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Case Report

An Innovative Simple Technique of Blood Conservation in Adult Patients with Tetralogy of Fallot and Severely Raised Hemoglobin

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Abstract: The adult patients of tetralogy of Fallot often present with high hemoglobin levels. High hemoglobin and hematocrit on cardiopulmonary bypass (CPB) are associated with increased hemolysis, plasma free hemoglobin, renal dysfunction or failure, postoperative bleeding, exploration for bleeding, and increased requirement of allogeneic blood and blood products. Despite the presence of high hemoglobin and its association with adverse outcome, blood conservation is rarely practiced in these patients because of the fear of possible hemodynamic instability, and hypoxemic spell. We describe an innovative, simple technique of blood conservation for adult patients of tetralogy of Fallot with severely raised hemoglobin. With this technique, hemoglobin can be normalized on CPB; moreover, there is no fear of hypoxemic spell or hemodynamic instability. Furthermore, the blood conserved is readily available for transfusion in the perioperative period, if needed. **Keywords:** cardiopulmonary bypass, adult tetralogy of Fallot, blood conservation, cyanotic heart disease. *JECT. 2007;39:257–259*

Adult patients of tetralogy of Fallot (TOF) often present with high hemoglobin levels. High hemoglobin on cardiopulmonary bypass (CPB) is associated with increased hemolysis and plasma-free hemoglobin (1). Severe postoperative bleeding that necessitates reexploration is frequently reported in these patients (2–5). Postoperative bleeding, re-exploration for bleeding, and transfusion of allogeneic blood and blood products are the recognized risk factors associated with increased morbidity and mortality (6).

Various methods of autologous blood conservation such as acute normovolemic hemodilution (ANH), preoperative autologous blood donation (PBD), and blood retrieval immediately before CPB but after heparinization are effective in reducing hemoglobin on CPB (7). However, despite the presence of high hemoglobin and the association of high hemoglobin with adverse outcome, blood conservation in these patients is rarely practiced in our institute. Preoperative autologous blood donation is considered a medical contraindication in cyanotic patients (8). Logically, expected acute decrease in viscosity during ANH can increase right to left shunt, which may precipitate hemodynamic instability and hypoxemic spell. Moreover, the blood of these patients is usually deficient in platelets and coagulation factors (9).

We describe an innovative, simple technique of blood conservation for adult patients of TOF with severely raised hemoglobin. With this method, hemoglobin can be normalized on CPB; moreover, there is no fear of hypoxemic spell or hemodynamic instability. Furthermore, the blood conserved is readily available for transfusion in the immediate postbypass and postoperative periods, if needed.

DESCRIPTION OF TECHNIQUE

Three to 5 minutes after initiation of CPB, oxygenated blood is sequestrated in blood collection bags (without preservation solution) from the recirculation line (Figure 1) of the oxygenator to attain a target hemoglobin of ~10 g/dL on CPB. The quantity of blood to be withdrawn is estimated by the formula given in Figure 2. During blood collection, an equal amount of Ringer's lactate is slowly added to the venous reservoir for maintaining a safe perfusate level in the reservoir. After completion of the surgical procedure and rewarming, and separation of the pa-

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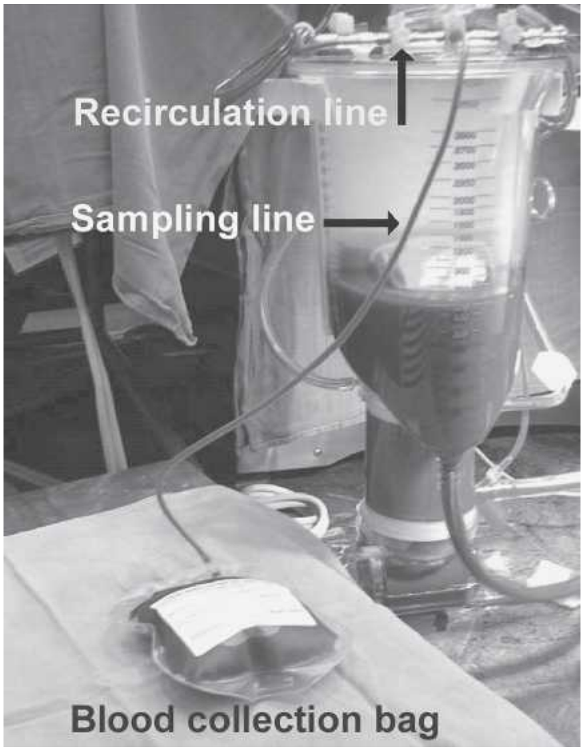

FIGURE 1. Show blood collection through the recirculation line of the oxygenator.

