

Rupture of Extra-Corporeal Circuit Tubing During Cardiopulmonary Bypass

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Abstract: Roller pumps are widely used for cardiopulmonary bypass in developing nations by virtue of proven safety during several years of institutional use and cost effectiveness. However, careful adjustment of roller occlusion is needed because they are known to cause spallation, tubing wear, and the occasional incident of rupture of tubing in the extracorporeal circuit. Rupture of polyvinylchloride tubing in the pump raceway during repair of a ventricular septal defect in a 4-year-old child is discussed. The event was managed by exclusion and replacement of the defective tubing during a short period of arrest. Use of an inappropriate boot pump and failure to detect its inclusion in the

bypass circuit was a significant departure from protocol. However, because occlusion settings and duration of perfusion were within acceptable limits, a manufacturing flaw could also have contributed to tubing failure, and the event may or may not have been averted by the use of larger tubing. In conclusion, this incident reiterates the need for adherence to established protocol during assembly of the pump and draws attention to the fact that tubing integrity is not a guarantee and vigilance is warranted to handle its failure. **Keywords:** cardiopulmonary bypass complications, cardiopulmonary bypass equipment, circulatory arrest, perfusion, spallation, tubing rupture. *JECT. 2007;40:74-76*

A 4-year-old male child with a large inlet ventricular septal defect (VSD) and severe pulmonary artery hypertension was scheduled for elective surgical repair. He weighed 11 kg, and had a body surface area of 0.5 m². The extracorporeal circuit (ECC) was assembled using a Capiiox Sx 10 oxygenator (Terumo, Ann Arbor, MI) with a Sarns 8000 series modular perfusion system (3M, Ann Arbor, MI). The arterial roller pump was auto-calibrated for a pump boot of 1/4 × 1/16-in. polyvinyl chloride (PVC) tubing and an occlusion setting adjusted to allow a fall of 1 cm/min in a 60-cm length of prime. PVC tubing (1/4 × 3/8 in.) was connected to the arterial and venous ports of the reservoir. Cardiopulmonary bypass (CPB) was established at 37°C with full flow rates of 1500 mL/min (136 mL/kg/min). The core temperature was reduced to 32°C, and cardioplegia was delivered. Flows were maintained at 1200 mL/min as a standard right atriotomy was made. Transatrial continuous suture repair of the VSD was begun, and

the antero-superior suture line was completed. A second dose of cardioplegia was administered, rewarming was started, and repair of the defect was resumed.

During the phase of rewarming, slow leakage of blood from the arterial pump raceway was noted at a core temperature of 34°C (Figure 1). The degree of leakage was increasing in proportion to the flow rate. There was no antecedent increase in the arterial line pressure, and a 30-mmHg fall occurred after the event. On closer inspection, blood was seen to leak from the PVC tubing beyond the point of maximum occlusion (Figure 1, inset). No macroscopic air was sucked into the circuit. An emergency plan to induce temporary circulatory arrest, exclude the ruptured tubing, and re-establish circulation through an adjacent module was formulated.

Low flows were maintained by reducing the core temperature to 26°C. Intravenous thiopentone sodium and methyl prednisolone were administered and ice packs were placed around the head of the child to ensure cerebral protection. Replacement tubing with appropriate connectors was passed through an adjacent module, which was re-calibrated, and the occlusion settings were readjusted. At this juncture, flows were further reduced, and temporary circulatory arrest was induced (Figure 2). The ruptured tubing was divided between clamps at the venous

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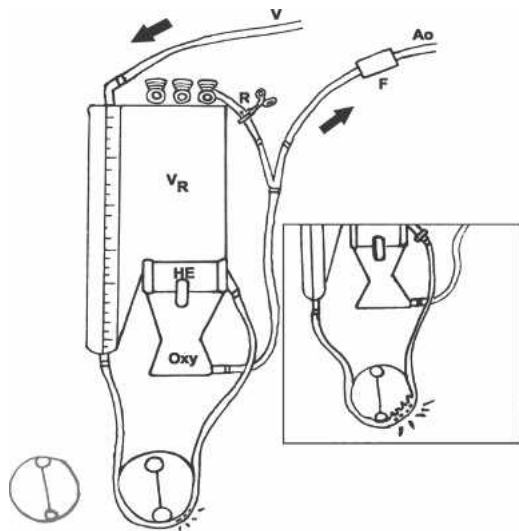


Figure 1. Schematic depiction of the dehiscent tubing within the arterial roller pump housing. Inset, Site of rupture.

outlet and oxygenator inlet ports and excluded from the circuit. Replacement tubing was connected to the respective ports (Figure 2, inset), the new circuit was de-aired through the recirculation line, and clamps on the patient side were removed to re-establish circulation. The surgical procedure was continued during this brief period, and the child was weaned off CPB in a stable hemodynamic condition. The CPB and aortic clamp times were 76 and 39 minutes, respectively. Circulatory arrest time was 1.5 minutes. Low flows were maintained through the ruptured

