Case Report

Prebypass Pheresis and Red Blood Cell Exchange in a Patient with Homozygous SS Sickle Cell Disease Undergoing Cardiopulmonary Bypass: A Case Report

James M. Parrish, PhD, CCP*, Paul A. Page, BS, PA∞, David Cohen, MD*, Mark R. Nyreen, MD*, Charles P. Kingsley, MD+, Tara Chronister, MD+, Berry F. Shesol, MD∞, Richard Drew∞

*Department of Surgery, Cardiothoracic Surgery Service
+Department of Surgery, Anesthesia & Operative Service
Brooke Army Medical Center, Fort Sam Houston, Texas

∞Electromedics Medtronic, Inc. Parker, CO

Please note: The opinions or assertions contained herein are the private views of the authors and are not to be construed as reflecting the views of the Departments of the Army or Defense

Keywords: sickle cell disease, prebypass pheresis, cardiopulmonary bypass, homozygous sickle cell disease, red blood cell exchange

ABSTRACT

Sickle cell disease was first described by Herrick in 1910. This disease involves an abnormality of the hemoglobin molecule which, under certain conditions, causes the red cell to take on a sickle shape. This abnormal shape and hemoglobin prevent the red cell from performing the normal respiratory functions and interfere with the normal flow through the circulatory system. Individuals demonstrate either a homozygous (dominant) *SS* or a heterozygous *Ss* state. Clinical symptoms for patients with *SS* disease are most often characterized by recurrent painful crises, sequestration of sickled cells, chronic hemolytic anemia, systemic diseases, vaso-occlusive crises, permanent organ damage and recurrent infection. These patients usually require exchange transfusions due to the concern that the stress of surgery will precipitate a sickling crisis. Exchange transfusions require large amounts of homologous red blood cells (RBCs) to lower the percentage of the homozygous *SS* hemoglobin. The use of autologous pheresis in the perioperative period reduces the amount of homologous RBCs required and lowers the patient's exposure to homologous blood and its associated risks. This paper discusses the disease, the planning and the techniques for prebypass pheresis and red cell exchange in a patient with homozygous *SS* hemoglobin sickle cell disease undergoing cardiopulmonary bypass.

INTRODUCTION

Sickle cell disease is caused by adenine replacing thymidine in the codon of chromosome 11 that causes a substitution of valine for glutamic acid in the beta hemoglobin chain. (1,2) This results in a hemoglobin (hemoglobin S) that polymerizes, gels and irreversibly precipitates when exposed to hypoxemic conditions. Precipitation of hemoglobin causes deformation of the red cell membrane resulting in sludging and destruction of the sickled red cells. (3) Acidosis, hypothermia and increased viscosity in conjunction with low blood flow conditions, which prolong capillary transit time, may allow the development of hypoxemia which can promote sickling and sludging. (4,5)

The sickle cell disease follows Mendelian genetics, although the severity of gene expression varies among individuals. (6) Individuals with homozygous *SS* (Sickle Cell Disease) have a clinical course of chronic anemia, recurrent sickle crises and multi-organ system damage leading to organ failure and ultimately, premature death. All organ systems are affected by the vascular occlusion caused by aggregates of sickled red cells. Acidosis, hypoxemia, hypothermia and low peripheral blood flow leading to stasis, are the precipitating events leading to infarctive crises. (7) Cardiac surgery with hypothermic cardiopulmonary bypass poses a significant threat to patients with *SS* disease because the very conditions that precipitate sickling and infarctive crises are associated with the procedure.

In patients with the *"Ss"* combination, the disease is expressed as the sickle cell trait. Individuals with the recessive trait will usually only demonstrate the complications of sickle cell disease when exposed to stressful conditions. Individuals with the dominant situation, *"SS,"* will demonstrate these clinical problems even in the absence of any stressful conditions. This case report will discuss the disease, the planning and the techniques for prebypass pheresis and red cell exchange in a patient with homozygous *SS* hemoglobin sickle cell disease undergoing cardiopulmonary bypass.

CASE REPORT

A 52 year old, 70 kg black female with hemoglobin *SS* disease presented to the Cardiology Service at Brooke Army Medical Center for evaluation of progressive dyspnea over the previous two months. Her cardiac failure had responded to captopril 50 mg t.i.d. and digoxin 0.3 mg daily. She received folic acid and ferrous sulfate for treatment of her sickle cell induced chronic anemia. Evaluation in January 1993 included an ECG, which showed atrial fibrillation, and a chest x-ray, which showed cardiomegaly and changes consistent with chronic obstructive pulmonary disease. Transesophageal echocardiographic evaluation demonstrated severe left atrial and left ventricular enlargement, severe mitral insufficiency, mild aortic insufficiency, intact chordae tendineae and normal papillary muscle function. There was also a variable degree of tricuspid insufficiency. Left ventricular function was normal to minimally diminished and the coronary arteries were normal.