Total hemoglobin (gm) = Body weight (kg) x 75 x Measured Hb / 100;
(Blood volume = 75 ml / kg)

Desired total hemoglobin (gm) on CPB = 10 gm / dl x Blood volume + Prime volume

Amount of Hb (gm) that can be withdrawn = Total hemoglobin – Desired HB on CPB

Initial Hb (gm %) on CPB =
Total Hb X 100 / (Blood volume + Prime volume)

Blood volume (ml) that can be withdrawn =
Total Hb that can be withdrawn X 100 / Initial Hb on CPB

FIGURE 2. Calculation for the quantity of blood that can be withdrawn.

tient from CPB, anticoagulation is reversed with 4 mg/kg protamine. Thereafter, for maintaining intravascular volume in the postbypass and postoperative periods, retrieved blood is transfused. Additional protamine, 5 mg/100 mL of the sequestrated blood transfused, is administered to neutralize heparin present in the conserved blood.

CASE 1

A 24-year-old woman weighing 50 kg underwent intracardiac repair for TOF. Laboratory studies showed the following: hemoglobin, 23.6 g/dL; hematocrit, 71%; prothrombin time, 18 seconds; platelet count, 1.0×10^6/mL. Anesthesia induction and the prebypass period were uneventful. After anticoagulation with heparin 300 units/kg, standard hypothermic (26°C) CPB, was performed using a membrane oxygenator, 1500 mL crystalloid-priming solu-

Patients Hemoglobin 23.6 gm / dl; Weight of the patient 50 kg;
Blood volume = 3750 ml; Priming volume = 1250 ml

Total hemoglobin (gm) of the patient	= 50 X 75 X 23.6 / 100 = 885 gm
Desired total hemoglobin (gm) on CPB	= 10 gm / dl X (3750 + 1250) = 500 gm
Amount of Hb (gm) that can be withdrawn	= (885 – 500) = 385 gm
Initial Hb (gm %) on CPB	= 885 X 100 / 5000 = 17.7 gm%
Blood volume (ml) that can be withdrawn	**= 385 X 100 / 17.7 = 2175 ml**

FIGURE 3. Calculation for the quantity of blood that can be withdrawn for case 1.

tion, and non-pulsatile flow (1.5–2.4 L/min/m^2). Based on the formula described in the technique, three to 5 minutes after initiation of CPB, ~2000 mL (Figure 3) oxygenated blood was sequestrated in blood collection bags (without preservation solution) from the recirculation line of the oxygenator over 20 minutes. During blood collection, an equal amount of Ringer's lactate was slowly added to the venous reservoir. Measured hemoglobin on CPB after blood retrieval was 11.4 g/dL. The harvested blood was stored at room temperature (20–22°C) in the operating room. After completion of the surgical procedure and rewarming, epinephrine was started at 0.1 μg/kg/min, and the patient was separated from the CPB at a systolic arterial pressure of ~70 mmHg. Thereafter, anticoagulation was reversed with 4 mg/kg protamine. For maintaining intravascular volume in the postbypass and postoperative periods, sequestrated blood was transfused (overall, 1000 mL). Additional protamine, 5 mg/100 mL of the retrieved blood transfused, was administered to neutralize heparin present in the sequestrated blood. The remaining sequestrated blood was discarded, because the laboratory analysis after transfusion of 1000 mL blood showed 16 g% hemoglobin. Platelet count after transfusion of the sequestrated blood was 0.8×10^6/mL. After overnight ventilation, the patient's trachea was extubated. Postoperative chest drain until 8:00 AM of the first postoperative day (~17 hours after surgery) showed 270 mL of mediastinal blood loss. The laboratory studies showed 15 g/dL hemoglobin and 1.1 mg/dL serum creatinine. On the first postoperative day, the patient received 300 mL of fresh frozen plasma (FFP) for volume expansion. The patient was discharged on the 12th day postoperatively.

