How to Fool Bubble Detectors

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Air embolism is a serious hazard related to extracorporeal blood circuits such as artificial kidneys, heart-lung machines, etc. Air may enter the circuit by suction at points open to the atmosphere, or gases in solution in blood may separate from it under negative pressure.

Rapid infusion of 100 ml of gas or air into a vein is lethal in most cases. Since the blood flow rates in artificial kidney circuits average 100 to 300 ml/min a patient could be killed in one minute or less if the blood was totally replaced by air or gas. A mock circulation simulating an artificial kidney shown in the diagram (Figure 1) was set up to demonstrate the various possi-

![Diagram](image)

Figure 1. Mock-Artificial Kidney circuit used for study of air embolism
bilities of air embolism. The amounts of air which entered the circuit and the amounts of air carried to the 'Pseudo-patient' were precisely measured in calibrated reservoirs. Bubble Detectors were tested on the circuit at a location similar to their position when used clinically.

The study demonstrated that slow entrance of air into a dialyser circuit may lead to formation of foam or froth which slowly fills the bubble trap. Sudden release of such foam would be as harmful to the patient as the same amount of free air. The usual Bubble Detector, however, will only detect free air or gas as large bubbles but not as foam.

Figure 2. Proportion of air to blood mixtures which produce either foam or large bubbles

The extent of embolism from either free air or foam was found to depend on the blood flow rate, the proportion of air or gas mixture, and the type of dialyser used. Coil dialysers had less tendency to produce foam than did the hollow fiber kidney (Figure 2). Other parallel flow dialysers were not checked at this time. A typical oscillographic picture of foam passing through a bloodline is shown in Figure 3.

The findings indicated that slow air entrance into the dialyser circuit produced enough foam or froth to reach the patient in fatal amounts. The appearance of such foam is not sufficiently different from blood to trigger the simple photocell bubble detectors. Similarly, at some distance it is difficult for the human eye to identify the foam. Because of this a new monitor was designed and tested (Figure 4). This device has been demonstrated to be sensitive to free air or gas, foam or froth in the bloodline, and also to solutions other than blood. The patient is protected by a clamp which immediately occludes the bloodline when the monitor is activated. At the same
Figure 3. Oscillograph picture produced by foam in the bloodline

Figure 4. Air-Bubble Detector sensitive to foam and bubbles. Product of Vital Assists, Inc., 30 Kensington Avenue, Salt Lake City, Utah, USA
time the bloodpump is stopped. It has not been possible to fool this monitor when tested in the mock circulation.

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