Medical history included documented hemoglobin *SS* sickle cell disease with multiple crises, although none had occurred in the past two years. The patient also experienced mild chronic renal insufficiency and chronic obstructive pulmonary disease. A hemoglobin of 7.6 g/dl (hematocrit 21.3%) and marked dysmorphic and sickled red cells were noted on the peripheral smear. Liver functions were found to be mildly abnormal. Bleeding time was initially prolonged on admission but responded to oral vitamin K therapy with a bleeding time of five minutes on the day prior to surgery. A fibrinogen level, thrombin time (TT), prothrombin time (PT) and partial thromboplastin time (PTT) were all within normal ranges. Hemoglobin electrophoresis revealed a hemoglobin *S* fraction of 80%. The hematologists' recommendations included normalization of the patient's bleeding time with vitamin K therapy and transfusion to a hematocrit of 30% prior to surgery.

In view of the deterioration of her cardiac status despite relatively well preserved ventricular function and the absence of coronary artery disease, and given the stability of her sickle cell disease without evidence of severe end organ damage, mitral valve repair or replacement was recommended.

MATERIALS AND METHODS

The usual procedure for patients with sickle cell disease involves preoperative transfusion or partial exchange transfusion to reduce the hemoglobin *S* fraction. This exposes the patient to large volumes of homologous blood and its associated risks. Rather than preoperative simple transfusion or partial exchange transfusion, intraoperative red cell exchange and platelet pheresis were done. (8)

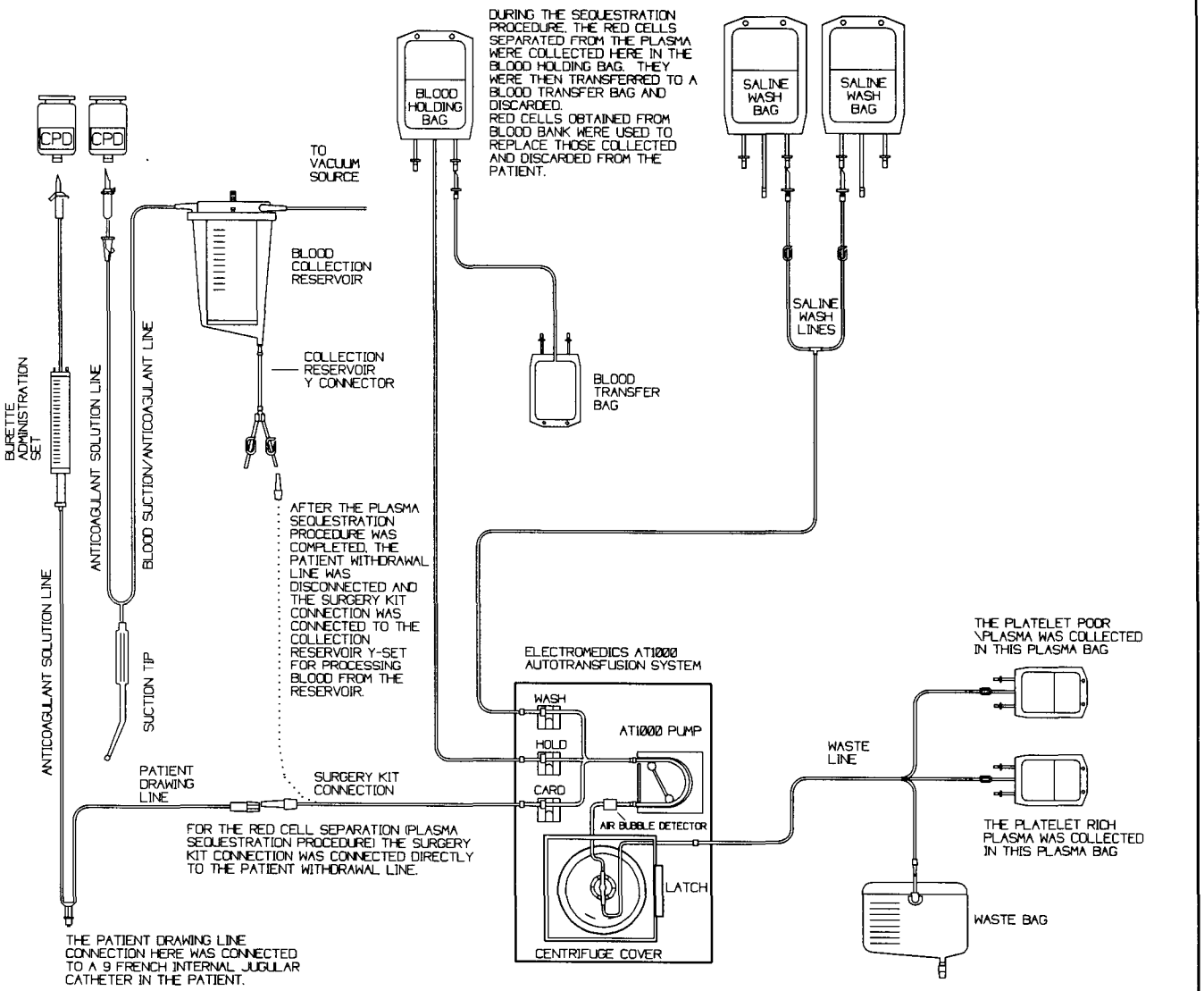
PHERESIS PROCEDURE

The patient was brought into the operating room and the appropriate monitoring devices such as arterial line, Swan-Ganz catheter, ECG, and necessary peripheral access lines were secured. Anesthetic induction was undertaken. Access to the patient's circulation was made through an internal jugular 9 fr. catheter. This catheter was then used to withdraw the blood required for the pheresis procedure.

