2772-9931 https://doi.org/10.1016/j.atssr.2023.09.003

Aorta: How To Do It

Modified Circuit for Left-Sided Heart Bypass in Thoracoabdominal Surgery

Victoria Cook, MD, MS,[1] Andy Wang, MBBS, FANZCA,[2,3]
Stephen Llewellyn, MBBS, FANZCA,[2] Bruce Adendorff, FCA(SA), FANZCA,[2] and
Tristan Yan, PhD, FRACS[1,3]

Left-sided heart bypass may be run with a complete cardiopulmonary bypass circuit or a venoarterial extracorporeal membrane oxygenation circuit in thoracoabdominal surgery. Both configurations have specific disadvantages. We describe a modified circuit for left-sided heart bypass that can be run as an extracorporeal membrane oxygenation–like circuit, allowing lower activated clotting time targets and simplified perfusion while improving blood conservation and facilitating visceral perfusion.

(Ann Thorac Surg Short Reports 2024;2:21-24)

Left-sided heart bypass (LHB) is an accepted alternative to full cardiopulmonary bypass (CPB) for providing circulatory support for thoracoabdominal surgery. LHB can be run with a venoarterial extracorporeal membrane oxygenation (VA-ECMO) circuit or with a conventional CPB circuit. CPB circuits include a venous reservoir. In an ECMO circuit, inflow and outflow are continuous through a mechanical pump. VA-ECMO circuits allow lower activated clotting time (ACT) targets and simplify perfusion management compared with CPB. VA-ECMO circuits rely on cell salvage and cannot provide selective perfusion or be converted to full CPB. Anecdotally, most high-volume centers have developed alternative circuits to optimize perfusion in thoracoabdominal cases, but few are published.[1-5]

TECHNIQUE

The venous line is bifurcated by a Y-reducing connector ($^1/_2 \times {}^1/_2 \times {}^3/_8$ inch) before a soft-shell reservoir. The reservoir outflow line is also bifurcated by a Y-equal connector ($^3/_8 \times {}^3/_8 \times {}^3/_8$ inch). The Y connectors are joined by a short length of $^3/_8$-inch tubing to form a line we name the reservoir bypass line (Figures 1, 2).

The patient is systemically heparinized with an ACT target of 300 to 350 seconds. A venous cannula is placed in the left superior pulmonary vein and an arterial cannula in the left common femoral artery. LHB is commenced in the VA-ECMO configuration. The reservoir inflow and outflow lines are clamped, and venous drainage continues directly to the centrifugal pump through the reservoir bypass line (Figure 1). The centrifugal pump directs flow through the membrane oxygenator/heat exchanger and arterial line filter and back to the patient through the left femoral return cannula.

A hard-shell reservoir is connected to suction and vent lines through roller pumps. The cardiotomy reservoir drains into the venous reservoir as usual. To return cardiotomy blood to the circuit in the VA-ECMO configuration, the clamp on the reservoir outflow line is removed and placed partially on the reservoir bypass line (Video). To remove blood from the circuit, the venous line inflow clamp is removed and the reservoir bypass line is fully or partially clamped to divert blood to the venous reservoir.

Visceral perfusion lines are available using the additional roller pumps, and arterial blood may be diverted for cold blood cardioplegia after the membrane oxygenator (Figures 1, 2). If conversion to full CPB is required, the venous reservoir is incorporated by removing the venous inflow and outflow clamps and placing a clamp on the reservoir bypass line (Figure 2).

Accepted for publication Sep 5, 2023.

[1]Department of Cardiothoracic Surgery, Royal Prince Alfred Hospital, Sydney, New South Wales, Australia; [2]Department of Anaesthetics, Royal Prince Alfred Hospital, Sydney, New South Wales, Australia; and [3]Sydney Medical School, Faculty of Medicine & Health, University of Sydney, Sydney, New South Wales, Australia

Address correspondence to Dr Cook, Department of Cardiothoracic Surgery, Royal Prince Alfred, 50 Missenden Rd, Camperdown, NSW 2050, Australia; email: victoria.w.cook@gmail.com.