CASE 2

A 28-year-old man weighing 65 kg underwent intracardiac repair for TOF. Laboratory results showed the following: hemoglobin, 19.6 g/dL; hematocrit, 62%; prothrombin time, 18 seconds (normal prothrombin time for our laboratory is 12 seconds); platelet count, 1.6×10^6/mL. The anesthetic, CPB, postbypass, and postoperative managements were similar to the first patient. The quantity of blood sequestrated was ~2000 mL (Figure 4); hemoglobin on CPB measured 11 g/dL. After surgical repair, overall,

Patients Hemoglobin 19.6 gm / dl; Weight of the patient 65 kg;	
Blood volume = 4875 ml; Priming volume = 1250 ml	
Total hemoglobin (gm) of the patient	= 65 X 75 X 19.6 / 100 = 955.5 gm
Desired total hemoglobin (gm) on CPB	= 10 gm / dl X (4875 + 1250) = 612.50 gm
Amount of Hb (gm) that can be withdrawn	= (955.5 – 612.5) = 343 gm
Initial Hb (gm %) on CPB	= 955.5 X 100 / 6125 = 15.6 gm%
Blood volume (ml) that can be withdrawn	= 343 X 100 / 15.6 = **2198 ml**

FIGURE 4. Calculation for the quantity of blood that can be withdrawn for case 2.

1000 mL of the sequestrated blood was transfused in the postbypass and postoperative periods. Platelet counts after transfusion of the sequestrated blood was 1.0×10^6/mL. Similar to first case, the remaining sequestrated blood was discarded. Postoperative chest drain until 8:00 AM of the first postoperative day (~18 hours after surgery) showed 270 mL of drainage. The patient received only autologous blood on the day of surgery, and allogeneic blood products were not required. The laboratory studies on the first postoperative day showed 14 g/dL hemoglobin and 1 mg/dL serum creatinine. The patient was discharged on the 10th postoperative day.

DISCUSSION

In cardiac surgery, two methods are commonly used for blood conservation: prebypass ANH and transfusion of the collected blood after termination of CPB, and pharmacologic methods, such as the use of aprotinin and tranexamic acid to reduce postoperative blood loss. This method is similar to ANH, except for the fact that the sequestrated blood is exposed to extracorporeal circuit for a short time. With this method, the patient's postoperative blood loss and the requirement of allogeneic blood, FFP, and platelets was significantly less compared with our previous experience. Furthermore, there are several earlier studies that describe the need of re-exploration in these patients because of excessive postoperative blood loss (2–5).

In cyanotic patients with severely raised hemoglobin, apparently three mechanisms contribute toward increased postoperative bleeding: 1) an inherently weak hemostatic system; 2) loss of clotting factors and platelets because of exposure to non-endothelial foreign surfaces of the extracorporeal circuit (10); and 3) release of procoagulant phospholipids from damaged red cells and platelets caused by excessive use of cell salvage systems (11). Theoretically, release of phospholipids can initiate intravascular coagulopathy. The possible mechanisms that decrease postoperative blood loss with this method includes 1) decreased hemolysis secondary to decreased hemoglobin during CPB; 2) because the patients were separated from the CPB at a systolic arterial pressure of ~70 mmHg and at low filling pressures and for volume optimization instead of pump blood, the sequestrated blood was transfused, which is expected to be free of hemolysis; in other words, the absolute load of hemolyzed red cells in the circulating blood volume was less; and 3) replenishment of platelets and coagulation factors present in the sequestrated blood stored at room temperature. The measured platelet count in both patients was $>0.8 \times 10^6$/mL. Only 30% of clotting factors and $>0.5–1.0 \times 10^6$/mL functional platelets are needed to achieve surgical hemostasis. Perhaps the sequestrated blood on transfusion (1000 mL; nearly 20%–25% of expected blood volume for both the patients) replenished a significant amount of clotting factors and platelets and resulted in reduced postoperative blood loss.

To summarize, the described method effectively conserved blood and reduced the requirement of allogeneic blood and allogeneic blood products in two adult patients with TOF with severely raised hemoglobin. The method may be useful in patients with high hemoglobin where blood harvesting in the prebypass period is hazardous because of the possibility of hemodynamic instability, such as patients with severe coronary artery disease or aortic stenosis. However, a larger study is needed to confirm the efficacy of this method.

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