Arterial and mixed venous blood gases were sent for blood

Address correspondence to:
James M. Parrish, Major, CCP
Cardiothoracic Surgery Service
Brooke Army Medical Center
Fort Sam Houston, Texas 78234-6200

Figure 1
Schematic diagram of the circuit and connections utilized for the pheresis procedure.

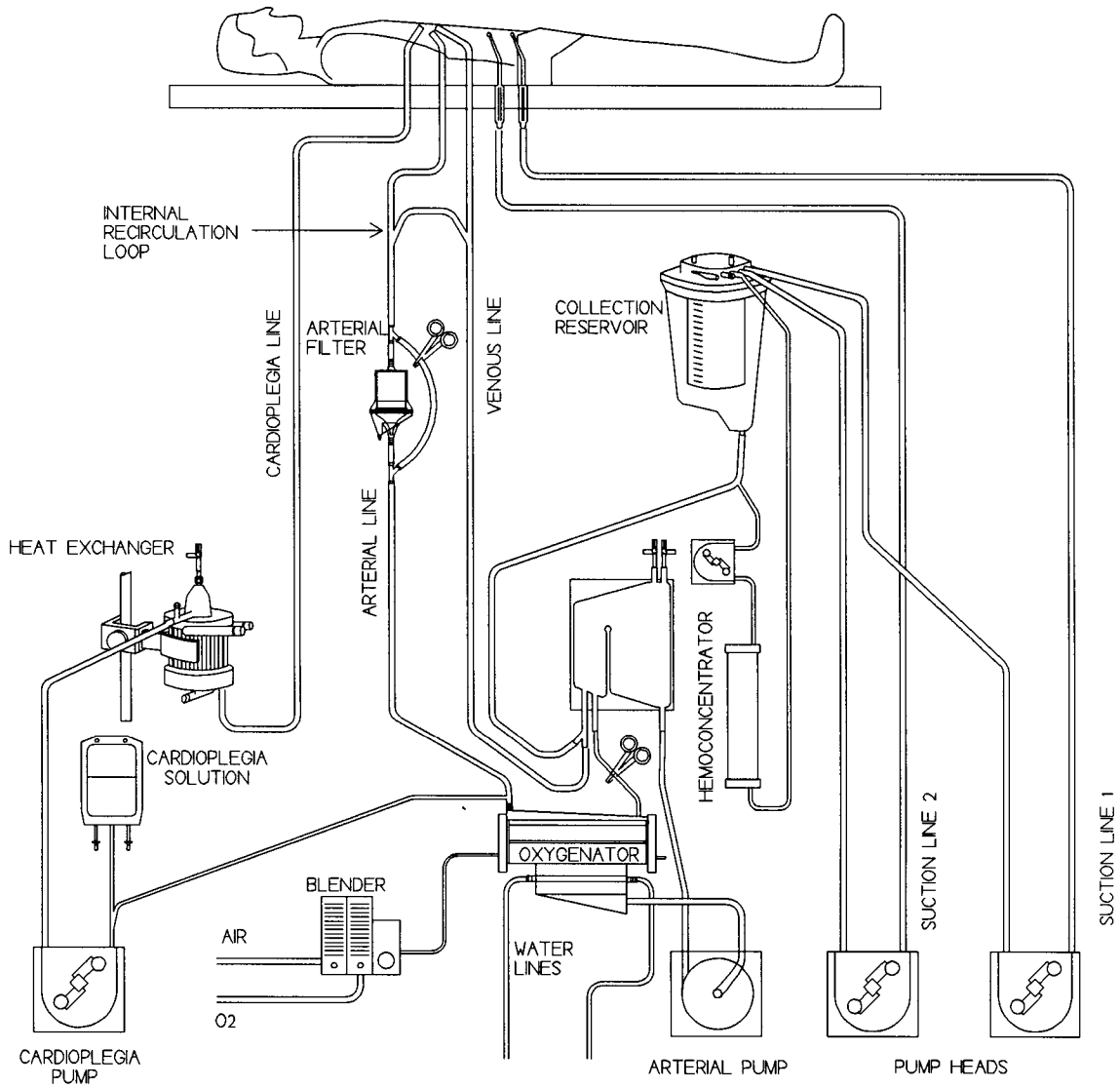


gas analysis and specimens were sent for hematocrit, platelet counts, and PT/PTT determinations. Activated clotting times (ACT) and a thromboelastogram (TEG) were performed in the operating room. A high flow fluid warmer and infuser system[a] was attached to a peripheral IV for rapid infusion of warmed fluids to maintain intravascular volume.

