Reversed Intracranial Blood Flow in Patients With an Intra-aortic Balloon Pump

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As a preliminary investigation into the cerebral effects of mechanical cardiac assist devices, using transcranial Doppler ultrasonography I examined the basal cerebral arteries in three patients placed on an intra-aortic balloon pump. Unassisted systoles had normal blood velocities and waveforms. When the pump was in use, diastolic blood velocity during balloon inflation increased. As the balloon was deflated and intra-aortic pressure dramatically lowered, diastolic blood velocity within the intracranial vessels decreased sharply. In two patients there was a reversal of blood flow in the middle cerebral, anterior cerebral, basilar, and vertebral arteries during late diastole. Although the clinical effects of cessation and reversal of blood flow in the cerebral circulation while on an intra-aortic balloon pump remain to be determined, transcranial Doppler ultrasonography appears to be a useful tool for measuring these hemodynamic effects. It may also be helpful in quantifying the effects of such pumps on cerebral blood flow and devising inflation/deflation timing sequences that maximize forward blood flow. (Stroke 1990;21:484-487)

When medical treatment fails to sustain cardiac output, mechanical assist devices can be used to support left ventricular function. One of the most widely used devices is the intra-aortic balloon pump. The most common applications of this device include its use in patients with unstable angina and cardiogenic shock, for preoperative support, and in weaning patients from cardiopulmonary bypass.

Intra-aortic balloon pumping decreases myocardial oxygen consumption, increases coronary blood flow, and increases cardiac output in patients with cardiogenic shock. In this procedure, a balloon is placed into the aorta just distal to the left subclavian artery, usually via the femoral artery. The balloon is connected to an external pump via a catheter. The pumping is timed so that the balloon inflates immediately after the aortic valve closes. Balloon inflation decreases diastolic aortic runoff and increases diastolic aortic pressure; these changes increase perfusion of the coronary arteries. The balloon deflates just before systole. Balloon deflation results in systolic unloading and a decrease in the aortic impedance to left ventricular ejection. This combination causes relatively little change in the mean aortic pressure but decreases the left ventricular pressure by approximately 20% and increases cardiac output by up to 40% in patients with cardiogenic shock.

Using transcranial Doppler ultrasonography (TCD), I examined three patients placed on an intra-aortic balloon pump in a preliminary investigation of the effects of the device on the cerebral circulation.

Case Reports

Methods

I used a Transpect TCD (Medasonics, Mountain View, California) with a 2-MHz pulsed Doppler probe. The pulse repetition frequency is adjustable to 3.9, 5.25, 7.8, or 10.5 kHz by software under user control. The spatial peak temporal average intensity of the ultrasound is 161 mW/cm². The TCD technique has been described.

A System 90T Transport intra-aortic balloon pump (Datascope Corp., Paramus, New Jersey) was used in all patients. It is a helium-charged, mobile intra-aortic balloon pump that times balloon inflation/deflation automatically, with only minimal adjustments required by the operator. The device triggers balloon inflation/deflation from patient electrodes or externally generated electrocardiographic signals, a pressure transducer or externally generated pressure signals, or a fixed internal square wave.

Three patients in the cardiac care unit on an intra-aortic balloon pump were studied at the request of their physicians.

Cases

I initially studied a 63-year-old right-handed man admitted to the hospital for an acute myocardial
intra-aortic balloon pump. In the posterior circulation, a reversal of blood flow late in diastole was noted. Two other men, 54 and 61 years old, in the cardiac care unit after an acute myocardial infarction were also studied by TCD. All three patients were studied when the intra-aortic balloon pump was about to be discontinued and could be safely turned off and on.

All three patients had normal TCD examinations with the pump turned off. Systolic blood velocities in the middle cerebral artery ranged from 70 to 105 cm/sec, in the anterior cerebral artery from 62 to 115 cm/sec, and in the basilar artery from 42 to 73 cm/sec.

Intracranial reversal of arterial blood flow at the end of balloon deflation (Figure 1) was seen in two of the three patients. This reversal was noted in both the anterior (anterior and middle cerebral arteries) and posterior (vertebral and basilar arteries) circulations. The blood velocity profile returned to near normal when pump support was temporarily discontinued (Figure 2). The pattern of late diastolic blood flow reversal returned as the pump was turned back on. It was also possible to observe this effect with intermittent balloon inflation (i.e., balloon inflated every second, third, or fourth systole).

