Transthoracic Doppler Frequency Shift Discerned Following Microbubble Test

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Introduction

Precordial Doppler ultrasound is a tool anesthesiologists can use to monitor patients undergoing intracranial procedures in the sitting semi-setting or reverse trendelenburg positions, which carry risk for venous air embolism (VAE). Incorporating software that could independently monitor Doppler ultrasound and alert the anesthesiologist of possible air entrainment via Doppler signal interrogation would provide an excellent opportunity for early recognition and treatment of VAE. This necessitates collecting data for characterization of potential VAE sound qualities. Our previous study revealed significant changes in sound intensity when microbubbles were present in the heart. In this study, we explore whether there are significant frequency changes in doppler audio during the presence of microbubbles.

Methods

Thirteen patients undergoing elective bubble studies for other indications were enrolled in the study. A precordial Doppler ultrasound was placed over the right atrium/ventricle of each participant's heart prior to agitated saline injection during an echocardiography exam. Doppler audio was continuously recorded before, during, and after injection. Echo video clips served as visual references for the presence of microbubbles in the heart. The recordings were then analyzed to determine if there were any quantifiable differences in frequency in the Doppler audio pre- and post-saline injection using the frequency analysis tool (FFT) in NCH Software WavePad.

Results

Data analysis was completed using JMP (v15, Cary, NC). Data were evaluated for normality and met assumptions. A matched pairs t-test was used to compare mean pre-injection Doppler frequency per heartbeat with mean post-injection Doppler frequency per heartbeat at the maximum Doppler intensity. Results shows that mean post-injection frequency (857 Hz) was found to be significantly higher than mean pre-injection frequency (440 Hz) ($p < 0.0001$).

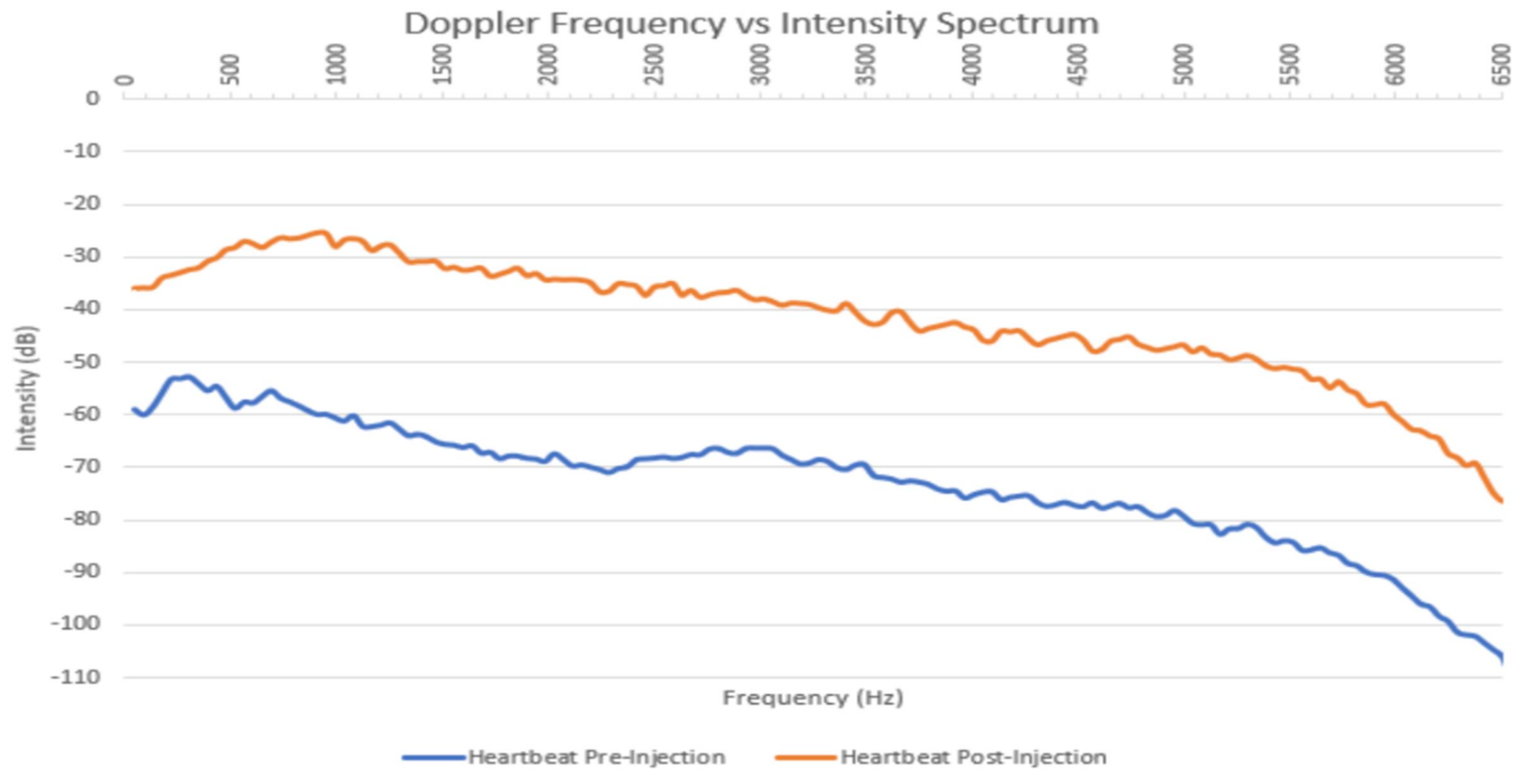

Figure 1: Doppler frequency vs intensity for Trial 4. Clear shifts in Doppler frequency and intensity can be noticed during the presence of microbubbles after administration of agitated saline.