An Electromedics AT1000 autotransfusion machine[b] was prepared for the plasma sequestration procedure. Programs had previously been installed in the AT1000 for the separation of platelet-rich plasma (PRP), platelet-poor plasma (PPP), and RBCs. The pheresis and red cell exchange were performed after the induction of anesthesia, but prior to the surgical incision. During the pheresis procedure the patient was normothermic and high oxygen delivery was maintained. In the normal patient red blood cells (RBCs) collected during the pheresis procedure are returned to the patient. In this patient with sickle cell *SS* disease the RBCs collected during pheresis were discarded and replaced with homologous RBCs. (10) The reduced blood volume from the removal of the patient's RBCs lowers the amount of homologous RBCs required to provide the desired reduction in the hemoglobin *S* fraction. In addition, the pheresis procedure provides the added benefit of sequestered fresh autologous platelets and clotting factors. This aids in postbypass hemostasis.

a Baxter I.V. Systems, Deerfield, IL 60015
b Electromedics Inc., Englewood, CO 80112

Figure 2
Schematic diagram of the perfusion circuit.



The pheresis procedure was started and whole blood was drawn from the 9 fr. internal jugular vein catheter directly into the centrifuge bowl of the Electromedics AT1000, initially at a rate of 100 ml/min and subsequently at a rate of 50 ml/min. The circuit and connections for this pheresis procedure are shown in Figure 1. To prevent coagulation, CPD solution was continuously mixed with the blood at a ratio of 15 ml CPD to 100 mls of blood as it was withdrawn. Packed RBCs and 5% albumin were infused as dictated by mean arterial pressure (MAP) < 60 mmHg or a decline in mixed venous oxygen saturation (MVO_2) to 60%.

During the pheresis procedure, three autologous collection bags were used to separate the platelet poor-plasma (rich in clotting factors, low in platelets), platelet-rich plasma (rich in platelets), and the RBCs and other components. A first "pass" (withdrawal) of 875 mls of whole blood was slowly removed from the patient without the need for additional pressor support or volume infusion. This first liter of whole blood was pheresed into three components, providing 500 ml of platelet-poor plasma (which was reinfused to help maintain intravascular volume), 150 ml of platelet-rich plasma (which was held for reinfusion after bypass), and 225 ml of red blood cell concentrate which was discarded because it consisted of RBCs carrying the *S* hemoglobin.

The blood withdrawal sequence was repeated with an additional 1200 ml of whole blood being removed. This second pass yielded approximately 700 ml of platelet-poor plasma and

Table 1
Hemodynamic data.
Height: 175 cm Weight: 70 kg BSA: 1.84 m^2

	PULSE b/min	SYS PR mmHg	PUL PR mmHg	PAOP mmHg	CVP mmHg	CO/CI L/min	MVO_2 %
Baseline	85	150/70 100	45/15 30	18	8	8.7/4.7	82
1st withdrawal	80	105/50 70	30/15 25	14	6	—	73
2nd withdrawal	110	82/40 68	12/8 10	12	5	4.9/2.7	63
After transfusion of 2 U PRBC prebypass	80	105/60 75	22/8 15	16	5	5.8/3.2	80
Wean from bypass	150	100/70 80	30/23 26	18	10	4.6/2.5	80
After platelet transfusion	125	130/60 90	31/19 18	20	15	8.8/4.8	79
Chest closure	110	120/60 80	21/14 18	18	15	6.6/3.6	79

150 ml of platelet-rich plasma; both were retained for reinfusion at the conclusion of bypass. As before, due to the potential for sickling, the 350 mls of the sequestered RBCs were discarded. At this point the patient's hemodynamic status indicated that it would not be safe to perform any further pheresis and the procedure was terminated. Two units of packed homologous RBCs, diluted with saline and 500 ml of 5% albumin, were infused through the fluid warmer and the operation was started. The hemodynamic data of the patient during this case is outlined in Table 1. Results of laboratory testing performed throughout the case are shown in Table 2.

CARDIOPULMONARY BYPASS

The cardiopulmonary bypass circuit consisted of a Sarns Delphin 7850 Centrifugal Pump, a Sarns Turbo Membrane Oxygenator 9443[c] utilizing a Bentley 1900 venous reservoir[d], an Electromedics 4:1 blood cardioplegia delivery system[b] and a HEMOCOR Plus[e] hemoconcentrator. The perfusion circuit was designed with a 3/8" x 3/8" bypass loop connecting the arterial line, distal to the arterial filter, to the venous line near the venous reservoir. The internal recirculation loop was incorporated into the circuit for several reasons. The loop allows the oxygenator, arterial filter and cardioplegia system to be primed prior to priming the full AV loop. This helps prevent large amounts of air from being held up in the prebypass filter in the AV loop when the arterial filter is being primed. The recirculation loop also allowed the continuous recirculation of the blood prime prior to bypass, while keeping the distal AV loop (with the prebypass filter) primed with the crystalloid prime solution. Another benefit of the internal loop is that it allows the infusion of fluid into the venous side of the patient. This would be of particular importance in the rare event of a massive air embolism. Also, in a patient with a fragile aorta the loop would allow the surgeon to decannulate the aorta following the conclusion of bypass and still retain the ability to rapidly infuse volume to the patient.

