Balloon pump–induced pulsatile perfusion during cardiopulmonary bypass does not improve brain oxygenation

To the Editor:

We read with interest the article by Kawahara and associates regarding the effects of pulsatile versus nonpulsatile perfusion on internal jugular venous oxygen saturation and regional cerebral venous oxygen saturation during normothermic cardiopulmonary bypass (CPB) in 22 patients.¹ They have concluded that when compared with nonpulsatile flow, pulsatile perfusion generated by an intra-aortic balloon pump had no beneficial effect on cerebral protection.

The authors stated that although many methods have been used to generate pulse pressure during CPB, no general definition and no criteria have been reported for pulsatile perfusion. In contrast, the literature reports that several investigators have attempted to establish a common criterion for pulsatile and nonpulsatile flow.^{2–6} Shepard, Simpson, and Sharp² suggested that the energy equivalent pressure (EEP) formula may be used to quantify pulsatile and nonpulsatile waveforms. The generation of the pulsatile flow depends on the energy gradient rather than the pressure gradient. EEP contains both pump flow and arterial pressure waveforms. The following formula is used to define the EEP:

$$EEP = (\int p \, df) / (\int f \, dt)$$

where p is the arterial pressure, f is the pump flow, and dt is the change in time at the end of flow and pressure cycles. The units for EEP are millimeters of mercury. EEP is the ratio of the area under the hemodynamic power curve ($\int p \, df$) and the flow curve ($\int f \, dt$) at the end of flow and pressure cycles.

Recently, we have quantified pulsatile and nonpulsatile waveforms in terms of EEP.⁷ With an identical pump flow rate and mean arterial pressure, the pulsatile roller pump (Stöckert SIII, Munich, Germany) generated significantly higher EEP than did conventional nonpulsatile perfusion. In addition, we have shown that this increase in EEP maintained higher regional and global cerebral, renal, and myocardial blood flow in a neonatal piglet model.⁸ In a separate study with a different pulsatile roller pump (Jostra HL-20, Jostra USA, Austin, Tex), we have shown that regional cerebral venous oxygen saturation increased during normothermic and hypothermic CPB in a neonatal piglet model.⁹ In this particular study, EEP was significantly higher than mean arterial pressure.

Our experience leads us to the conclusion that EEP is the most complete formula to quantify pulsatile and nonpulsatile waveforms for direct comparisons.

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Reply to the Editor:

We appreciate the interest and comments of Drs Ündar and Fraser. Several investigators¹ have tried to establish common criteria for pulsatile flow, but it is not clear which type of pulsatile waveform has positive effects on cerebral circulation and improves outcome of patients.² As stated by Ündar and associates,³ it is impossible to compare the results of different investigations in which different types of pulsatility were used.

We can see that the concept of energy equivalent pressure introduced by Shepard, Simpson, and Sharp⁴ is useful for understanding the quality of pulsatile perfusion. Wright⁵ believes that hemodynamic considerations were fundamental to resolve the controversy of the pulsatility waveform. We hope that further clinical investigations will determine the best pulsatile form and will be supported by logical theories, such as energy equivalent pressure.

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