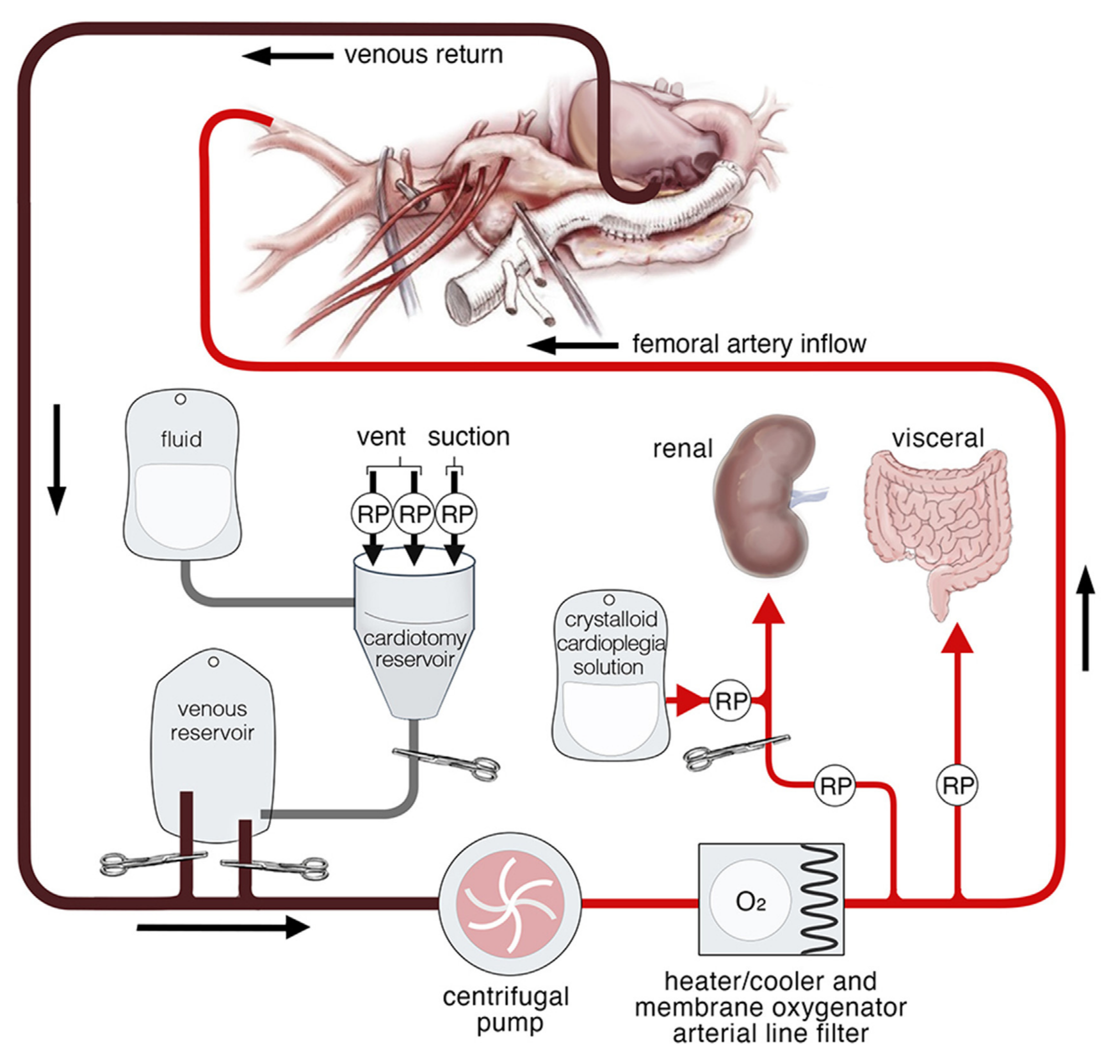

FIGURE 1 Modified cardiopulmonary bypass circuit in the extracorporeal membrane oxygenation–like configuration. Reservoir is isolated from circuit by 2 line-clamps at the venous reservoir inflow and outflow. Venous drainage flows directly onward to the centrifugal pump. During venoarterial extracorporeal membrane oxygenation mode, volume from the reservoir may be added to the circuit by temporarily removing the reservoir outflow clamp. (RP, roller pump.)

COMMENT

The modified circuit offers the functionality of a CPB circuit with the ability to isolate the venous reservoir to run an ECMO-like circuit. Matte and coworkers described[4] a hybrid LHB system that also uses a reservoir bypass line, referred to as a shunt.