During bypass this recirculation loop is double clamped. A 3/8 x 3/8 x 1/4 inch "Y" connector is inserted in the line coming from the cardiotomy reservoir. The 3/8 inch leg of this "Y" is connected to the venous reservoir bag. The 1/4 inch is connected to a section of 1/4 inch tubing that is run through a roller head and connected to the inlet of the hemoconcentrator. The outlet of the hemoconcentrator is connected to an inlet connection on the cardiotomy reservoir. A schematic diagram of the perfusion circuit is shown in Figure 2. The circuit was primed with 2000 ml of Normasol[a] to which 10,000 units of heparin and 40 gm of mannitol were added. The pH was adjusted to 7.40 with sodium bicarbonate. The prime was allowed to circulate through a prebypass filter. After the circuit was primed and free of air, the bypass loop was opened and the patient A-V loop was clamped

c Sarns/3M Health Care, Ann Arbor, MI 48103
d Bentley Laboratories Division - Baxter Healthcare Corp., Irvine, CA 92714
e Minntech, Minneapolis, MN 55447

Table 2
Laboratory data.

	HGB/HCT mg/dl/%	PT/PTT Sec	PLTS x10³	ACT Sec	Hgb %	TEG x	x	ma	K
Baseline	7.6/21.3	12.3/23.4	486	155	80	78	9	82	2
1st withdrawal	6.0/18.6	—	390	—	—	—	—	—	—
2nd withdrawal	5.0/15.0	—	—	—	—	60	9	72	4
Return 2 U PRBC	6.9/21.0	—	222	—	50	—	—	—	—
Bypass	8.5/35.0	—	—	589	—	—	—	—	—
Transfuse 2 U on Bypass	9.1/26.8	—	—	—	—	—	—	—	—
Post-bypass after plasma and platelets	9.1/26.6	17.4/49.9	236	166	—	32	23	48	10.5
At chest closure after 150 mg Add'l Protamine	17.4 9.3/28.0	—	—	145	—	—	—	—	—

Table 3
Fluid Additions.

Fluid	Prebypass	Bypass	Post-Bypass	Total	Pump Prime
Crystalloids	800 ml	1000 ml	1950 ml	5750 ml	2000 ml
Colloids	500 ml 5% Albumin	—	2500 ml - 5% Alb 500 ml Hetastarch	1000 ml	1200 ml Ultra-filtrate removed
Platelets	—	—	300 ml	300 ml	—
Plasma	300 ml	—	600 ml	900 ml	—
PRBC	500 ml (2 U)	500 ml (2 U)	—	2500 ml	1500 ml (6 U)
Bypass Plasma	—	—	1200 ml	1200 ml	—
Cell Salvage RBC	—	—	900 ml (4 U)	900 ml	—
Urine	-300 ml	-200 ml	-500 ml	-1000 ml	—
Pump Ultrafiltrate	-1200 ml	-800 ml	—	—	1200 ml Prebypass

to prevent further circulation through a 5 micron Bentley RF-10 prebypass filter[d]. Six units of packed homologous RBCs (1500 ml) were then added to the priming volume, bringing the total prime volume to 3500 ml and allowed to circulate through the system. The hemoconcentrator was used at this time to remove excess volume (1200 ml) and potassium. This reduced the prime volume to 2300 ml. A series of laboratory studies were performed during the hemoconcentration to achieve a prime hematocrit of 21%.

At the start of bypass the first two liters of venous blood, from the venous line, were routed into the AT1000 blood collection of reservoir using an Electromedics FT-207 Venous Access Sequestering Line[b]. These two liters of blood provided an additional 1200 ml of plasma and platelet mixture that were stored for later reinfusion. The 450 ml of RBCs generated from this additional pheresis procedure were discarded as before. The patient was cooled to 28°C, cardiac arrest using cold blood cardioplegia solution was achieved and valve repair was completed. During cardiopulmonary bypass two additional units of homologous packed RBCs were added to the heart-lung machine circuit to

maintain an on pump hematocrit of 25%. The pH was maintained as close to 7.40 as possible using sodium bicarbonate. After a total bypass time of 130 minutes, with a cross-clamp time of 81 minutes, the patient was easily weaned from cardiopulmonary bypass. Heparin was reversed with protamine using a 1:1.3 ratio. Once the protamine was administered and the heparin neutralized, the previously sequestered autologous platelet and plasma fractions were administered. Table 3 shows I.V. fluid and blood product utilization, and urine output. The operative site appeared dry with the exception of significant marrow bleeding from the sternum. This was packed with bone wax and cauterized, and the chest was closed. Chest tube drainage was minimal and amounted to only 226 mls in 15 hours.

On postoperative day one the patient was responsive. After two days of additional ventilatory support to allow stabilization of her fluid and ventilatory status, she was extubated without difficulty on postoperative day four. The operative procedure did not appear to incur any significant hemodynamic problems due to the prebypass pheresis of 2200 ml of whole blood or the removal of the additional 2000 ml at the initiation of cardiopulmonary bypass for pheresis. The remainder of her postoperative course was uneventful.