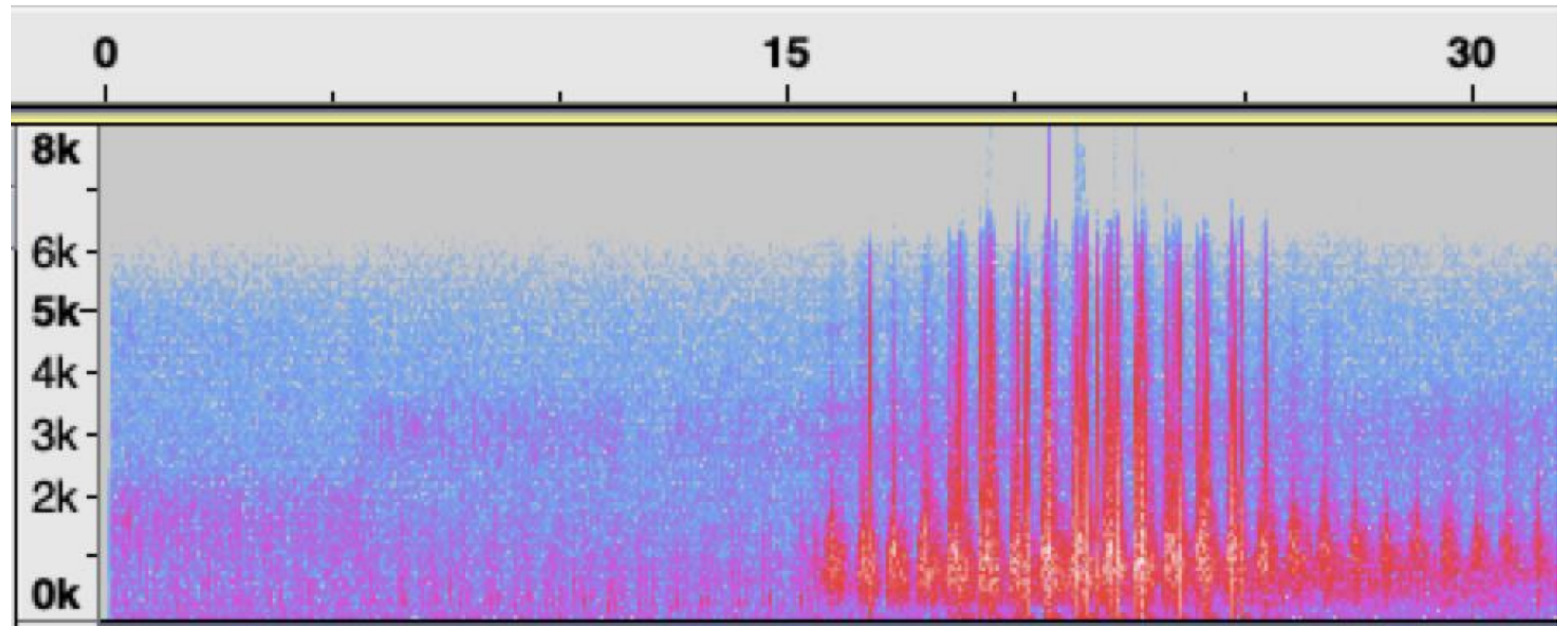

Figure 2: Plot of frequency (Hz) vs. time (s) for Trial 4.

Trial	Average frequency per heartbeat (Hz)		
	Pre injection	Post Injection	Ratio (Post/Pre)
3	363	825	2.28
4	255	901	3.53
5	515	781	1.52
6	489	819	1.67
7	391	807	2.06
8	439	895	2.04
9	335	877	2.62
10	323	914	2.83
11	574	878	1.53
12	711	872	1.23
Average	440	857	2.13
Stdev	129	43	0.67

Figure 3: Change in Doppler frequency at peak intensity before and after injection of agitated saline.

Discussion

The average Doppler frequency at peak intensity before and after agitated saline administration was used to determine if there were transient changes in Doppler frequency. Our data shows that the presence of microbubbles on average transiently increases the Doppler frequency twofold at peak intensities. Limitations of the study that produced variability in the data include Doppler probe placement, patient variability, and possible inconsistencies in agitated saline quality. Additionally, the audio files from the first and second trials were not included in the analysis, because they were either low quality due to improper probe placement or unable to be opened and therefore analyzed in WavePad. Combining these results from those of our previous study could be used to construct alarm parameters to aid in earlier detection of VAE during neurosurgery. Future research will utilize the sound qualities frequency and intensity to generate an VAE monitor alert function using software-based audio pattern recognition.