Date:

Title: Transesophageal Doppler Monitoring of Air Embolism

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Introduction: The use of a Doppler ultrasound probe has greatly facilitated the detection of small amounts of air emboli. The technique of precordial placement may, however, result in uncertainty of correct positioning and decreased quality of Doppler sounds in patients with increased A-P chest diameter. It provides little quantitative measure of the size, location, and duration of the air embolism and requires attachment of an additional device to the patient. We have developed and are investigating the use of a transesophageal method of probe placement based on the rational that an esophageal stethoscope is routinally used during surgery and its tip is in close proximity to the superior vena cava (SVC) and heart. Consequently, detection should be unaffected by the shape or thickness of the chest, and positioning should be more easily maintained.

Methods: We employ: (1) a 360 degree circumferential transducer to avoid the need to rotate the probe, (2) electronic processing circuitry to provide an analog output signal related to the amount of air emboli and duration that it remains in the ultrasound field, and (3) an audio presentation of the Doppler sounds. The transesophageal probe was evaluated in 12 anesthetized dogs. The probe was passed into the esophagus to varying distances from the incisor teeth with the dogs at different degrees of inclination. Sensitivity to intravenous air injection as well as optimal probe position was assessed using a constant size of air injection (.6cc). Probe position was determined using esophageal P-wave changes and fluoroscopy.

Results: The threshold for detection of air ranged from .05cc to .2cc in all 12 dogs. A decrease in sensitivity was found in some dogs after several hours. In recent studies removal of gas from the esophagus restored the sensitivity. Under normal operation, rapid injections of saline produced a brief deflection in our output signal (Fig. 1). Saline plus air injection produced a marked increase in sound intensity lasting for varying periods of time depending on the location of the esophageal probe (Fig. 1&2). The optimal site for air embolism detection appeared to be just above the junction of the SVC and right atrium as indicated by negative P-waves and fluoroscopy (Fig. 2). In many cases air emboli were delayed in the terminal SVC, especially when the cardiac output was low.

Discussion: The transesophageal ultrasound probe appears to be a sensitive and straight forward method of detecting air emboli. Its use also provides information as to the behavior of intravascular air. Of particular note is the finding that air frequently "hangs up" in the terminal portion of the SVC. This site, rather than the right atrium, may be optimal for aspiration of intravascular air. Further studies are underway to clarify this and other findings.

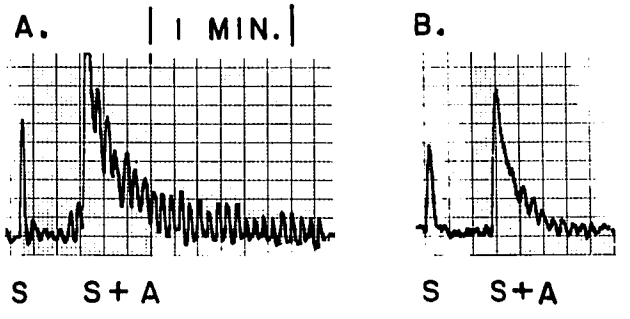


Fig. 1. Signal response to external jugular vein injection of saline (S) followed by saline plus 0.6cc air (S+A). Sensor tip at 42 cm (A) and 45 cm (B) from incisors.

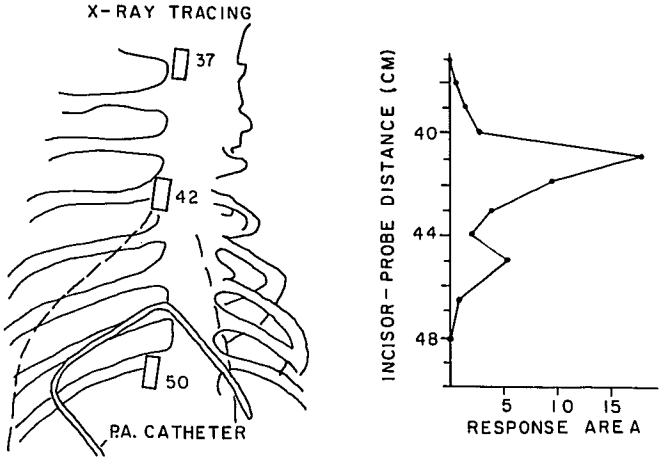


Fig. 2. Left: Fluoroscopic outline of thoracic structures vs. probe position at 3 locations. Right: Relationship between probe location and the area under the signal response curve (mm·sec x 100) following external jugular vein injection of saline plus .6cc air.

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