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Case Report

Effectiveness of a Cardiopulmonary Bypass Circuit with Parallel Centrifugal and Roller Pumps in an Accidental Centrifugal Pump Stoppage — secondary publication (complete translation) —

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Abstract

At our institution, a pre-connected cardiopulmonary bypass circuit was designed to ensure operational convenience and safety by connecting the centrifugal and roller pumps in parallel, allowing selective use. During surgery for acute aortic dissection (Stanford type A) in a man in his 50s, the centrifugal pump (CP5) suddenly stopped when its control panel blacked out. The incident was promptly reported to the surgical field, the centrifugal pump outlet was clamped, and perfusion was switched to the roller pump. The interruption of perfusion lasted approximately 7-8 seconds.

Because arterial pump cessation is a critical event requiring rapid and sound judgment, a pre-established parallel circuit proved effective in minimizing perfusion interruption and ensuring patient safety. Although the exact cause of pump stoppage was not identified, this case highlights the importance of circuit design and preparedness for prompt response to unexpected pump failure.

Key words : pre-connect circuit, accidental stoppage, centrifugal pump, roller pump, parallel circuit

Ⅰ. Introduction

According to the *Questionnaire Survey on Incidents, Accidents, and Safety Concerning Cardiopulmonary Bypass (CPB) and Circulatory Support 2021* (hereinafter "CPB Questionnaire 2021"), arterial pump failure resulting in perfusion interruption was reported in 15 of 78,397 cases (0.02%) [1]. Among these, eight cases were classified as incidents (levels 1-3a), indicating that arterial pump stoppage constitutes a serious event that requires a prompt and well-judged response.

Takai et al. reported that all facilities that had experienced arterial pump stoppages caused by mechanical errors — such as roller pump body failure or centrifugal pump drive motor malfunction — had conducted regular inspections. This finding highlights that while such inspections are essential, they do not necessarily guarantee complete prevention of accidents [2]. Therefore, the importance of backup devices, such as hand cranks, has been emphasized.

At our institution, we previously experienced arterial pump stoppage while using the HL30 perfu-

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sion system (Getinge AB, Gothenburg, Sweden), during which CPB was maintained by operating a hand crank. Based on that experience, our current pre-connected circuit incorporates both a centrifugal pump and a roller pump arranged in parallel, enabling selective use to prepare for potential pump stoppage.

Subsequently, while using the S5 heart-lung machine (LivaNova PLC, Munich, Germany), we again experienced centrifugal pump stoppage. Owing to the use of the parallel circuit, the roller pump functioned as an effective backup, allowing a prompt response. We herein report this case.

Ⅱ. Materials and Methods

1. Equipment used

Our institution uses the S5® extracorporeal circulation system and the CP5 centrifugal pump system (LivaNova PLC, Munich, Germany). The circuits include the Ise Red Cross Hospital customized pre-connected circuit and the selective cerebral perfusion (SCP) circuit, both manufactured by Senko Medical Instrument Mfg. Co., Ltd. (Tokyo, Japan). A schematic of the extracorporeal circulation system is shown in **Fig. 1**, and the equipment used is listed in **Table 1**.

2. Circuit characteristics

The arterial line is divided at both the inlet and outlet of the centrifugal pump using Y-connectors and shunted with 3/8-inch tubing, allowing it to function as a roller pump head. To prevent circuit twisting, a swivel connector is installed between the centrifugal pump outlet and the Y-connector. The priming volume is approximately 80 mL on the cen-

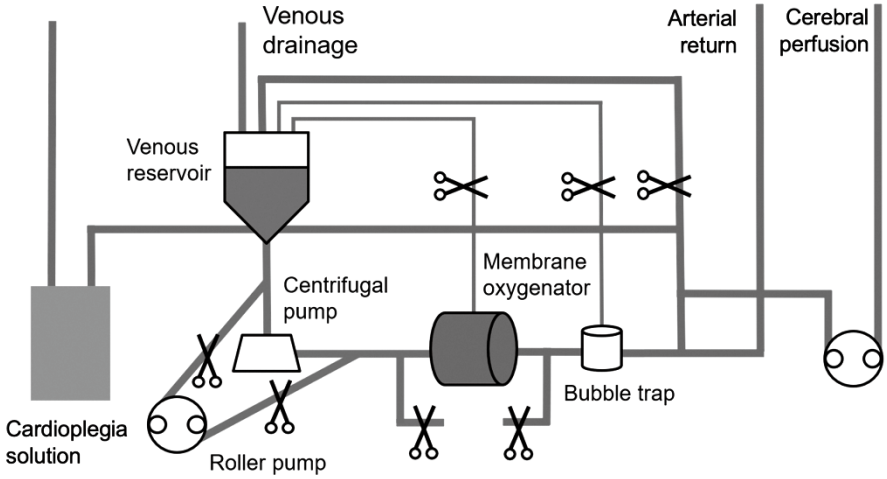

Fig. 1 Schematic diagram of the CPB circuit

Table 1 Equipment used

Equipment	Model / Type	Manufacturer
CPB system	S5®	LivaNova
Centrifugal pump system	CP5	LivaNova
CPB circuit	Ise Red Cross customized circuit	Senko
SCP circuit	Ise Red Cross SCP circuit	Senko
Centrifugal pump	Revolution®	LivaNova
Venous reservoir	HPO-23RHF-CP	Senko
Membrane oxygenator	HPO-23RHF-CP	Senko
Bubble trap	HBT-L1	Senko

