Sonic echocardiography: what does it mean when there are no bubbles in the left ventricle?

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The studies reported by Elliott and coworkers (3) in the Journal of Applied Physiology were prompted by criticisms of the way saline-contrast echocardiography results are interpreted (4–7). Our objective here is to rethink the interpretations in the light of our experience with bubbles in the body (1, 2).

When a bubble is introduced into a vein, all gases in it immediately begin the diffusive exchanges with the surroundings that will eventually absorb it. A gas that diffuses rapidly comes close to equalizing its internal partial pressure with its partial pressure outside. Gases that diffuse less rapidly are left behind in the bubble, with relatively larger partial pressure gradients between inside and outside. The bubble persists until the least diffusive gas is gone. In subjects who have nitrogen in their tissues and blood, nitrogen is the least diffusive gas. If a non-air bubble is introduced into a vein, nitrogen immediately begins entering while the non-air gas exits; soon the partial pressure of nitrogen inside becomes higher than outside and the bubble shrinks. In the lung of a subject breathing pure oxygen, there is little or no nitrogen, so nitrogen exits a bubble several times more rapidly than when air is breathed; although oxygen would be in high concentration inside the bubble because it is high outside, it would be absorbed very rapidly when the nitrogen is gone.

We recognize several uncertainties in echocardiography. What if bubbles appear in the left ventricle? 1) If they are larger than capillaries, they may have come through arteriovenous shunts. 2) If they are small, bubbles may have come through lung capillaries. One expects that small bubbles will be absorbed quickly. They would not reach the left ventricle if the time it takes to absorb the small bubbles is less than the time it takes for them to pass through the pulmonary capillaries. If the blood’s passage is more rapid, as in exercise, the small bubbles may not be completely absorbed, so the inappropriate interpretation would be that there are open anastomoses. One experiment that could shed light on the time of absorption in the pulmonary capillaries and veins, not to mention the time it takes for them to pass through the pulmonary capillaries.

What if bubbles do not appear in the left ventricle? 1) AV shunts may be closed so bubbles are stopped by capture at the precapillary level. 2) Bubbles may have passed through open shunts, but they may have been absorbed before they reach the left ventricle, leading to an incorrect interpretation that shunts are closed. 3) Bubbles may have passed through capillaries and then been absorbed.

Why are no bubbles seen when exercising subjects breathe 100% oxygen? The strong potential for absorption due to lack of nitrogen in the pulmonary capillaries, pulmonary veins, and left atrium makes it likely that they pass through the lung by any route—anastomoses, capillaries, or being freed from precapillary capture—bubbles will be absorbed before they reach the left ventricle. If so, the incorrect interpretation would be that oxygen closed the shunts so the bubbles were captured at the precapillary level.

Elliott and coworkers substituted bubbles of pure oxygen, pure nitrogen, pure carbon dioxide, or pure helium for the usual air bubbles; the results were always similar to those with air bubbles. The likely explanation is that all these bubbles lost some of the special gas and gained some nitrogen from contact with the blood and tissue on the way from the antecubital vein and in passage through the heart and lungs, so they were all effectively the same as air bubbles.

Nonbubble methods convince us that pulmonary shunts exist (4–7), but the uncertainties enumerated above lead us to question the reliability of saline-contrast echocardiography for studying shunts. In particular, we suspect that the lack of bubbles in exercising subjects who breathe oxygen is due to absorption in the pulmonary capillaries and veins, not to closure of arteriovenous anastomoses.

DISCLOSURES

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REFERENCES