Thoracoabdominal surgery is characterized by massive blood loss exacerbated by high-dose systemic heparinization required for CPB (ACT >480 seconds). VA-ECMO circuits target a lower ACT (180-220 seconds). The modified circuit uses a soft-shell reservoir and a heparin-bonded circuit. Addition of the cardiotomy reservoir introduces an air-fluid level, and therefore we target an ACT of 300 to 350 seconds.[6] Huang and colleagues[2] target a lower ACT of >280 seconds using cardiotomy suction. Ertugay and coworkers[1] target an ACT of >300 seconds increased to >400 seconds if a membrane oxygenator is incorporated. Heparin-bonded complete CPB circuits have been run with an ACT target of 250 seconds.[6,7] If a reduced ACT is targeted, vigilance for the presence of clot is important. ACT targets should be guided by local protocols.

Complete CPB incorporates cardiotomy suction to retrieve whole blood from the operative field. VA-ECMO circuits rely on cell salvage systems and rapid infusers. During thoracoabdominal surgery, the entire blood volume may cycle through blood recovery systems several

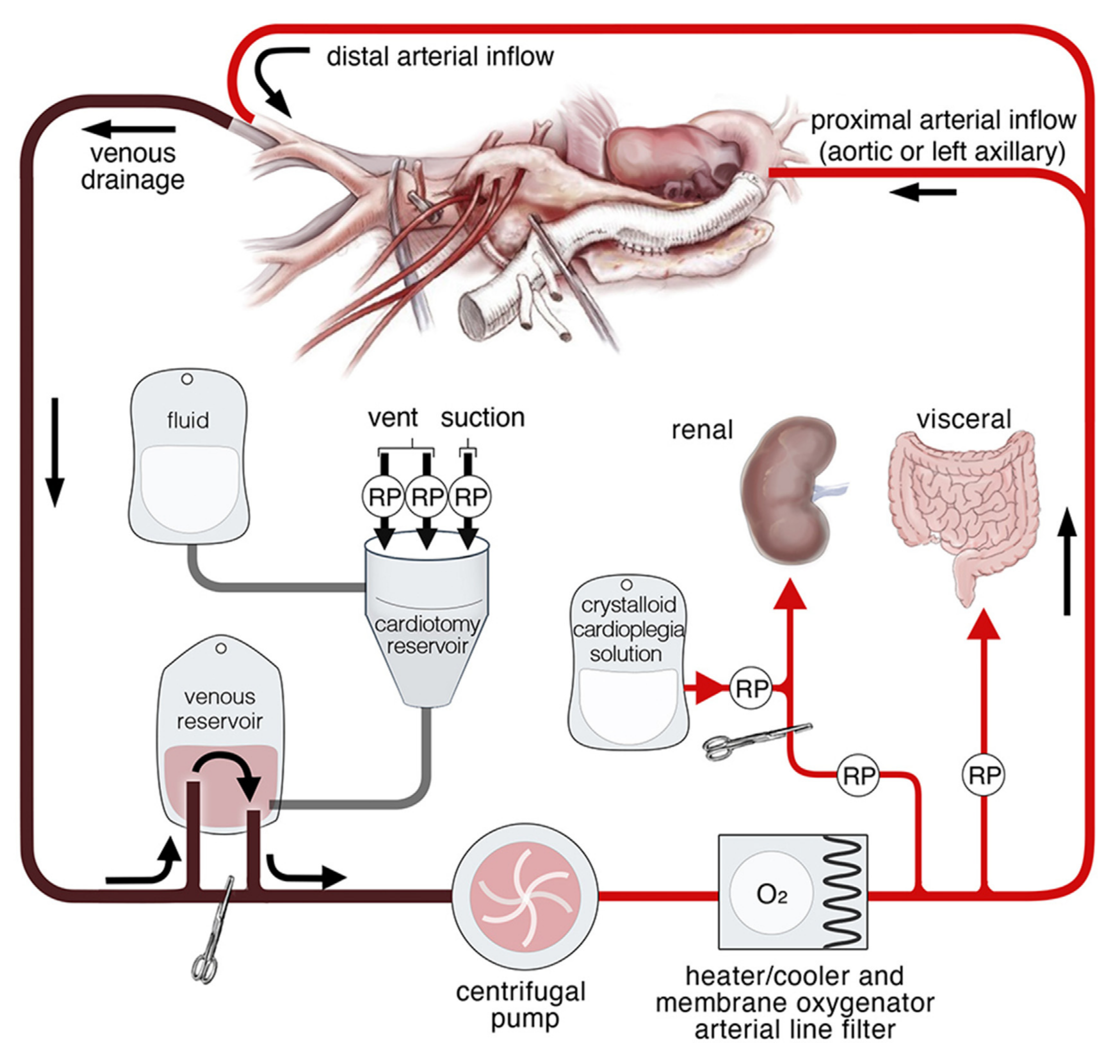

FIGURE 2 Modified cardiopulmonary bypass circuit in full cardiopulmonary bypass configuration. Inflow and outflow clamps are removed, and a clamp is replaced across the reservoir bypass line. Venous drainage is diverted into the venous reservoir. For full conversion to cardiopulmonary bypass, the surgeon places a long venous cannula for right atrial drainage and a proximal arterial inflow (aortic or axillary). (RP, roller pump.)

