

Invited Commentary

Gaseous Microemboli: Do We Finally Start to Comprehend How to Remove Them?

Since the early introduction of cardiopulmonary bypass, gaseous microemboli (GME) have been considered one of the potential causes of neurological deficit (1). A major step in attenuating the number of GME was the introduction of the arterial screen filter (2). The working principle of the filter is twofold; the filter screen creates a mechanical barrier for GME larger than its pore size and simultaneously the blood velocity is reduced in the filter housing. The latter in combination with a purge port allows GME to rise and to be evacuated. However, it is important to notice that the purge port is mainly effective for GME larger than 500 μm because buoyancy mainly depends on size. Smaller GME are predominantly trapped inside the pleated filter media (3).

In this issue, Svenmarker et al. make a comparison between an oxygenator with and without an integrated arterial filter. They present some pertinent observations. The use of a screen filter incorporated inside the oxygenator is more efficient than an oxygenator alone in removing a given volume of air. They also note that both oxygenators become less efficient in removing a given volume of air as blood flow is increased. This makes sense because the fiber bundle of the oxygenator can be considered a depth filter where the filter material actively removes, over time, adhering GME by diffusion through the microporous hollow fiber (4–6). The efficiency of a depth filter to remove particles or GME depends on the flow velocity inside the filter medium. As such, the reported lower efficiency at higher flow is no surprise. Some caution is necessary when converting measured GME diameters into volume, because larger diameter bubbles will strongly influence the final calculated volume (7). This is reflected in the published results of the measured counts showing less efficiency in removing GME. A second interesting observation in the study is the fact that a larger number of small GME was found after the oxygenator with the integrated filter compared with the one without the filter. The authors speculate that this is caused by fractionation of the bubbles by the filter screen. This hypothesis is difficult to verify but it is interesting to observe that the tested oxygenator with the integrated filter had no real purge line. The GME are trapped against the filter medium and kept in place because of the pressure exerted by the bloodstream. Because of this

pressure exerted by the bloodstream and the friction between a given bubble and the screen, the buoyant force will be very low. From that moment on, GME are no longer in contact with the hollow fibers as they are pushed outward against the screen and diffusion from gases out of the GME can only take place toward the passing highly saturated arterial blood. This reopens on one hand the debate on what is the best position of an integrated filter in an oxygenator but also proves that more in-depth research is necessary to investigate which design of integrated filter is most effective in combination with the depth filtration of the microporous hollow fiber membrane compartment.

Another important issue that still needs to be solved is what the best fluid to perform GME experiments is. There is no doubt that water is not acceptable because of its major difference in density and viscosity compared with blood, leading to a faster transition from laminar to a transient or turbulent flow regimen. The difference in viscosity can be solved by using blood analogs, e.g., water–glycerin solution as used in this study, which have the advantage that flow dynamics are comparable with those of blood. An additional advantage of blood analogs is their translucency, which makes it possible to visualize bubble behavior with cameras (7). However, blood analogs do not contain proteins and fat nor blood elements as whole blood does. Proteins and fat will lower the surface tension of the fluid and will coat gaseous microemboli. The blood elements, especially red blood cells, can absorb large amounts of gas depending on the binding status of hemoglobin and thus can rapidly remove mainly oxygen and carbon dioxide from GME. So, when using blood as a test fluid, its partial tension of O_2 , CO_2 , and nitrogen as well as hemoglobin saturation will influence the final result of an experiment. Finally, when working platelets are available in the test blood, these can bind on the protein-covered GME and worsen diffusion from gas out of the GME. Based on this information, it is quite obvious that we always need a clear description of the start characteristics of the used blood. Due to the differences between blood analogs and blood, it is evident that results obtained with blood analogs will never completely reflect results obtained with blood, but both will provide unique information in their respect.

Although we have learned a lot about GME over the last years, there are still some gray zones that need further exploration.

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