A Table Mounted Cardiopulmonary Bypass System for Pediatric Cardiac Surgery

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Systemic inflammatory response and hemodilution are prominent factors associated with cardiopulmonary bypass and result in increased morbidity and mortality in children. Miniaturized systems have evolved to decrease such effects and restrict use of blood products, especially in the neonatal population. We have developed a table mounted cardiopulmonary bypass system that allows closer proximity of the system to the patient with consequent decrease in priming volumes, hemodilution, and its associated effects, and contributes to development into an ideally bloodless surgical approach.

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Cardiopulmonary bypass (CPB) is well associated with the development of a systemic inflammatory response due to activation of inflammatory and immunologic mediators that results in multiple organ dysfunction and increased morbidity and mortality in children [1–2]. Hemodilution is another prominent side effect of CPB and, at higher degrees, leads to decreased oxygen-carrying capacity and concentration of major plasma proteins and coagulation factor. That is exacerbated in the neonatal population owing to decreased blood to prime volume ratio [3].

Miniaturized systems have progressively evolved in the last 20 years, aiming mainly for decreasing prime volumes [4, 5]. It has classically been accomplished by the use of smaller tubing and smaller components and by having the system in closer proximity to the patient. Following these same principles and maintaining safety in mind, the next logical step for us was to maximize proximity by transferring the whole system onto the operating room (OR) table.

Technique

We have conceived and developed a CPB support apparatus that allows the system to be assembled onto the OR table. This support apparatus is composed of a T-shaped mounting column on which the components of the CPB are assembled and an OR table mounting column to receive the CPB assembly. The CPB units on the T column are transferred from the base machine to the OR table by affixing the T column to the OR table column (a side rail–mounted vertical bar). It is on the patient's right side, between the surgeon and the ether screen frame. A cross bar under the table from the left side rail provides further support (Fig 1). The patient is positioned slightly past the CPB unit to be within the surgeon's range and accessible by the anesthesiologist (Fig 2). The sterile drape covering the machine is transparent to help the perfusionists with direct visualization of the circuit for monitoring and troubleshooting (Fig 3). A small fenestration on the drape adjacent to the CPB machine is created. The 1/8-inch

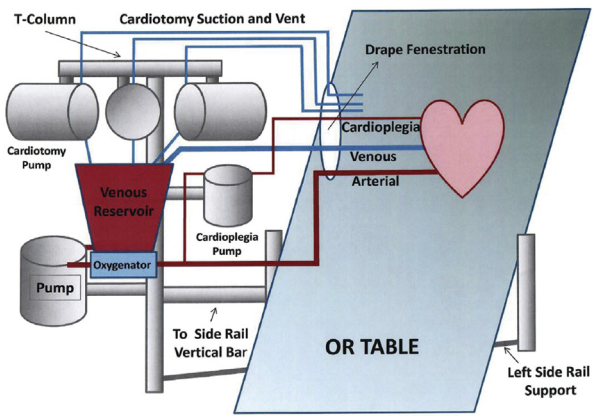

Fig 1. Table-mounted cardiopulmonary bypass setup schematic. (OR = operating room.)

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Fig 2. Assembled table-mounted cardiopulmonary bypass system.

arterial and 3/16-inch venous loop, cardioplegia, and cardiotomy suction tubings are passed through this opening in a sterile manner. The perfusionist connects the other ends to the CPB setup behind the sterile barrier. The fenestration is then sealed with a large adhesive dressing. The length of the arteriovenous loop before cutting is 68 inches. It is divided and trimmed further to make the tubing as short as possible.

This setup, in association with small neonatal CPB components (Sorin S5 roller pumps [Sorin, Milan, Italy] and Terumo Capiox FX05 oxygenator [Terumo, Tokyo, Japan]) and smaller tubing (1/8-inch arterial tubing and 3/16-inch venous tubing) in a specific configuration, significantly minimizes priming volumes to a total of 85 mL to 95 mL.

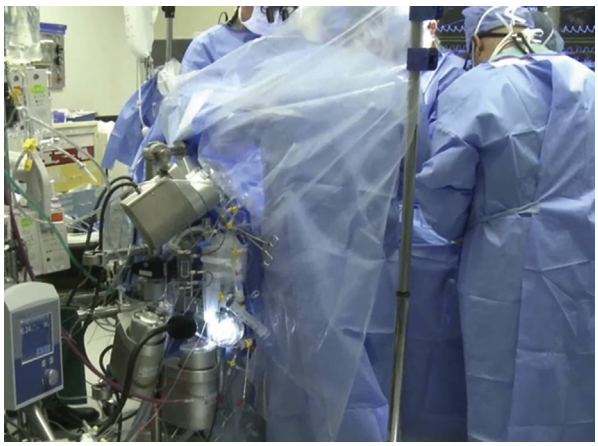

Fig 3. Perfusionist view of table-mounted cardiopulmonary bypass system during the operation.

Although it is crucial to keep the patient's hematocrit at an acceptable level, it is allowed to drift to the mid to low 20s in bloodless setup, especially during straightforward elective repairs. Cerebral oximetry, flow index, and lactate levels are closely monitored during the procedure, and blood is added if indicated. We perform modified ultrafiltration routinely at the conclusion of CPB to further raise the hematocrit level.

Comment

Miniaturized CBP systems are classically defined as having less than 200 mL priming volume systems. For the past 2 decades, the majority of the systems clinically in use require approximately 130 mL to 140 mL priming solution [5–8]. Most of them already make use of the smallest commercially available components and tubing. Therefore, shortening tubing length even further seems to be the next logical step for further reduction in priming volumes. That has to be weighted, however, against safety of the system as shorter lines can be easily stretched or disconnected, especially during table position adjustments throughout the operation.

By transferring the system onto the table, we maximize proximity to the patient but assure safety by not allowing line stressing. We also decrease priming volume to 85 mL to 95 mL, which becomes even less after tubing customization before initiation of cardiopulmonary bypass. Our system is designed for use in patients weighing less than 5 kg. We have now initial experience with a total of 4 cases. They included children weighing from 3.2 kg to 4.5 kg who were undergoing correction of atrial septal defects, ventricular septal defects, transposition of great arteries, and complete atrioventricular canal. They all had good surgical outcomes, and CPB was uneventful.

The use of blood products has been of note. One patient did not require transfusion at all, 2 required transfusion postoperatively only, and only 1 required a blood-primed circuit. Our standard hematocrit goal on pump remains more than 21% to 23%. However, lower levels might be temporarily tolerated in the absence of evidence of organ dysfunction by continuous close monitoring for an expected brief period. Adjunct techniques such as modified ultrafiltration and prebypass collection of fresh autologous blood for transfusion after termination of CPB are routinely used.

Some challenges are expected. Although we have not faced this situation, trouble shooting or exchanging components in a compact system may be more technically demanding than in regular systems. Whereas the use of a transparent sterile barrier is helpful, visibility of the system during the operation is decreased. We therefore stress the importance of a trained and engaged perfusion team (Fig 3).

We believe in the advantages of a bloodless approach to neonatal surgery. This work is only the first important and useful step toward the complete avoidance of blood products. Association of this system with preoperative optimization of hematocrit levels in elective cases may allow consistent and safe bloodless CBP in neonates in the near future.

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