Hearing Loss is Associated with Grey Matter Thickness Following Close Blast Exposure

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Introduction

- Hearing loss & tinnitus are the most prevalent disabilities leading to service-connected claims by Post-9/11 Veterans[1].
- Blast-related long-term hearing loss is predominantly sensorineural in origin[1] and impacts higher frequency thresholds (6,000Hz) more than lower frequencies[2].
- Recent work has shown that auditory perception is supported by a distributed network of regions including temporal, parietal and frontal lobes[3].
- Close-blast exposure (<10m from detonation) can cause diffuse neuronal damage, with multiple mechanisms damaging central auditory system or the cortical and subcortical regions underlying auditory perception[4].
- Late-onset hearing loss has been associated with decreases in grey matter thickness[5].

Experimental Hypothesis:
Hearing loss due to close-blast exposure can be predicted from distributed patterns of grey matter thickness.

Methods

- 141 deployed Post-9/11 Veterans
  - mean age: 32.9 ± 9.1 years (123 Males)
  - 39 have history of close-blast exposure
- Participants were recruited from the larger Translational Research Center for TBI & Stress Disorders (TRACTS) cohort and completed an initial assessment battery of neurological and cognitive testing which includes:
  - Clinical interviews for psychological, mood, and TBI lifetime assessments
  - Background and health questionnaires
  - Self-report questionnaires on sensory functioning and functional disability
  - Structural and resting-state MRI scans
- This subset of TRACTS participants also completed an auditory screening assessment using a model 119 Beltone portable audiometer.
- Pure-tone hearing thresholds were measured at 1,000Hz and 6,000Hz for the left and right ear separately.
- Two MPRAGE scans were averaged to improve signal to noise. Cortical reconstruction and grey matter segmentation were completed with FreeSurfer.
- Average cortical thickness was calculated for 68 regions of interest (ROI) using the Desikan-Killiany Atlas

Results

Behavioral & Psychiatric Comorbidities

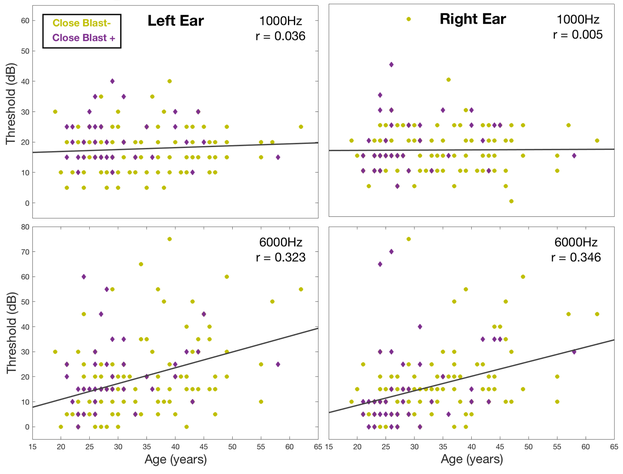
	Close Blast-		Close Blast+		
	n or M	% or SD	n or M	% or SD	χ^2 or t
Combat Exposure	10.16	9.327	21.92	11.46	-6.181***
N of military mTBIs	0.29	0.639	0.90	1.021	-3.443**
Current Pain (n=133)	61	62.2%	27	77.1%	2.557
Sleep Disturbance (n=136)	59	60.2%	31	81.6%	5.589*
PTSD (n=140 for all else)	42	41.6%	28	71.8%	10.272**
PTSD Severity	37.37	27.99	57.54	26.84	-3.865***
Depressive Disorder	20	19.8%	11	28.2%	1.152
Anxiety Disorder	17	16.8%	11	28.2%	2.275
Substance Disorder	16	15.8%	7	17.9%	0.091

Self-Reported Hearing Impairments

	Close Blast-		Close Blast+		
	n or M	% or SD	n or M	% or SD	χ^2 or t
NSI: Hearing Difficulty	.58	.959	1.38	1.25	-3.644**
NSI: Noise Sensitivity	.49	.885	1.03	1.27	-2.396**
NSI: Somatosensory Score	3.09	3.55	5.28	5.29	-2.384*
NSI: Total Score (n=138)	15.23	13.52	23.59	17.19	-3.020**
Hearing Impairment (n=134)	19	19.4%	16	44.4%	8.566**
Tinnitus (n=134)	32	33.7%	27	69.2%	14.177***
Hearing changes since deployment(s) (n=132)	49	51.6%	39	81.1%	9.645**

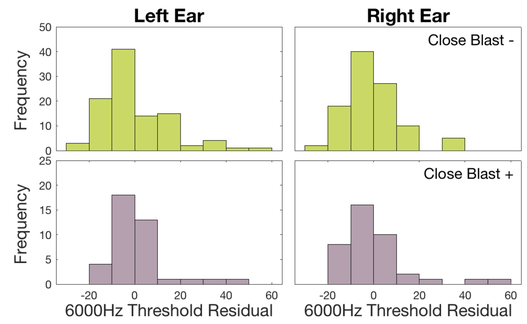
- Close blast+ group reports greater hearing impairment on Neurobehavioral Symptom Inventory (NSI) and questionnaire.
- Clinical interviews and questionnaires also show higher combat exposure and higher prevalence of PTSD and sleep disorders but no difference in other common comorbidities.

