LETTERS TO THE EDITOR

The relation between pump flow rate and pulsatility on cerebral hemodynamics during pediatric cardiopulmonary bypass

To the Editor:

We read with great interest the report by Chow and associates[1] about the effects of pulsatile versus nonpulsatile flow on the cerebral hemodynamics in children. Pulsatile and nonpulsatile flow were tested for six 5-minute intervals at three different pump flow rates in 40 patients. Chow and associates concluded that pulsatile flow delivered with a Stöckert pump (Stöckert, Munich, Germany) did not increase cerebral blood flow (CBF) or alter hemoglobin concentration during cardiopulmonary bypass in children.

Although pulsatile flow settings such as pump rate, baseline flow rate, and run time were included in their study, these parameters are inadequate to quantify the pulsatility. To compare pulsatile versus nonpulsatile flow or different types of pulsatility, first investigators have to establish common criteria for pulsatile flow. The criteria should be easy to understand and apply without using complex mathematical calculations. Although several attempts have been made to establish common criteria, no consensus has been reached.[2-5] Until a common definition is reached, investigators should be specific about the quality of pulsatility by including pressure and flow waveforms, rate of pressure rise, ejection time, pulse pressure, and stroke volume, along with the brand name of the pulsatile device.

In addition to the pump, an acceptable membrane oxygenator and aortic cannula are extremely important to produce sufficient pulsatility.[5a] Hollow-fiber membrane oxygenators dampen pulsatile flow significantly less than other types of membrane oxygenators.[6] Since the diameter of the aortic cannula is significantly smaller for neonates and infants than for adults, the geometry of the aortic cannula is also extremely important in producing adequate pulsatile flow. It has also been proven that the shorter the tip of the aortic cannula, the better the pulsatility.

Referring to an article by Sadahiro and coworkers,[7] Chow and associates stated that the higher CBF was obtained during pulsatile pump flow at cerebral perfusion pressures (CPPs) below 50 mm Hg in dogs. Referring to an article by Hindman and colleagues,[8] however, they stated that this higher CBF has not been reproduced in rabbits. In the rabbit model, the mean arterial pressures were above 60 mm Hg, not lower than 50 mm Hg. It has also been proven that the cerebral pressure/flow autoregulation is intact if the CPP is greater than 50 mm Hg. In addition, Hindman and coworkers[8] had a severe technical limitation in their rabbit model. The distal aorta was ligated and cannulated in retrograde fashion, which produced artificially higher pressures and CBFs in rabbits. This may be the reason that they could not show the benefits of pulsatile perfusion in the rabbit model. However, they have produced physiologic pulsatile pressures with a unique two-chamber hydraulically driven pump system (Medical Engineering Consultants, Bishop, Calif.) during cardiopulmonary bypass. The first chamber was placed between the venous reservoir and the oxygenator, and the second pumping chamber was placed after the oxygenator. Thus the membrane had no effect on the quality of the pulsatility in this particular model. However, this physiologic pulsatile pump system has not been yet approved for clinical trials by the Food and Drug Administration.

It has already been proven that CBF is improved with pulsatile flow at CPP of 40 mm Hg in piglets.[9, 10] Although pulsatile perfusion had no beneficial effects on global and regional CBF at a CPP of greater than 50 mm Hg, myocardial and renal blood flow were better maintained with pulsatile flow than with nonpulsatile perfusion in a piglet model.[11]

Chow and associates have also stated that "preliminary studies from our group suggest that pulsatile flow does not increase CBF in adults either."[12] Once again, they have used pulsatile and nonpulsatile flow with 5-minute intervals, which was a limitation of their model. However, systemic vascular resistance with pulsatile flow was lower in five of seven adult patients, but results were not statistically significant.

Certainly, there is an urgent need to design better pulsatile pumps other than roller pumps, which generate only 12.4% of the pulsatile power of a human heart.[13] In addition, investigators should have common criteria for pulsatility when comparing results from different institutions.

Despite these concerns, the study by Chow and associates is interesting. We were particularly pleased to see the use of near-infrared spectroscopy during pulsatile versus nonpulsatile perfusion for pediatric patients undergoing cardiopulmonary bypass. This adds another useful noninvasive tool in comparing pulsatile versus nonpulsatile perfusion. We look forward to future articles by the investigators with different settings of pulsatile versus nonpulsatile perfusion.

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Reply to the Editor:

We thank Ündar and Fraser for their interest in our work. We agree that there are significant difficulties in defining pulsatility; indeed modified roller pumps may produce relatively little pulsatile power, particularly when used with membrane oxygenators. Nevertheless, since they are commercially available and their proponents consider them to have significant advantages for their patients in terms of neurologic outcome, as well as cardiac function, it is not unreasonable to assess their effects on the cerebral circulation. We used the hollow-fiber membrane oxygenators, chosen for our neonatal and paediatric patients (M. Davis, personal communication), because they have the lowest transmembrane pressure gradient both before and after the oxygenator. It is difficult in a clinical situation to produce data on all the aspects of pulsatility that might be examined on a research basis, but we provided evidence that our modified roller pump did produce a pulsatile waveform in the middle cerebral artery. Since the aim in patients must be to minimize the need for invasive hardware, the transcranial Doppler ultrasound technique and the Gosling pulsatility index[1] might be useful tools in future studies of pulsatile pumps in clinical cardiopulmonary bypass.

It may well be that any benefit of pulsatile pumps will be seen at low cerebral perfusion pressures. Our study was designed to look at this question, but could not demonstrate a higher total hemoglobin value at low perfusion pressures using the Stöckert pump (Stöckert, Munich, Germany) in the pulsatile compared with the nonpulsatile mode. The short time periods were chosen to ensure that six different situations (pulsatile vs nonpulsatile flow at each of three pump flows) could be examined in each patient. We were interested to hear of the development of a pulsatile pump designed for use in infants; clinical studies specifically targeted at examining their performance at the low pump flows commonly used during cardiopulmonary bypass in very young children might look at total hemoglobin over longer time periods. However, inasmuch as Lodge and associates[2] also found no difference in cerebral blood flow between pulsatile and nonpulsatile flow in their animal model, there are no data available to support the use of pulsatile flow in children as a means of improving cerebral hemodynamics.

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