DISCUSSION

The consequence of the sickling of the RBCs is chronic anemia due to the destruction and removal of these abnormal cells by the reticuloendothelial system. In addition, the sludging and blockage of small blood vessels may lead to damage of all organ systems from resultant infarction in these patients. The incidence for sickle cell trait *Ss* among Afro-Americans is estimated at 8% with one in 200-500 newborns having sickle cell disease. (9,11) The heterozygous state, *Ss*, is characterized by a more benign clinical course since the presence of hemoglobin *A*, produced as a result of the alteration in the DNA strand within the red blood cell, lowers the "critical pO_2" (the level below which sickling occurs) from 40 mmHg to 20 mmHg. Partial pressures of oxygen this low are unlikely to occur except under rare circumstances. (5) The clinical course of patients with *Ss* disease is most often characterized by recurrent painful crises, sequestration of sickled cells and recurrent infection. Acute pulmonary dysfunction, Acute Chest Syndrome (ACS), chronic renal failure, autosplenectomy, recurrent stroke, and cholelithiasis are other manifestations of sickle cell disease. (5,10) While the cardiovascular physiology is abnormal, most of these changes are a result of compensation for the chronic anemia and not directly attributable to the illness. (12) Although there is no cure at present, therapies should be directed towards improving red blood cell survival by membrane stabilization and elevating the levels of normal hemoglobin. The role of nutritional support and addressing the other medical problems that frequently weaken the patient should not be overlooked when preparing a patient for upcoming surgery. (5)

Current recommendations for management include: avoidance of hypoxemia, acidosis, hypothermia and hypovolemia. This, in concert with a carefully planned transfusion program to optimize total hemoglobin, reduce viscosity, and hemoglobin *S* levels, would provide for maximal oxygen delivery to the tissues during surgical procedures. This helps prevent the development of the Acute Chest Syndrome which is a common perioperative manifestation of sickle cell disease. (13)

Management of those individuals with sickle trait is essentially the same as for other patients, with transfusion being recommended only as needed for blood loss. The use of simple transfusions to provide a hematocrit of 30-36% is acceptable. In major surgical procedures with a high risk of blood loss and hypothermia, a partial exchange transfusion to a hematocrit of 30-36% with a hemoglobin *S* concentration < 30% is recommended for these sickle cell trait patients. (5,14) The use of the techniques described in this paper will allow the reduction of hemoglobin *S* concentration to lower than 30%.

Cardiac surgery has been performed safely on patients, both adult and pediatric, with sickle cell trait and sickle cell disease. Early recommendations for cardiopulmonary bypass with hypothermia in patients with hemoglobin *AS*, included partial exchange transfusion because each cell contains a mixture of hemoglobin *A* [Adult hemoglobin molecule] and an abnormal *S* hemoglobin molecule which combine to give a recessive trait. (15) It is for this reason that partial red cell exchange is recommended.

It is known that for patients with sickle cell trait to begin sickling, they would require levels of hypoxemia that are unlikely to develop during cardiopulmonary bypass. In patients with homozygous *SS*, in vitro studies have shown that sickling starts at arterial oxygen saturations of less than 85% and the sickling is 100% complete at a saturation of 38%. In patients with heterozygous hemoglobin, sickling starts at arterial oxygen saturations of 40%. (16) Due to the availability of improved monitoring during induction of anesthesia and cardiopulmonary bypass, hypoxemia can be avoided in these patients. Current studies of pediatric and adult patients show that patients have undergone successful hypothermic cardiopulmonary bypass without receiving preoperative partial exchange transfusions.(17,18) Métas, et al, (15) report on 15 patients, ages 3-40 years, 13 with hemoglobin *AS*, one with *SC* disease (genetically abnormal hemoglobin molecules) and one with *S*/Thalassemia, for cardiac surgery. All procedures were performed without routine exchange transfusion and with hypothermia and a crystalloid priming solution. Five of these patients did not require any transfusions during their hospital course. There were two fatalities from low cardiac output, one instance of intraoperative sickling, and three episodes of hemolysis. Two of the episodes of hemolysis occurred in the patients that died. They concluded that routine preoperative transfusion to raise normal hemoglobin levels or exchange transfusion and blood solutions, are not necessary. These authors also concluded that aortic cross clamping and hypothermia can be used safely in patients with heterozygous hemoglobin *S*.