No patient developed signs of a transient ischemic attack, stroke, or other neurologic complications during intra-aortic balloon pump support. None had an overt encephalopathy, although detailed neuropsychiatric testing was not performed.

Discussion

The finding of reversed blood flow during late diastole in the basilar artery of our first patient was initially interpreted as a subclavian steal phenomenon. Subsequent examination of both vertebral arteries and the anterior circulation in this patient excluded the diagnosis of subclavian steal and suggested that the intra-aortic balloon pump was responsible for this finding. This was confirmed by TCD examination of two additional patients in whom the pump was used intermittently.

The most commonly reported complications of such left ventricular assist devices are local vascular injury (leading to thromboembolism) and infection. Neurologic complications of the device occur in approximately 4% of patients. Thromboembolic stroke is rare, in part because most often the device is inserted into the femoral artery and the balloon remains distal to the left subclavian artery (i.e., distal to the arterial supply to the brain). Cerebral infarction has been reported due to helium embolism after rupture of the balloon and air embolization after insertion of the balloon and catheter. Spinal cord infarction, a more common complication, is attributed to either a small arterial dissection or an arterial embolus. Peripheral nerves can also be damaged secondary to arterial occlusion or direct trauma at the cannulation site.

Cerebral blood flow augmentation in animal studies with an intra-aortic balloon pump appears to vary with the degree of cardiac failure. In control animals, cerebral blood flow may be decreased by 10% by a pump, due to redistribution of blood flow and not to reduced cardiac output. With severe cardiogenic shock (cardiac output reduced by one third and
cerebral perfusion reduced by 80%), the addition of an intra-aortic balloon pump increased cerebral blood flow by 50% over that in animals with cardiogenic shock and no pump.12

In human studies, Gee et al13 noted an overall reduction of 11.4% in ocular blood flow measured by ocular pneumoplethysmography in patients on an intra-aortic balloon pump. In 56 patients, 73% showed a decrease (average 24%), 23% showed an increase (average 26%), and 4% showed no change in blood flow.

Reversed blood flow in the intracranial arteries during diastole is seen in few clinical diseases. These include increased intracranial pressure,14 intracranial circulatory arrest,15 and, in the posterior circulation, the subclavian steal syndrome.4

Although it is well established that intra-aortic balloon pumping improves cardiac output and decreases myocardial work, its effects on the cerebral circulation have not been systematically examined. The clinical significance of this dramatic alteration in the cerebral blood flow pattern is unknown. Neurologic sequelae from such a pump may be detectable only with careful psychometric testing, as is needed to detect the intellectual impairment and subtle personality changes following cardiopulmonary bypass.16,17

Neuropsychological deficits may be found in 50–75% of patients undergoing coronary artery bypass surgery.18,19 Early reports of the neurologic complications of cardiopulmonary bypass greatly underestimated these complications because of the lack of detailed cognitive testing. Early work suggests that TCD may be a useful tool for monitoring cerebral perfusion during cardiac surgery.20 Similar work remains to be done for both the clinical and hemodynamic effects of intra-aortic balloon pumps.

TCD provides valuable information about the blood flow patterns with intra-aortic balloon pumping. TCD is superior to conventional cerebral blood flow techniques for detecting these changes because it can measure subsecond changes in velocity. Similar blood flow patterns are seen in the subclavian steal syndrome.4,21 In this disease, with blood flow abnormalities restricted predominantly to the posterior circulation, the TCD pattern is usually benign.21

Long-term monitoring of the cerebral circulation with TCD can identify microemboli within the middle cerebral artery during cardiopulmonary bypass procedures.22 Similar techniques during the use of left ventricular assist devices may help identify occult cerebral embolization with intra-aortic balloon pumps.

Currently, this device uses a square-wave function to control gas flow into the balloon. With TCD, it may be possible to devise nonlinear inflation/deflation sequences for intra-aortic balloon pumps that maximize forward blood flow in the intracranial circulation.

TCD measures of cerebral blood flow velocity may help determine optimal regimens for the use of intra-aortic balloon pumps and other left ventricular assist devices. Further conclusions from this observation await larger clinical series and the use of detailed cognitive testing.

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References


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