trifugal pump side and 100 mL on the roller pump side. Both pumps are always set up and primed in advance, enabling selective use (**Fig. 2**).

The centrifugal pump serves as the main pump for extracorporeal circulation. The roller pump is used as needed — for example, at the initiation or termination of CPB, or during blood salvage — because it allows more precise flow control at low flow rates.

Switching from the centrifugal to the roller pump during pump stoppage is completed by releasing the clamps placed on the roller pump inlet and outlet, and then reapplying one of them to the outlet of the centrifugal pump.

A bubble trap (HBT-L1; Senko Medical Instrument Mfg. Co., Ltd., Tokyo, Japan) is installed as the final filter, with a swivel connector placed between the membrane oxygenator and the bubble trap to prevent twisting. To allow connection of additional myocardial protection or SCP circuits, three 1/4-inch branch lines were custom-made on the recirculation line of the Ise Red Cross Hospital customized circuit, each fitted with a 1/4-inch connector and capped at the end. The total priming volume, excluding the SCP circuit, was approximately 1,200 mL.

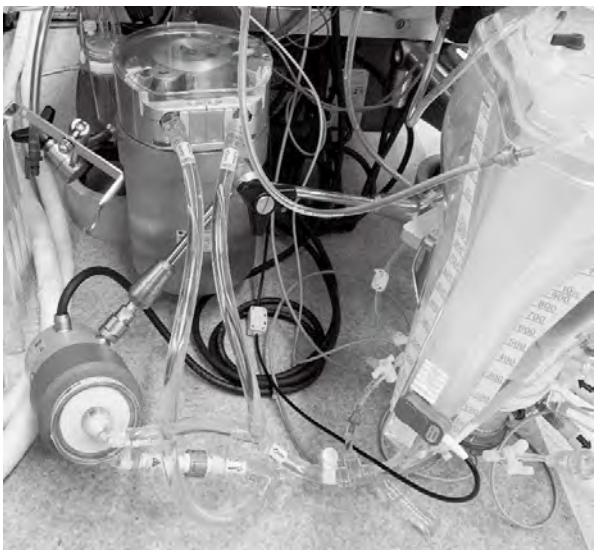

Fig. 2 Connection of the custom-made circuits to the S5® heart-lung machine
(LivaNova PLC, Munich, Germany)

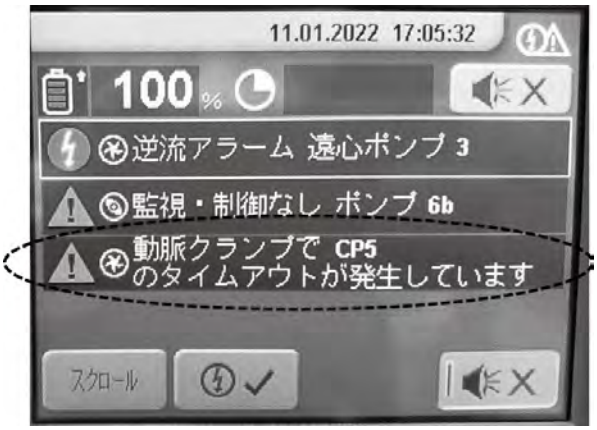

Fig. 3 Warning message (circled): "Timeout on CP5 with arterial clamp."
(Other alarms displayed on the monitor are unrelated.)

Ⅲ. Case Presentation

1. Patient background

The patient was a man in his late 50s, 165 cm tall and weighing 81.6 kg, with a body surface area (BSA) of 1.89 m^2. He was transported to our hospital by ambulance following the sudden onset of epigastric pain at home. Emergency surgery was performed under the diagnosis of acute aortic dissection (Stanford type A). The operative procedure was ascending aortic replacement.

2. Clinical course

CPB was initiated with right atrial drainage and femoral artery perfusion. After stable flow was achieved, cooling was initiated to reach a target pharyngeal temperature of 25 ℃ as the core temperature. Thirty minutes after the initiation of CPB, and before aortic cross-clamping, an alarm reading "Timeout on CP5 with arterial clamp" appeared, immediately followed by blackout of the centrifugal pump control panel and cessation of the pump (**Fig. 3**).