times (>40 L). High-volume cell salvage contributes to coagulopathy and increased mortality.[8] Modified circuits are described that incorporate in-field suction but rely on a rapid infusion system to return shed blood.[1,2] In the event of major bleeding, the difference in rapidity of volume resuscitation between cardiotomy suction, cell salvage, and rapid infusers may be critical.[2]

LHB is laborious to manage with a CPB circuit because of volume shifts associated with the presence of a reservoir. Isolating the reservoir means that inflow and outflow are matched. No intervention is required except during periods of significant blood loss, aortic clamping, or temperature change. The venous reservoir allows volume to be added or removed to alter systemic perfusion pressures (Video). This may contribute to smoother hemodynamics.[1]

Crawford extent II and III thoracoabdominal aortic aneurysm repairs are often complemented with selective visceral perfusion. This is not possible in a VA-ECMO circuit without modification.[5] In our system, multiple roller pumps are available (Figures 1, 2). The advantages of optimized LHB circuits are of most consequence in more extensive repairs characterized by longer operation times, higher volume blood loss, and increased risk of malperfusion.[2,5]

The ability to convert to CPB is an important functional aspect of a modified circuit.[3] LHB may not be tolerated or the operative strategy may change. A VA-

Ann Thorac Surg Short Reports
2024;2:21-24

ECMO circuit cannot be converted to CPB. Our system allows the reservoir to be reintroduced without requiring line division. Huang and colleagues[2] include "reserve" components for transition to CPB; however, this involves multiple steps and may be difficult to perform in an emergency.

Replication of this system is associated with a learning curve for perfusionists, in particular the maneuvers to include or to isolate the reservoir. As the venous reservoir can be empty, air entrainment is a greater risk than in traditional CPB.

The Video can be viewed in the online version of this article [https://doi.org/10.1016/j.atssr.2023.09.003] on http://www.annalsthoracicsurgery.org.

FUNDING SOURCES

The authors have no funding sources to disclose.

DISCLOSURES

The authors have no conflicts of interest to disclose.

REFERENCES

1. Ertugay S, Apaydin AZ, Karaca S, Ergi DG, Posacioglu H. Distal perfusion with modified centrifugal pump circuit in thoracic and thoracoabdominal aortic aneurysm repair. *Vasc Endovascular Surg*. 2022;56:737-742.
2. Huang L, Chen X, Hu Q, et al. The application of modular multifunctional left heart bypass circuit system integrated with ultrafiltration in thoracoabdominal aortic aneurysm repair. *Front Cardiovasc Med*. 2022;9:944287.
3. Bisleri G, Tisi G, Negri A, et al. The BICIRCUIT system: innovative perfusional options for surgical treatment of the thoracic aorta. *Ann Thorac Surg*. 2005;79:678-680 [discussion: 680-681].
4. Matte GS, Regan WL, Connor KR, Daaboul DG, Hoganson DM, Quinonez LG. Hybrid left heart bypass circuit for repair of the descending aorta in an 8-kg Williams syndrome patient. *J Extra Corpor Technol*. 2021;53:186-192.
5. LeMaire SA, Jones MM, Conklin LD, et al. Randomized comparison of cold blood and cold crystalloid renal perfusion for renal protection during thoracoabdominal aortic aneurysm repair. *J Vasc Surg*. 2009;49:11-19.
6. Wahba A, Milojevic M, Boer C, et al. 2019 EACTS/EACTA/EBCP guidelines on cardiopulmonary bypass in adult cardiac surgery. *Eur J Cardiothorac Surg*. 2020;57:210-251.
7. Øvrum E, Tangen G, Tølløfsrud S, et al. Heparinized cardiopulmonary bypass circuits and low systemic anticoagulation: an analysis of nearly 6000 patients undergoing coronary artery bypass grafting. *J Thorac Cardiovasc Surg*. 2011;141:1145-1149.
8. Kiser KA, Tanaka A, Sandhu HK, et al. Extensive cell salvage and postoperative outcomes following thoracoabdominal and descending aortic repair. *J Thorac Cardiovasc Surg*. 2022;163:914-921.e1.