The recommendations for the management of patients with

hemoglobin *SS* are somewhat more consistent. Steward recommends that children with sickle cell disease have their hemoglobin *S* fraction reduced to less than 5% prior to surgery. (19) This criteria is not rigidly adhered to by all surgeons however. Many methods have been proposed such as: simple transfusion over several weeks prior to surgery, standard partial exchange transfusion in the preoperative period, exchange transfusion using cell separators available in blood banks, and even complete exchange using the cardiopulmonary bypass circuit. Some surgeons have utilized various combinations of these approaches. (15,16,20-26) Although simple transfusions are time consuming, there is some indication that elevation of the normal hemoglobin levels suppresses production of hemoglobin , and may be beneficial in the perioperative period. Other modalities require less time but, in unstable patients, they may precipitate cardiac failure. Chun reports the use of partial exchange transfusions of eight units of blood transfused over a three week period to prepare a 32-year old patient for a double valve replacement. The preoperative hematocrit was 40% with a hemoglobin *S* fraction of 5%. Black reports a case of a two year old child with *SS* disease. (24) The child received preoperative transfusions to obtain a hemoglobin of 11.4 g/dl. The procedure then incorporated the use of a homologous blood prime solution with separation of the platelet-rich plasma during cardiopulmonary bypass for later reinfusion. The separated RBCs were discarded since they contained hemoglobin *SS* cells. This child required three units of fresh frozen plasma and 900 ml of homologous RBCs during her hospital stay. Balasundaram, et al., report their experience with five children, ages 3-16 years, for procedures requiring cardiopulmonary bypass. (16) None were transfused preoperatively and all had hemoglobin values in the range of 8-10 g/dl. (6) These patients received a priming solution of blood and fresh frozen plasma. At the initiation of bypass, the patient's blood volume was collected into a reservoir and subsequently separated into RBCs which were discarded, and plasma which was returned at the conclusion of bypass. No autologous red blood cell salvage was employed during the postbypass period.

Our technique for this patient with sickle cell *SS* disease incorporates elements which combine aspects from several of the methods outlined by the previous authors. (16,24) Unlike Black (24), no preoperative transfusions were used. Prebypass separation of the platelet-poor plasma facilitated its immediate return to maintain volume, while the platelet-rich fraction was retained for postbypass reinfusion. Oxygen carrying capacity was returned to preoperative values with the homologous transfusions. In addition to the prebypass removal of patient RBCs, we utilized a similar approach to the method described by Balasundaram. (16) The blood withdrawn at the initiation of bypass was pheresed and the RBCs were discarded (the plasma and platelets were stored for later infusion). This, in combination with the autologous blood and Normosol priming solution, ensured a low level of hemoglobin *S* prior to the initiation of total bypass. Simple transfusion, as recommended by the hematologists, would have diluted, but not reduced, the patient's hemoglobin level as significantly as was done by utilizing the pheresis procedure. Preoperative partial exchange transfusion in patients who are severely anemic could result in cardiac decompensation. Performing the pheresis procedure in the perioperative period allowed for the removal of RBCs while the patient was under general anesthesia. This ensured conditions of high oxygen delivery and low oxygen consumption with close hemodynamic monitoring of volume status and blood gas monitoring for oxygen utilization.

In this case, after the combination of transfusion, pheresis, and priming, the hemoglobin *S* fraction was reduced to less than 10%. It also allowed the patient to proceed on cardiopulmonary bypass with a hematocrit equivalent to that of the pump prime with a minimal hemoglobin *S* concentration. This minimized the amount of hemoglobin *S* exposed to the stresses of bypass and surgery.

At first glance this approach may appear to involve an excessive use of homologous RBCs. However, the total homologous red cell requirement (ten units) in this case is in line with that reported by Chun (18), Cook and Hanowell. (27) Their cases required nine homologous units of blood to preoperatively exchange transfuse a patient from a starting hemoglobin of 7.7 g/dl to a hemoglobin *S* fraction of 25% and a preoperative hemoglobin of 11.5 g/dl. A typical non-sickle cell patient with a hematocrit of 20% who undergoes cardiopulmonary bypass with a crystalloid priming solution, might require a transfusion of 3-4 units of RBCs prior to the bypass. Our reported technique efficiently and predictably lowered the hemoglobin *S* fraction, with the added advantage of making available sequestered autologous fresh platelets and clotting factors for postbypass reinfusion. Having the autologous blood products available minimized the need for additional homologous blood products in the immediate perioperative period. The mediastinal tube drainage for 18 hours was 286 ml and 111 ml. This reinforces the belief that perioperative harvesting of platelets through PRP helps to provide surgical hemostasis and the return of normal coagulation function.

The use of cell salvage (intraoperative autotransfusion) techniques in patients with hemoglobin *SS* is not indicated and is controversial in those with hemoglobin *AS*. (28,29) There have been reports that sickling may occur during the period of collection, washing and returning of the RBCs. The use of autotransfusion and cell washing in this case was undertaken after the hemoglobin *S* fraction had been reduced to very low levels. Therefore, no problems were encountered with returning the blood to the patient from the autotransfusion system or from the pump circuit at the conclusion of bypass.

Although the more commonly seen patients with heterozygous hemoglobin disease appear to tolerate cardiac surgery with routine cardiopulmonary bypass techniques, the less commonly seen homozygous *SS* patients likely warrant additional measures such as those outlined in this paper. The aggressive intraoperative removal of hemoglobin containing cells, appears to be an efficient alternative to standard partial exchange transfusion practice in reducing the perioperative risk to these patients.