While the event was being reported to the surgical field, the clamps on the roller pump inlet and outlet were released, and the centrifugal pump outlet was clamped. After the arterial line clamp was released, perfusion was switched to the roller pump. The interruption of perfusion lasted 7-8 seconds. At that time, the core temperature was approximately 30 ℃. Although the CP5 system recovered after reboot, the roller pump was used for the remainder of the operation.

Ⅳ. Discussion

1. Cause of centrifugal pump stoppage

According to the *Handbook of Safety in CPB* (2nd edition) [3], possible causes of centrifugal pump stoppage include: (1) power failure; (2) accidental operation of a control switch; (3) detachment of the pump head; (4) poor magnetic coupling between the pump head and motor; (5) pump head damage; (6) cable disconnection or poor contact; (7) control system malfunction; (8) controller malfunction; and (9) other failures [3].

In the present case, analysis of the serial readout sent to the manufacturer revealed that the control panel had lost its CAN connection and power supply, leaving no error codes saved. Based on the warning message (**Fig. 3**), a control system error was suspected — specifically, either cause (7) or (8). The manufacturer subsequently replaced the CPU board and, after a long-duration test run, confirmed normal operation. The unit was then returned to our hospital.

2. Effectiveness of the parallel circuit and safety measures

In the *CPB Questionnaire 2021*, reported responses to arterial pump stoppage included the following: (1) exchange for a backup pump, 3 cases; (2) replacement of tubing or the centrifugal pump head during the preparation stage, 3 cases; (3) replacement of tubing or the centrifugal pump head during CPB, 3 cases; (4) restart of the arterial pump or CPB system, 1 case; (5) release or replacement of a safety device, 1 case; and (6) other measures, 5 cases [1]. Option (7), switching from a centrifugal to a roller pump (or vice versa), as performed in this case, was also listed but no cases were reported.

For emergency situations, all manufacturers equip hand cranks as standard backup devices. Takai et al. reported that manual operation was occasionally required, and thus each facility should consider the preparedness and maintenance of hand cranks and other backup devices [2]. Kobayashi et al. noted that depending on the model, circuit extension may be necessary; the crank itself is large and heavy, and considerable force is required to maintain rotation, which may make continuous operation difficult for some staff members [4]. They have pointed out the importance of thoroughly understanding device characteristics, including circuit layout, and conducting training that simulates actual trouble scenarios.

At our institution, hand cranks are kept near the CPB system, and regular training is conducted to master their operation in anticipation of various potential malfunctions. In this particular case, because our team had been well trained in the response method (7) — switching from the centrifugal to the roller pump (or vice versa) — we were able to respond promptly without using the hand crank. The interruption of perfusion lasted 7-8 seconds at a core temperature of approximately 30 ℃; therefore, no special measures were required to prevent cerebral ischemia. However, because irreversible brain injury may occur after approximately 3-5 minutes of cerebral blood flow arrest at a body temperature of 36 ℃ [5], rapid response is crucial when dealing with arterial pump stoppage. Although the CPB Questionnaire 2021 provides no data on the duration of stoppage caused by pump failure, switching from a centrifugal to a roller pump can be accomplished rapidly. This approach is therefore considered effective in minimizing perfusion interruption and ensuring patient safety.

Even with technical countermeasures in place, maintaining composure in tense situations can be difficult. To foster a shared sense of crisis and ensure psychological safety, we conduct multidisciplinary simulation training involving clinical engineers, surgeons, anesthesiologists, and nurses. Furthermore, based on our previous experience with the HL30, in which the arterial pump stopped and CPB was maintained manually using a hand crank, we developed an emergency procedure card (**Fig. 4**) to facilitate calm and organized responses during emergencies. This experience reaffirmed that equipment failure is inevitable, emphasizing the need for continuous training and thorough preparation for all possible contingencies

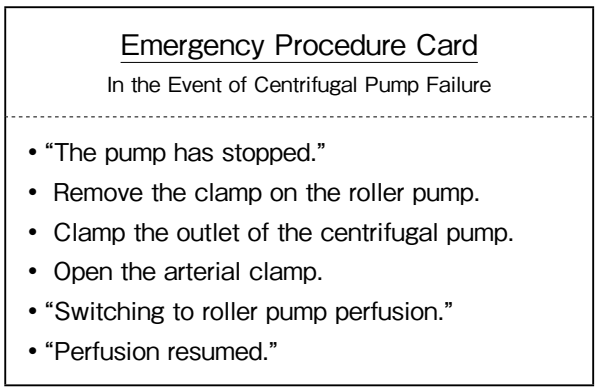

Fig. 4　Emergency procedure card for centrifugal pump failure
(originally written in Japanese and translated into English for this article)

Conclusion

We reported a case in which the roller pump connected in parallel functioned effectively as a backup during centrifugal pump stoppage, enabling a rapid and appropriate response. Parallel connection of arterial pumps offers both operational convenience and improved safety. Further refinement of circuit design and ongoing training are essential to enhance patient safety.

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