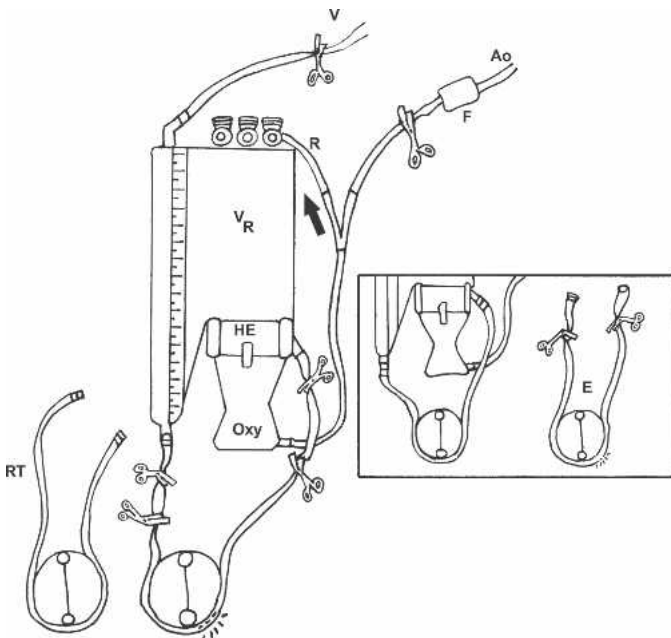


Figure 2. Schematic depiction of the arrested extra-corporeal circulation and passage of replacement tubing (RT) through an adjacent pump head. Inset, Replacement tubing in place with exclusion of the damaged tubing and the roller pump (E). Arrows, direction of blood flow; V, venous line; V_R, venous reservoir; HE, heat exchanger; Oxy, membrane oxygenator; F, arterial line filter; R, recirculation line; Ao, arterial line.

tubing during the 12 minutes that were required to establish the alternative circuit. There were no neurologic sequelae, and the child made an uneventful recovery.

A partial dehiscence of the tubing on the positive side of the roller pump raceway at the point of maximum occlusion was noted.

DISCUSSION

Fracture of the tubing used in the ECC is a known complication of roller pumps (1). PVC tubing is most widely used during CPB because of its durability and acceptable rates of hemolysis (2,3). However it does have a tendency to induce spallation and stiffen during hypothermia (1). Although not fully understood, factors that influence tubing life include occlusion settings, speed of revolution, pressure, and temperature (4). Failure of tubing in the raceway could occur because of the effects of both shear stress and compression mechanisms, as shown during experimental studies. Consequently, improvements in pump design to reduce shear stress and use of under-occlusion to reduce compressive forces is thought to improve durability of the tubing in situations requiring prolonged perfusion times as during clinical extra-corporeal membrane oxygenation (5).

The occlusion of PVC tubing of varying diameters to very high pressures in an experimental model of roller pump showed 5%–10% increase in their distensibility, suggesting that tubing rupture is unlikely to occur in clinical situations (6). However, other experimental studies of roller pump-induced tubing wear reveal invariable presence of spallation and wear on the luminal surfaces of both PVC and silicone tubing, irrespective of the degree of occlusion (7).

This incident occurred during the phase of rewarming as full flows were being restored. Although higher revolutions per minute were required to maintain target flows (Table 1), it is speculative to attribute the event entirely to an exaggerated shear stress on the 1/4-in. pump boot. Because the occlusion settings and duration of the perfusion were within acceptable limits, a manufacturing flaw could also have contributed to failure of the tubing.

Dehiscence of the tubing on the positive side of the raceway prevented air from being sucked into the circuit.

Table 1. Number of RPM required to maintain target flow rates at different core temperatures with boot pump of two different diameters.

Core Temperature	Flow		RPM According to Boot Pump Diameter	
	ml/min	ml/kg/min	¼ inch	⅜ inch
37°C	1500	136	120	60
34°C	1300	118	95	50
32°C	1200	109	85	45

An arterial line filter prevented the propagation of micro-emboli and the recirculation line was invaluable for de-airing the new circuit. Hypothermia enabled reduction of flow rates and control of volume loss from the ruptured tubing in addition to ensuring cerebral and myocardial protection.

Tubing failure has been extensively studied in experimental conditions (5–7), and this report refers to its occurrence during clinical CPB. Our perfusion protocol mandates a pre-bypass check of the tubing used in the ECC, and non-compliance led to failure to notice the inclusion of a 1/4-in. pump boot in lieu of a 3/8-in. pump boot. Although it might not be possible to predict whether a larger tubing could have prevented the event, need for strict compliance with protocol has been acknowledged by the perfusion team. An alert perfusionist, routine safety mechanisms deployed in the circuit, and an effective bail out procedure ensured uneventful recovery of the child from this unusual complication.

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