Characterizing Precordial Doppler Audio in Patients Receiving Agitated Saline Injection During Echocardiography

Anthony DeStephens, MSME; Cesar Cardoso; Meghan Brennan, MD; John Petersen, MD; Nikolaus Gravenstein, MD; Ferenc Rabai, MD

Department of Anesthesiology and Center for Safety, Simulation & Advanced Learning Technologies, University of Florida College of Medicine, Gainesville

Introduction

Precordial Doppler ultrasound is one of the many monitoring tools anesthesiologists use to detect venous air embolisms (VAE). Anesthesia providers under a heavy cognitive load could miss early signs of VAE even when using precordial Doppler ultrasound. Using software to independently monitor Doppler audio and alert the anesthesiologist of possible VAE would provide an excellent opportunity for earlier detection and treatment of a VAE. Generation of such software necessitates the characterization of VAE audio. Therefore, we record precordial Doppler ultrasound audio in patients who undergo echocardiogram with an agitated saline microbubble test, which may emulate a small VAE.

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 the study participant's heart in coordination with the echocardiography team prior to injection of the agitated saline during the echocardiography exam (Fig. 1). Patients were slightly tilted to the left to optimize echocardiography. The Doppler audio was continuously recorded before, during, and after the saline injection. The echo video clips that were recorded as part of the bubble study were used as a visual reference for when the microbubbles were present in the heart (Fig. 2). The recordings were then analyzed to determine if there were any quantifiable differences between the Doppler audio before, during, or after the microbubble study.

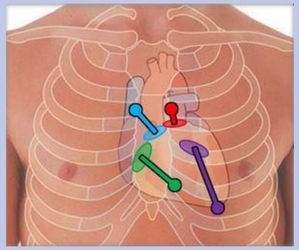

Figure 1. Sounds from the right ventricle project to the left side of the sternum in the 5th intercostal space, which is the optimal site for Doppler recording.

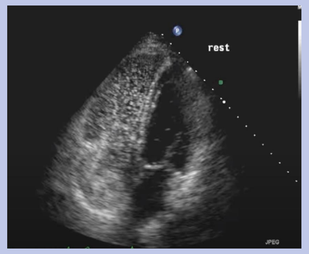

Figure 2. 2D echocardiogram reveals the presence of air in the right ventricle and atrium during a bubble study.

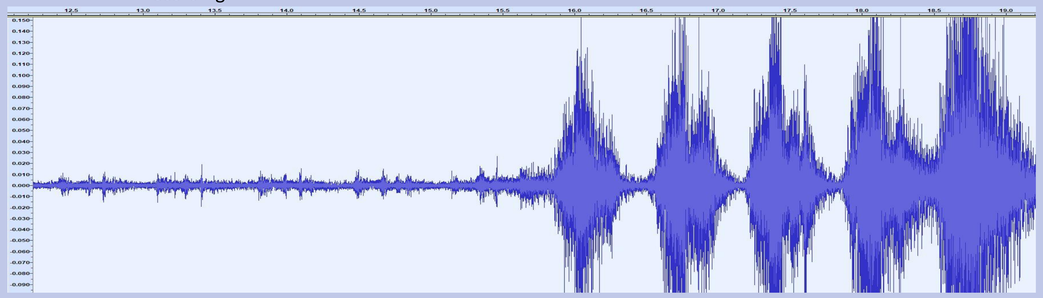

Figure 3. Representative plot of sound intensity over time of Doppler audio before, during, and after injection of agitated saline.

Participant	Pre Injection	Post Injection	Ratio(Post / Pre)
2	0.0038	0.0090	2.4
3	0.0086	0.0354	4.1
4	0.0023	0.0626	27.0
6	0.0030	0.0119	4.0
7	0.0024	0.0117	4.8
8	0.0044	0.0050	1.1
9	0.0027	0.0176	6.5
10	0.0276	0.0337	1.2
11	0.0030	0.0916	30.8
12	0.0030	0.0424	14.3
13	0.0038	0.0221	5.9

Table 1. Change in Doppler Audio Intensity Pre and Post-Agitated Saline Administration

Results

Successful recordings taken from both the right and left sternal border were obtained from 11 patients. A paired t-test was used to compare pre- and post-injection Doppler intensity (Table 1). The standard deviation of the normalized mean post-injection sound intensity (0.0312) was significantly higher than that of pre-injection (0.00586) ($P = 0.0065$; $SE = 0.00831$).

Discussion

Standard deviation of the mean was chosen as the method to compare changes in Doppler intensity due to the symmetry the data had with the x-axis (the average intensity over time would have been near 0). The standard deviation of the normalized Doppler intensity data between patients was high, which we suspect is a result of Doppler audio sensitivity to proper probe placement in relation to heart surface anatomy and potential variability of agitated saline quality. We noted that Doppler probe placement on the right sternal border sometimes failed to produce quality audio or detect significant audio intensity changes, despite clear heart sounds before injection of agitated saline. Probe placement on the left sternal border was able to consistently pick up high-quality heart sounds and significant changes in Doppler intensity, which was possibly caused by a slight leftward shift of the heart within the mediastinum in the left lateral tilt position. Despite a high standard deviation, the results show a clear and quantifiable distinction between absent vs present bubbles with an average fivefold increase in Doppler intensity between pre- and post-agitated saline injections. This data could be used to drive alarm parameters in monitoring software for VAE in the future.