REFERENCES

1. Searle JF. Anaesthesia in sickle cell states. A review. Anaesthesia. 1973;28-48-58.
2. Esseltine DW, Baxter MRN, Bean JC. Sickle cell states and the anaesthetist. Can J. Anaesth 1988; 35(4):385-403.
3. Schmalzer EA, Lee JO, Brown AK, et al. Viscosity of mixtures of sickle and normal red cells at varying hematocrit levels. Implications for transfusion. Transfusion, 1987; 27:228-233.
4. Eaton WA, Hofrichter J. Hemoglobin S gelation and sickle cell disease. Blood. 1987; 70(5):1245-1266.
5. Heabbel RP. Beyond hemoglobin polymerization: The red blood cell membrane and sickle disease pathophysiology. Blood. 1991; 77(2):214-237.
6. Holzmann L. Finn H, Lichtman HC, Harmel MH. Anesthesia in patients with sickle cell disease. A review of 112 cases. Anesth Analg. 1969;48(4):566-572.
7. Miller DR, Giardina PV. Congenital hemolytic anemias, in Petez LD, Swisher SN(eds): Clinical Practice of Transfusion Medicine. 2nd ed. New York: Churchill Livingstone; 1989:591-595.
8. Davies GG, Wells DG, Mabee TM, et al. Platelet-leukocyte plasmapheresis attenuates the deleterious effects of cardiopulmonary bypass. Ann Thorac Surg., 1991;53:274-277.
9. Giordano GF, Rivers SL, Chung GKT, et al. Autologous platelet-rich plasma in cardiac surgery: Effect on intraoperative and postoperative transfusion requirements. Ann Thorac Surg. 1988;46:416-419.
10. Rifkind S, Waisman J, Thompson R, Goldfinger D. RBC exchange pheresis for priapism in sickle cell disease. JAMA. 1979; 242(21):2317-2318.
11. Wayne AS, Kevy SV, Nathan DG. Transfusion management of Sickle Cell Disease. Blood. 1993;81(5):1109-1123.
12. Falk RH, Hood, Jr. WB. The heart in sickle cell anemia. Arch Intern Med. 1992;142:1680-1684.
13. National SCA Preoperative Transfusion Study Group (Vichinsky E). Preoperative transfusion in sickle cell anemia. Blood. 1989;74(7)Suppl 1:184a.
14. Fullerton MW, Philippart AI, Sarnaik S, Lusher, JM. Preoperative transfusion in sickle cell anemia. J Pediatr Surg. 1981;16(3):297-300.
15. Heiner M, Teasdale SJ, David T, et al. Aorto-coronary bypass in a patient with sickle cell trait. Can Anaesth Soc J. 1979;26(5):428-434.
16. Bunn HF, Forget BG. Hemoglobin: Molecular, Genetic and Clinical Aspects. Philadelphia: WB Saunders;1986-476.
17. Métras D, Ouezzin Coulibaly A, Quattara K, et al. Open-heart surgery in sickle-cell haemoglobinopathies: report of 15 cases. Thorax. 1982;37:486-491.
18. Balasundaram MS, Duran CG, Al-Halees Z, Kassay M. Cardiopulmonary bypass in sickle cell anemmia. J. Cardiovasc Surg. 1991;32:271-274.
19. Steward DJ. Miscellaneous disorders with significant implications for anesthesia, in Manual of Pediatric Anesthesia. 2nd ed. New York: Churchill Livingstone;1985.
20. Chun PKC, Flannery EP, Bowen TE. Open-heart surgery in patients with hematologic disorders. Am Heart J. 1983;105(5):835-842.
21. Szentpetery S, Robertson L, Lower RR. Complete repair of tetralogy associated with sickle cell anemia and G-6-PD deficiency. J Thorac Cardiovasc Surg. 1976;72(2):276-279.
22. Pearson HA, Schiebler GL, Krovetz LJ, et al. Sickle-cell anemia associated with sickle cell trait. (Letter) Anesthesiology. 1989;70:878.
23. Harris LC, Haggard ME, Travis LB. The coexistence of sickle cell disease and congenital heart disease: A report of three cases, with repair under cardiopulmonary bypass in two. Pediatrics. 1964;33:562-570.
24. Craenen J, Kilman J, Hosier DM, Weinberger M. Mitral valve replacement in a child with sickle cell anemia. J Thorac Cardiovasc Surg. 1972;63(5):797-799.
25. Riethmuller R, Grundy EM, Radley-Smith R. Open heart surgery in a patient with homozygous sickle cell disease. Anesthesia. 1982;37:324-327.
26. Black HA, Dearing JP. Exchange transfusion prior to cardiopulmonary bypass in sickle cell anemia. J Extra-Corpor Technol. 1980;12(4):82-85.
27. Cook A, Hanowell LH. Intraoperative autotransfusion for a patient with homozygous sickle cell disease. Anesthesiology. 1990;74:177-179.
28. Romanoff ME, Woodward DC, Bullard WG. Autologous blood transfusion in patients with sickle cell trait. (Letter) Anesthesiology. 1988;68:821.
29. Brajtbord D, Johnson D, Ramsay M, et al. Use of the cell saver in patients with sickle cell trait. (Letter) Anesthesiology. 1989;70:878-879.