

Technique

Elimination of Arterial Line Clamping when Coming Off Bypass with Centrifugal Pumps with the Centri-Safe™ Valve In-Line

Eduardo Esper, MD; Helene M. Rigsby, RN; Rajsekhar Devineni, MD; Jacob Kolff, MD

Department of Surgery, Division of Cardiothoracic Surgery, Temple University/Conemaugh Memorial Medical Center, Johnstown, Pennsylvania.

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Dr. Jacob Kolff is the inventor and partial owner of the patent for the Centri-Safe™ valve.

ABSTRACT

Retrograde blood flow through the aortic cannula into the cardiopulmonary circuit may lead to aortic air emboli when nonocclusive centrifugal pumps are used. Perfusionists have been taught to clamp the arterial line to prevent retrograde flow when the pump fails. They also have to protect against the possibility of air entering the arterial cannula when low flows are requested or when the patient is taken off bypass. The present report details the advantages of having a check valve placed in-line with the arterial cannula during centrifugal blood pumping. It will allow weaning patients from cardiopulmonary bypass without the use of arterial line clamping.

Address correspondence to:
Jacob Kolff, MD
Department of Surgery
Temple University/Conemaugh Memorial Medical Center
1086 Franklin St.
Johnstown, PA 15905

INTRODUCTION

During cardiopulmonary bypass (CPB), oxygenated blood is directed into the patient's arterial circulation via roller pumps or centrifugal pumps. Failure of the CPB pump can lead to devastating complications. A complete failure of centrifugal or roller pumps results in no blood flow to the patient. Centrifugal pumps pose an additional, inherent danger in that they permit retrograde flow from the patient. This flow is forced by the same hydrostatic head relied on for venous drainage. Unchecked retrograde flow creates a siphon in the patient's arterial system that can draw air into the cannula (1). The air may go undetected because the line is frequently covered by surgical drapes. This bolus of air also can be unknowingly pumped to the patient when forward flow resumes. The result is a potentially fatal air embolus. Although perfusionists are taught to place a clamp on the arterial line whenever the pump is stopped, *in vitro* testing shows that retrograde flow commences in as little as 540 msec after the pump is turned off (2).

A nonregurgitant, unidirectional check valve, the Centri-Safe™ (CSV)^a, with a Teflon ball occluder has been developed to prevent such backflow (2). *In vitro* testing of the valve revealed that at flows of 5 L/min, the pressure drop across the valve was less than 5 mmHg, and the leakage rate at pressures up to 200 mmHg was less than 0.15 ml/min. In addition, the valve had a burst strength greater than 60 PSI (3,100 mmHg), which gives it a strength equal to or greater than every other component in the perfusion setup. Moreover, the hemolysis rate during *in vitro* and *in vivo* studies in animals and humans was not different from the hemolysis caused by the remaining circuit components (2). The CSV works with all CPB circuits that use centrifugal pumps.

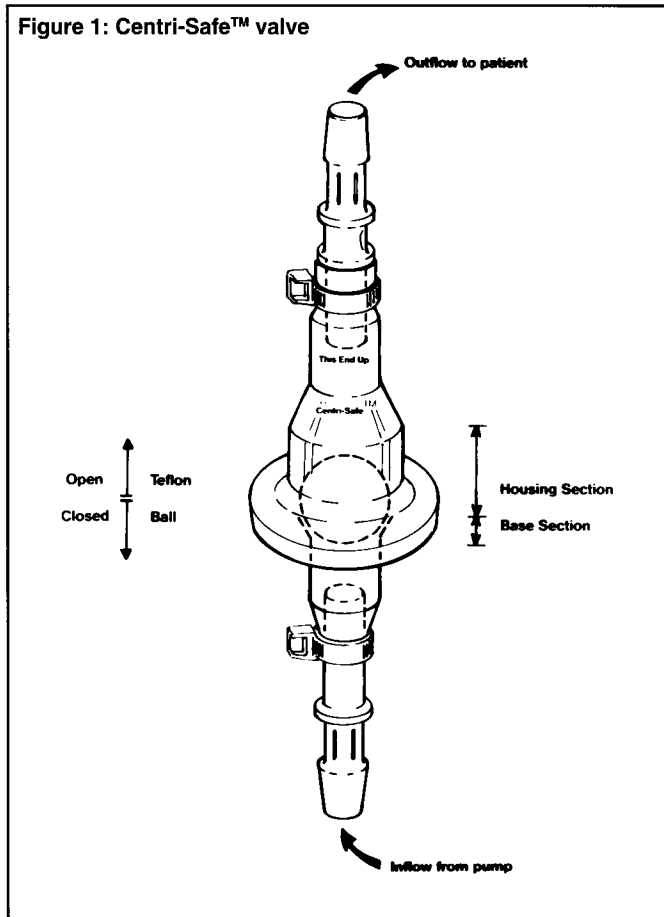
The purpose of this paper is to communicate the technique of placing the CSV in the arterial line so that arterial clamps may be eliminated. We believe one of the major advantages of the CSV in-line is that patient safety is not compromised when low flows are requested or when patients are weaned from bypass.