Hearing Thresholds Across Four Conditions



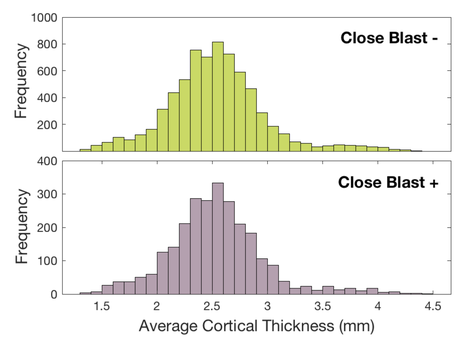
- Close Blast+ group is younger (Z=-2.69, p =0.007)
- High frequency thresholds increase with age (ps < 0.001)
- Regress both age and low-frequency thresholds from 6,000Hz thresholds to account for global hearing deficits

No overall difference in hearing thresholds across Close Blast groups ($ps \leq 0.09$)



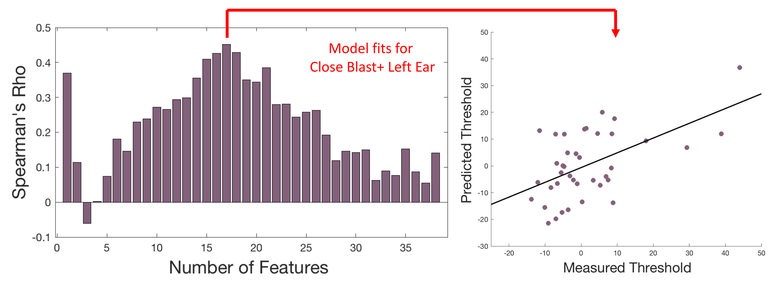
	Left Ear	Right Ear
Close Blast -	68 Features ρ = 0.073, p_{mc} = 0.28	6 Features ρ = 0.211, p_{mc} = 0.09
Close Blast +	17 Features ρ = 0.452, p_{mc} = 0.02	1 Feature ρ = 0.326, p_{mc} = 0.13
39 Highest Threshold	6 Features ρ = 0.057, p_{mc} = 0.37	37 Features ρ = 0.035, p_{mc} = 0.42

No overall difference in cortical thickness across Close Blast groups (p = 0.86)



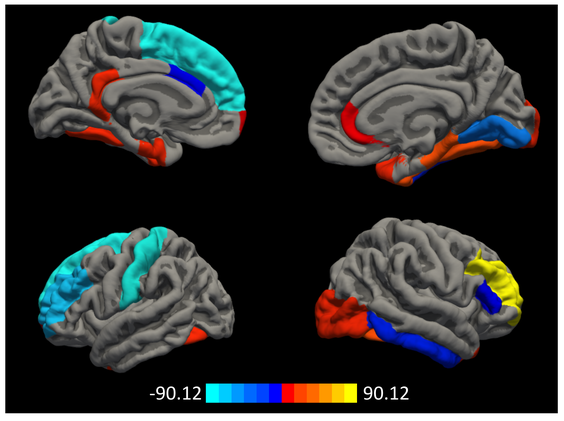
PREDICTING HEARING THRESHOLDS FROM CORTICAL THICKNESS

- For each group and ear, build multiple linear regression models using ROI thickness to predict hearing thresholds (age and low-frequency residualized)
- Use leave-one-subject out validation for multiple feature set sizes, then use beta weights to determine predicted hearing threshold in left-out subject
- Additional control group: 39 participants with highest hearing thresholds
- Monte-carlo permutation (N=1000) shuffling hearing thresholds and rerunning LOSO regression to determine p_{mc}-value.



- Can predict hearing thresholds in left ear of Close Blast+ group using 17 feature model.
- Higher hearing thresholds associated with decreased thickness in left frontal cortex, postcentral gyrus, right inferior temporal, lingual gyrus, and pars triangularis, and relatively greater thickness in left and right fusiform and midline regions, and right lateral occipital and rostral middle frontal gyrus.

Average beta weights for 17 Feature Model



Blue = increased hearing thresholds/reduced cortical thickness

Red = increased hearing thresholds/increased cortical thickness

Conclusions

- Results show association between hearing loss and grey matter thickness following close-blast exposure not seen in either control group.
- Future work needed to better isolate blast-exposure from general deployment-related noise-induced hearing loss[6].
- Cortical thinning in frontal lobes associated with hearing loss suggests the need to better characterize the impact of hearing loss on general cognitive functioning in Veterans with history of close-blast exposure.

References
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Acknowledgements: This work was supported by the Translational Research Center for TBI and Stress Disorders (TRACTS) a VA Rehabilitation Research & Development Traumatic Brain Injury National Research Center (B3001-C); a VA Career Development Award: RR&D 1IK2RX002268-01A2 (F.C.F.); NIH NCCIH R21 AT009430-01 (W.M.); and VA Merit Review Award CX001327 (R.M).