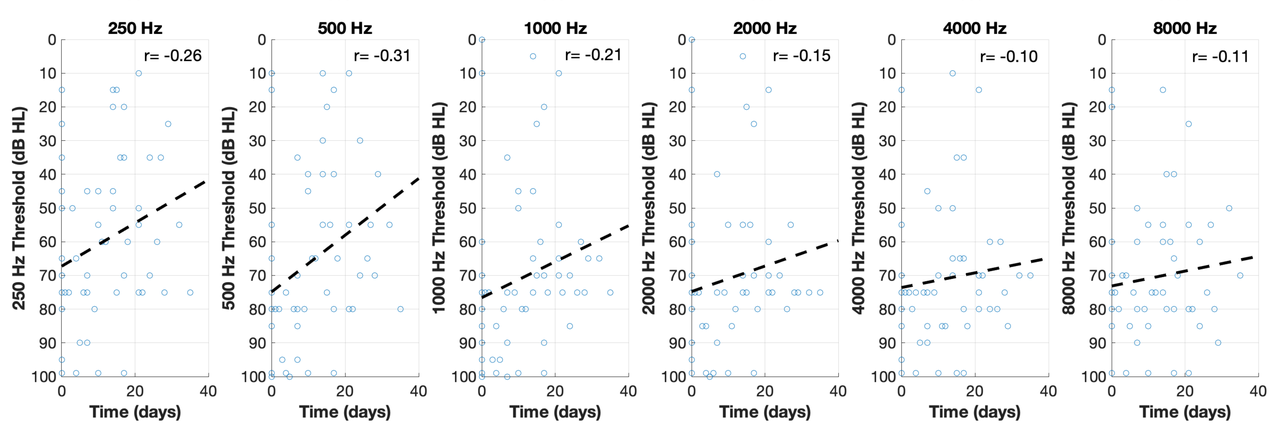




Age, Sex, and Days Pre HBOT:
- PTA recovery (.5, 1.0, and 2.0 kHz) across ages showed a moderate negative correlation with older adults displaying less recovery.
- PTA recovery was greater in males, but due to the percentage of females in the dataset, this difference was not significant.
- Days pre HBOT showed a moderately strong correlation with PTA recovery, consistent with larger recovery corresponding with fewer days before HBOT. This could suggest that rapid administration of HBOT may lead to better PTA outcomes, but future work is needed to confirm. In addition, the timing of oral and intratympanic steroids was not available for all participants.

Recovery Across Frequencies and Threshold Change Over Time:
- Recovery across audiometric frequencies showed greater recovery at lower frequencies (.25-1.0 kHz). Specifically, the mean recovery at .5 kHz was the largest at 27.4 dB HL, but also had the largest variation (SD 28.7). As the average age of subjects was ~60 years, we cannot compare recovery rate back to baseline hearing accurately across thresholds due to the unknown pre SSHL audiograms.
- Audiometric thresholds improved over time with HBOT. Correlations were strongest for lower frequencies (.25-1.0 kHz) and flattened with increasing frequency. In the linear mixed effect models, threshold improvement in days ranged from 0.43-0.97 dB/day and were significant at every frequency ($p<.039$). These results are consistent with HBOT promoting recovery at all frequencies. But all subjects received other treatments (e.g., oral or intratympanic steroids) and spontaneous recovery of thresholds could have occurred.





Demographics

Total n		14
Male (%)		10 (71%)
Age in Years (SD)		59.1 (12.9)
PTA Recovery in Affected Ear	**0.5, 1.0, 2.0 kHz** (SD)	51.8 (27.4)
	0.25, 0.5, 1.0 kHz (SD)	47.9 (26.5)
Recovery in Affected Ear	**0.25 kHz** (SD)	20.6 (20.8)
	0.50 kHz (SD)	27.4 (28.7)
	1.00 kHz (SD)	22.5 (26.1)
	2.00 kHz (SD)	17.5 (22.3)
	4.00 kHz (SD)	12.8 (14.7)
	8.00 kHz (SD)	11.0 (12.8)

Results

Frequency	Coefficient	Mixed-Effects Model		
		Estimate	p-Value	95% CI
250 Hz	Time (days)	-0.751	0.005	-1.257, -0.244
	Age	-0.009	0.987	-1.112, 1.095
	Time pre HBOT	-0.960	0.326	-2.937, 1.018
500 Hz	Time (days)	-0.973	0.007	-1.650, -0.295
	Age	-0.017	0.976	-1.171, 1.137
	Time pre HBOT	-1.362	0.187	-3.431, 0.707
1000 Hz	Time (days)	-0.721	0.030	-1.368, -0.074
	Age	-0.287	0.642	-1.544, 0.971
	Time pre HBOT	-1.447	0.198	-3.702, 0.807
2000 Hz	Time (days)	-0.573	0.039	-1.115, -0.030
	Age	-0.543	0.383	-1.803, 0.718
	Time pre HBOT	-1.356	0.227	-3.614, 0.902
4000 Hz	Time (days)	-0.431	0.025	-0.804, -0.058
	Age	-0.100	0.862	-1.270, 1.071
	Time pre HBOT	-1.005	0.333	-3.103, 1.093
8000 Hz	Time (days)	-0.428	0.011	-0.750, -0.106
	Age	0.065	0.909	-1.095, 1.225
	Time pre HBOT	-0.530	0.603	-2.610, 1.549

Summary and Conclusions

- HBOT was associated with recovery of audiometric thresholds across the audiogram. Recovery of low frequency thresholds (250-1000 Hz) was greater compared to high frequency thresholds (2000-8000 Hz). Threshold recovery over time was significant at all frequencies in the linear mixed models showing significant improvement from initial to final threshold. Age and time pre HBOT were not significant at any frequency.
- The reason for increased recovery at low frequency thresholds remains unknown. Possible interpretations include the anatomy of the cochlear vasculature, where the apex is at the end of the arterial supply for the cochlea. Future studies with pre SSHL audiograms are warranted to better understand this phenomena.
- Future studies should also assess the combined effect of steroids with HBOT, the amount of spontaneous recovery of thresholds after SSHL, and the timing/duration of HBOT.

Contact: Christopher Niemczak, Au.D., Ph.D.
Email: *Chris.Niemczak@Dartmouth.edu*