MATERIALS AND METHODS

The CSV is a nonregurgitant, unidirectional valve assembled from three components (Figure 1): a housing section, a base section, and a Teflon ball occluder. The housing and base sections are manufactured from compliant medical grade (U.S.P. Class VI) polyurethane (2). During operation the ball is free to move in the valve's axial direction. In the "closed" position, the ball seats itself against a compliant bowl in the base section, sealing off the inflow conduit and blocking flow from the patient.

The ball occludes flow as long as the distal (patient side) pressure is equal to or greater than the proximal (heart-lung machine) pressure. When the proximal pressure becomes greater than the distal pressure, the ball moves in the direction of flow until the valve opens.

The blood then flows around the ball to the distal conduit



and the patient. The ball is also free to move in the radial direction during operation. The movement creates a noticeable vibration that can be used as an indicator that the device is operating. In practice, the CSV is intended to block retrograde flow and prevent air embolization from the patient to the heart-lung machine.

PLACEMENT OF THE DEVICE

Our bypass circuit consists of a cardiotomy^b, a collapsible venous reservoir^b, the centrifugal pump^b, a Maxima Plus oxygenator^b, an arterial oxygen saturation device^b, an arterial pressure monitor^b, and an arterial line filter^c. The CSV is placed in the vertical position in the arterial line as depicted in Figure 2.

We routinely hand down the A/V loop table lines with the CSV already incorporated in-line to the 3/8" arterial tubing. We leave approximately 8-10 inches of tubing distal to the device to connect it with the arterial filter. Because the CSV is a one-way valve, it should be checked for proper direction (labeling on the valve is upright and readable). This checkup is done during

a CSV, Critical Care Technologies, Conshohocken, PA

b Medtronic Cardiopulmonary/Biomedicus, Anaheim, CA

c Cardiopulmonary Division, C.P. Bard, Inc., Tewksbury, MA

priming of the circuit. If the CSV is placed incorrectly, there will be no forward flow of the prime solution. This would be noted by the perfusionist long before bypass is attempted.

The CSV is cleared of air by tapping it with a clamp. The tubing is secured to the CSV with tie bands, and the valve is placed in the vertical holder (see Figure 2). Once the circuit is free of air, the centrifugal pump is calibrated to zero, the venous and arterial lines are clamped, and the table lines are divided. The position of the arterial line clamp is distal to the oxygen saturation device and proximal to the arterial pressure monitor.

The patient is anticoagulated with intravenous heparin at 3 mg/kg. The aortic cannula^d is connected to the arterial line and the surgeon ensures

