Comparison of a Transesophageal and Precordial Ultrasonic Doppler Sensor in the Detection of Venous Air Embolism

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Early detection and prompt treatment are important factors that limit morbidity and mortality secondary to venous air embolism (VAE) (1). The precordial Doppler ultrasonic sensor and transesophageal echocardiograph are the two most sensitive monitors currently available to detect VAE (2,3). The Aloka SSD-870 transesophageal echocardiograph is equipped with a Doppler sensor at the distal end of the probe, thereby providing Doppler ultrasound monitoring for VAE in addition to visual monitoring for VAE with echocardiography. Potential advantages in the use of the transesophageal sensor as opposed to a precordial Doppler sensor for monitoring of VAE are the following: (a) one is able to confirm the area within the heart that is being monitored by Doppler ultrasound; and (b) the quality of the Doppler signal is independent of external body habitus with the transesophageal Doppler sensor, in contrast to the precordial Doppler with which signal quality is very dependent on external body habitus (4). The purpose of our study was to compare the sensitivity of the precordial Doppler with the transesophageal Doppler sensor in detection of VAE.

Methods

With institutional review board approval ten patients who were undergoing neurosurgical procedures in the sitting position in which a transesophageal echocardiographic (TEE) probe was to be used were enrolled in the study. All patients had general anesthesia induced with thiopental and fentanyl. Muscle relaxation was achieved and maintained with vecuronium. All patients had their tracheas intubated and were placed on mechanical ventilation. Anesthesia was maintained with isoflurane and nitrous oxide/oxygen in a 1:1 mixture. Clinical monitoring included electrocardiogram, pulse oximeter, mass spectrometer, and indwelling arterial catheter. After induction of general anesthesia, all patients had a right atrial catheter inserted via the right or left basilic vein and localized at the junction of the right atrium and superior vena cava utilizing an electrocardiographic guided technique (5). A precordial Doppler stethoscope was placed over the right atrium. The position of the precordial Doppler was verified by injecting 5 mL of agitated saline through the right atrial catheter (6). A staff neuroanesthesiologist was responsible for verifying that the injection test was positive and that the precordial Doppler position was optimal. An Aloka SSD-870 TEE probe with a Doppler ultrasonic sensor at the tip was positioned to obtain a view of the right atrium and interatrial septum. The cursor on the screen that indicates the area being monitored by the TEE Doppler sensor was placed at the high right atrium or junction of the right atrium and superior vena cava. A controlled injection test utilizing 40 mL of agitated saline at a rate of 40 mL/min was performed three times on each patient. A staff neuroanesthesiologist noted when the injection test became positive on the TEE Doppler and on the precordial Doppler. An audible signal on any of the three injection tests in each individual patient was considered a positive test in each respective monitor. Visualization of micro air bubbles on the transesophageal echo was also noted (Table 1). Data were analyzed with a two-tailed Fisher exact test. Results were considered statistically significant if $P < 0.05$.

Results

The TEE Doppler sensor on the Aloka SSD-870 was more sensitive in detecting micro air bubbles elicited

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Table 1. Number of Injection Tests in Which Micro Air Bubbles Were Detected

Patient	TE Doppler	PC Doppler	TEE
1	3	0	3
2	3	0	3
3	3	0	3
4	3	0	3
5	3	0	3
6	3	2	3
7	3	0	3
8	3	0	3
9	3	0	3
10	3	0	3

TE, transesophageal; PC, precordial; and TEE, transesophageal echo.

by the controlled injection test than the precordial Doppler sensor ($P < 0.005$). The Doppler on the Aloka SSD-870 TEE probe detected a positive injection test in ten of ten patients (100%). The precordial Doppler detected a positive injection test in only one of ten patients (10%). In all ten patients we were able to visualize micro air bubbles secondary to the injection test with the Aloka SSD-870 TEE probe (see Table 1). No patient suffered any hemodynamic or neurologic consequences as a result of the injection test.

Discussion

It has been well established that early detection of VAE is enhanced with a precordial Doppler ultrasonic sensor (1). Although a precordial Doppler may be adequate in some patients, because of chest wall configuration, lung volume, or other unknown factors, the quality of Doppler sounds may be less than optimal (3,4).

Several clinical reports have demonstrated failure of a precordial Doppler to detect VAE that had been confirmed by other monitoring methods (3,7). Edmonds-Seal and Maroon (1), in a description of the precordial Doppler sensor, suggested that the esophagus might serve as an alternative site for Doppler sensor placement. In a study of dogs, the sensitivity of a TEE Doppler sensor has been shown to be equal to or greater than that reported for the precordial Doppler (8).

Our data indicate that the Doppler sensor on the Aloka SSD-870 is more sensitive in detecting micro air bubbles in venous blood from an injection test than is the precordial Doppler ultrasonic sensor. We also found that the TEE Doppler was clinically as sensitive as esophageal echocardiography in detecting VAE elicited from an injection test. The increased sensitivity of the TEE Doppler was more than likely related to its ability to remove chest wall configuration and lung volumes as confounding factors in transmission of an ultrasonic signal. The ability to visually place the TEE Doppler sensor directly in the high right atrium rather than indirectly (as done with the precordial Doppler utilizing the injection test) may also have enhanced its sensitivity in detecting VAE. Below the level of the fifth thoracic vertebra, the trachea is divided, and therefore there is no air column between the esophagus and surrounding vascular structures. The superior vena cava and right pulmonary artery lie anterior to the esophagus at the T-5 level, the superior vena cava and left atrium lie anterior to the esophagus at T-6, and the right and left atrium lie anterior to the esophagus at T-8 (9). Therefore the esophagus would seem to be an ideal location for placement of an ultrasonic sensor to detect VAE whether air was located in the superior vena cava, right atrium, or pulmonary artery.

In summary, the transesophageal Doppler sensor on the Aloka SSD-870 transesophageal echocardiographic probe was more sensitive than a precordial Doppler sensor in detecting VAE elicited from an injection test and was equally as sensitive clinically as the transesophageal echocardiograph.

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