

Microbubble Production by Bubble Oxygenators

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Sakauye, et al. (1982)¹ present a novel and potentially useful technique for evaluating microbubble production by bubble oxygenators. While the authors appear to recognize some of the limitations of Doppler ultrasound, before the actual values they report can be utilized as criteria to evaluate various commercial units, several additional points should be raised.

The use of Doppler for detection of blood-borne gaseous emboli can be a reliable and necessary diagnostic tool. The limitations, however, are significant and potentially misleading in interpretative situations. Indeed, most applications of commercial Doppler devices are of little use in accurately counting or sizing microbubbles in a fluid system, due to coincident signals or mismatch of the incident beam and the bubble location within the vessel or tube. Another important limitation regards the sensitivity of the device or recorder, to detect microbubbles in the 0.1 to 50 micron range, which are extremely difficult to visualize. Sakauye, et al. could have added much needed credibility to their report by calibrating the TM-8 Doppler with microbubbles of known size. In our studies^{2,3,4} we have tested two units with calibrated microbubbles with diameters below 10 microns. Furthermore, when reporting indirectly obtained bubble sizes as in their report, it is often misleading to present bubble counts as well, since there is a natural tendency to use the product of the count and size which may yield incorrect values for total volume.

Hemodynamic influences with gaseous microemboli include bubble size, nature of the carrier fluid (e.g. surface tension), total gas volume as well as any tendency for the bubbles to either

coalesce or breakup into smaller ultramicrobubbles upon collision. Sakauye, et. al. did not definitively size the microbubbles in their investigation. In several studies^{2,3} we have employed a Coulter-counter which utilizes electric gating to accurately size microbubbles.

The surface tension of the fluid has a strong influence on bubble mechanics. Surfactants (phospholipids) tend to adhere to the air:liquid interface^{5,6} as well as platelets and protein molecules which result in bubble stabilization. Saline or ringers solutions have no surfactants which explains the instability of the bubbles in the Sakauye, et. al. report for the ringers group. Any opportunity for bubbles to collide in moving fluid media may result in smaller microbubbles which, if in blood or plasma, will remain stable. Furthermore, their diameter may be well below the size necessary to infarct a tissue⁷. Where the opportunity for bubble collision is high as in the Sakauye method, due to the vortex separation cells and pump, the likelihood for coincident counting by the Doppler is predictable. From this analogy one might question the data presented in Tables 1A and 1B as well as figure 7.

When presenting values for total gas volume produced by blood oxygenators perhaps a more useful figure would employ curves comparing microliters of air versus time at fixed V:Q ratios. Figure 6 in the Sakauye report implies a continued accelerated production of air. If this were the case, then all units would have similar problems if allowed sufficient time. Unfortunately no discussion is presented concerning figure 6 in their report.

In the evaluation of bubble oxygenators for micro air emboli production, attention should be made to the total gas volume contributed to the blood as well as the size of the emboli produced. This data would enable further development in the efforts to remove or prevent air emboli. Perhaps more

studies like the Sakauye, et al. report will stimulate such studies.

References

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Response

Dear Editor:

Dr. Butler presents a valid comment regarding the inherent weakness involved in studies with Doppler-type devices, i.e., the difficulty in obtaining reliable calibration materials. While it is possible to do single point calibrations of the TM-8 device with small numbers of calibration standards, our studies dealt with oxygenators which

produced hundreds of bubbles per second. To calibrate the TM-8 under those conditions was not within current technology available. Also, as Dr. Butler points out, numbers generated by the TM-8 in themselves can be misleading unless properly analyzed/interpreted. The TM-8 readings presented in our study were intended to provide a profile of the activity trend, and were not intended to be read as absolute values. Indeed, when counts produced were converted to absolute volume via arithmetic means, the calculated volumes did not correlate to the vortex cell volumes measured.

Our concern relative to coincident counting phenomenon was based upon the presence of bubble activity well into the 1000 um size range. Since the Shiley S-100A (HED) has a 105 um polyester screen, one would expect the bubble activity to drop off somewhere between the 100-200 um bubble range. For this reason, we referred to the TM-8 data as qualitative rather than quantitative.

We thank Dr. Butler for his comments and views on our study. Further studies are in progress, and as our experience increases, our techniques are improved. We hope that further studies are carried out by other researchers in this critical area of concern. As a matter of interest, a limited number of vortex cells have been made available to researchers.

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