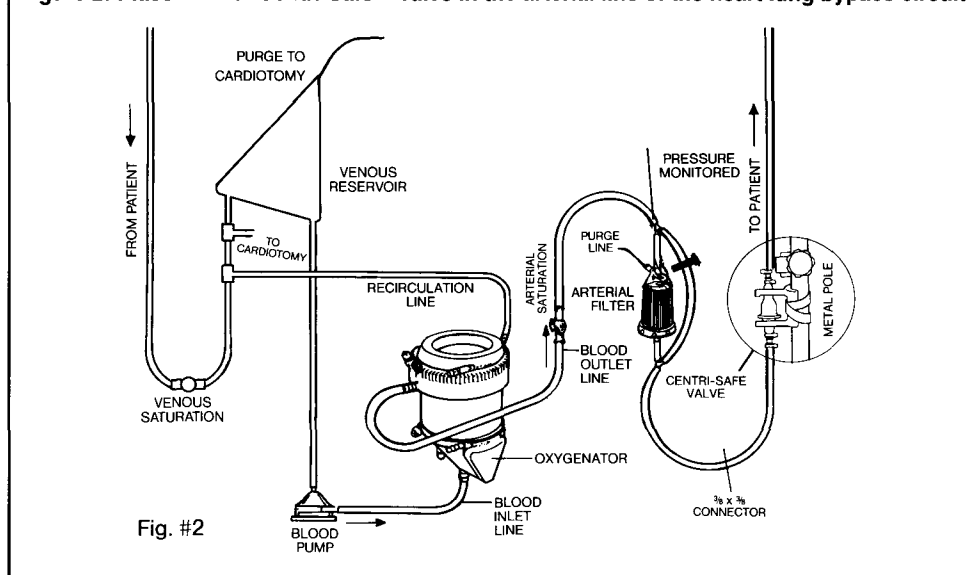
that there are no air bubbles. Because the CSV is a one-way valve and located distal to the arterial line pressure monitor, in order to determine the patient's aortic blood pressure, the CSV is removed from its holder and inverted to dislodge the ball and measure the pressure. This moves the ball from its closed sitting position to the open position and allows direct monitoring of the central aortic blood pressure. The central aortic pressure can be compared with the radial/femoral arterial line pressures. The valve is returned to its holder in the vertical position. After the venous cannula is placed and the sweep rate and FIO₂ are set, bypass is initiated, and blood flow is increased to reach the desired outputs. When the surgeon requests a low flow, such as when the aorta is cross clamped, having the CSV in-line allows the perfusionist to decrease flows directly with the biopump control knob without worrying if flows/RPM are too low to create retrograde flow in the arterial line.

To wean a patient from bypass, the venous line is partially clamped. When the patient's filling pressures are hemodynamically adequate, the arterial centrifugal pump flow is gradually decreased. When the venous line is totally clamped and there is no forward flow through the biohead, bypass is terminated. The biohead is switched into the *off* position to prevent any possibility of accidental forward flow and emptying of the venous bag. To empty the bypass circuit, and particularly the arterial line, after decannulation the CSV is made incompetent by gently squeezing the base of the housing section with a tubing clamp.

RESULTS

Since the Food and Drug Administration allowed marketing of the CSV in July 1993, we have used the valve for more than 400 open heart surgery cases utilizing centrifugal pumps. In

Figure 2: Placement of Centri-Safe™ valve in the arterial line of the heart lung bypass circuit



the initial 250 patients, while the perfusionists acquired more experience with the use of the device, we were coming off CPB still clamping the arterial line.

More recently, more than 150 patients have been weaned from CPB without clamping the arterial line. This method has allowed the perfusionists to be more relaxed and to direct their attention to other parameters required for bypass weaning, such as hemodynamics, blood flows, and the venous bag levels. No patient has experienced any complication from retrograde flow or from air entrapment in the arterial cannula.

DISCUSSION

There have been several documented cases of malfunctions or failures of centrifugal pumps that may have led to the death or disability of patients (2). Although in the majority of cases no mortality occurred, these events had the potential to allow retrograde flow, which predisposes the patient to air embolism. The CSV adds a minimal resistance to the forward flow and does not interfere with the hematologic values of circuits where the valve has been positioned for the prevention of retrograde flow and the introduction of air. Once the device is in-line, and positioned as indicated, it should not require a bypass loop. Bypass loops would again require clamping and needlessly complicate the circuit.

Another issue is potential device misplacement; however, perfusionists would be aware of this problem long before CPB is initiated. During the priming of the bypass circuit, if the valve is in-line backwards, there would be no forward flow.

d DLP, Medtronic Cardiopulmonary, Grand Rapids, MI

Measurements of blood pressure from the aortic cannula are not possible unless the valve is inverted and made incompetent or if the transducer is placed distally to the valve. We currently incorporate the CSV in the arterial line of the bypass machine in all open heart surgery cases. Because this device is indicated for use only in anticoagulated blood, there are no thromboembolic concerns. Perfusionists wean patients off bypass only by decreasing RPM to decrease flows as indicated by the flow meter and without clamping or partially clamping the arterial line. When bypass is terminated, the centrifugal pump RPM is simply turned off and the valve effectively occludes the arterial line unidirectionally.

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