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Is left heart bypass by cannulation of both femoral arteries an effective form of assisted circulation?

To the Editor:

I read with great interest the article by Ide and coworkers,¹ which represents yet another effort toward the development of a left ventricular (LV) assist device for rapid percutaneous insertion. Their system combines the partial unloading of the heart by means of a small-diameter catheter inserted retrogradely into the LV with the pulsatility of an integrated intraaortic balloon. In their study on dogs with heart failure they compare hemodynamic status and myocardial blood flow under conditions of nonpulsatile and synchronous pulsatile LV bypass. They conclude that the pulsatility added to a partial LV bypass increases the mean aortic pressure and the total cardiac output and ameliorates the myocardial supply/demand ratio. This is an interesting finding inasmuch as complete LV unloading cannot be obtained with such systems. When transferring their conclusion to the clinical setting, they speculate that a flow support of more than 2 L/min is necessary to obtain the same hemodynamic advantages as in their experimental setting. Therefore, they propose a model for clinical application that has a catheter with an inner diameter of 15F, an outer diameter of 20F, and a length of 90 cm.

Recently, while testing a similar model of LV assistance, we performed an in vitro study to evaluate the pressure drop over flow for cannulas of different lengths and inside diameters in conditions of steady and pulsatile flow circulation.² When we tested in a steady flow circulation a cannula with a length of 100 cm and an inner diameter of 5 mm (approximately the same characteristics as those proposed by Ide and coworkers), we found a

Fig. 1. Pressure drop over flow for cannulas with different lengths and inner diameters (4, 5, 6, 7, and 8 mm). The vertical dotted line divides areas of flow with different characteristics (laminar and turbulent). (From De Paulis R, Engelhardt H, Chiariello L, Reul H, Morea M. In vitro evaluation of left ventricular assistance by cannulation of both femoral arteries. *Int J Artif Organs* 1990;13:237-46. Published with permission of Wichting Editore, Milan, Italy.)

pressure drop over the cannula that was 150 mm Hg for a flow of 2 L/min and above 200 mm Hg for a flow of 2.5 L/min (Fig. 1).² When the pressure drop over the cannula is greater than the pressure at the cannula inlet, the centrifugal pump will start to develop a suction pressure that is below atmospheric pressure. If the suction is too high, air might be sucked inside the system and the outlet of the cannula may have a tendency to collapse. The cannula is more likely to collapse if its wall is extremely thin. Furthermore, creating conditions of high turbulent flow on high suction pressure could eventually lead to a higher hemolysis rate. For all these considerations we thought that a 5 mm inner diameter cannula was inadequate in providing the 3 L/min flow that was deemed necessary to assure adequate circulatory support. A 6 mm inner diameter cannula was considered the minimum requirement for potential clinical applications, and therefore it was selected for testing in a pulsatile mock circulation. Under conditions of pulsatile flow the pressure drop across the cannula increased with the amount of pulsatility of the cannula inlet pressure (the prosthetic left ventricle) at a constant bypass flow. This finding was

Fig. 2. Suction pressure (SP) over pulsatile ventricular pressure (PVP) at different assisted pump flows. The slope of the lines is a measure of the momentary pressure drop at a certain magnitude of pulsatility of the ventricular pressure. Arrows indicate the example in the text. (From De Paulis R, Englehardt H, Chiariello L, Reul H, Morea M. In vitro evaluation of left ventricular assistance by cannulation of both femoral arteries. *Int J Artif Organs* 1990;13:237-46. Published with permission of Wichting Editore, Milan, Italy.)

ascribed to inertia and increased friction because of fluid acceleration inside the cannula. In our model, at 3 L/min of bypass flow and a prosthetic ventricular pressure varying from 5 to 50 mm Hg, the suction pressure ranged from -92 to -56 because the pressure drop changed from 97 to 106 mm Hg (Fig. 2).² This means that for the same intraventricular pressure the pressure drop is smaller where the magnitude of the pulsatility is less (as in the case of a failing ventricle) and that any increase of the intraventricular pressure (as in the case of ventricular recovery) will result in a lower suction pressure. From this example, data for a 5 mm inner diameter cannula could be extrapolated.

On the basis of our data, we think that a 5 mm inner diameter cannula might be too small to achieve a sufficient bypass flow in an adult. On the other end, we are well aware that a bigger cannula will make more difficult the prevention of lower limb ischemia, which is critical in this type of ventricular assistance in which both femoral arteries are cannulated. On the other hand, Babic and coworkers³ have clinically used a percutaneous left heart bypass either as a left atrial-aortic bypass or as a left ventricle-aortic bypass with a long 14F cannula with a Teflon sheath and a minimally nonocclusive roller pump.

They were able to achieve flows ranging from 1.5 to 3.5 L/min, kinking of the cannula was never noticed, and hemolysis and other hematologic alterations were never clinically relevant. Furthermore, they claimed that leg ischemia could be simply prevented by positioning the arterial inflow sheath tip into the aorta and not into the iliac artery.

Although percutaneously applied LV bypass combines several advantages over other LV assistance systems, it has never gained widespread clinical use. The reason lies within the difficult compromise in the choice of a cannula with a size sufficient in providing an adequate flow but small enough to avoid an impaired perfusion of the lower limbs. Although it might be effective for LV assistance during short-term procedures such as coronary angioplasty, it is likely to be inadequate for intermediate-term or long-term ventricular support.

In conclusion Ide and coworkers are to be congratulated for the brilliant idea of integrating pulsatility in a system of LV assistance with the intention of balancing for incomplete LV unloading. However, on the basis of our experience, we still doubt the possibility of obtaining good drainage through a 15F inner diameter long cannula, and at the same time we believe that a 20F outer diameter cannula is likely to cause limb ischemia when left in place for more than a few hours.

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Reply to the Editor:

We acknowledge Dr. De Paulis and his colleagues for their suggestion about the clinical application of the integrated cardioassist catheter (ICAC) method, a pulsatile left ventricular-aortic bypass method developed by us. Regarding clinical use, we have developed the ICAC as a left ventricular bypass system that can be easily applied in cases of left ventricular failure. It is used for conditions in which the intraaortic balloon pump is insufficient but the use of a conventional left ventricular assist device would be excessive. In developing this system, we intended to obtain a partial left ventricular bypass to provide short-term (about 1 week) support. As pointed out by Dr. De