Autotransfusion by cell saver technique in surgery of lumbar and thoracic spinal fusion with instrumentation

AMITABHA CHANDA, M.D., M.CH., DONALD R. SMITH, M.D., AND ANIL NANDA, M.D.
Department of Neurosurgery, Louisiana State University Health Sciences Center, Shreveport, Louisiana

Object. The authors used a modern cell saver technique to perform autotransfusion in patients undergoing instrumentation-assisted lumbar and/or thoracic spinal fusion, in whom significant blood loss was anticipated. The safety and benefits of this procedure as well as its cost effectiveness were analyzed.

Methods. The authors studied 50 patients who underwent lumbar and/or thoracic spinal fusion in which instrumentation was placed between January 1998 and June 2000 and in whom an estimated blood loss of 500 ml or more was expected. All surgeries were conducted by a single neurosurgeon (D.R.S.). During surgery, the Brat 2 cell saver system was used to salvage the autologous blood. The anesthesiologist and surgeon jointly decided, on the basis of hematocrit and clinical stability, whether transfusion was necessary in each patient. Various parameters (hematocrit, plasma and urine hemoglobin, platelet counts, coagulation profile, and serum bilirubin) were measured pre-, intra-, and postoperatively.

Thirty-three patients (66%) required transfusion. The mean blood loss in these patients was 1046 ml. The most important factor affecting blood loss was the number of levels fused (p < 0.0001). Only two patients required postoperative homologous transfusion. The mean decrease in hematocrit was 7.82%. The maximum reduction of platelet count was limited to 80,000/mm³. Major complications such as hemoglobinuria, coagulopathy, cardiopulmonary problems, air embolism, and major sepsis were not observed in this study.

Conclusions. Autotransfusion performed using a modern cell saver technique is safe and has many advantages over homologous transfusion. It conserves the homologous blood resources. The costs of the two modes are statistically comparable when greater than 500 ml of red blood cell transfusion is necessary.

KEY WORDS • autotransfusion • cell saver • spinal fusion

In spinal surgery, especially during lumbar or thoracic fusion in which instrumentation is placed, blood replacement is often required. An increased incidence of complications, however, occurs in these patients when homologous transfusions are performed. These complications include transmitted diseases such as viral hepatitis, cytomegalovirus infection, and human immunodeficiency virus infection.

Other complications include alloimmunization and hypersensitivity reactions. These complications can be avoided by conducting autologous transfusion.

In autotransfusion blood is collected and subsequently reinfused in the same patient. The obstetrician Blundell first used autotransfusion of shed blood in 1818. After the advent of homologous blood transfusion, the practice of autotransfusion was all but abandoned; however, from the mid- to late 1970s, there was a resurgence of interest, partly necessitated by the increased consumption of limited blood bank resources. To avoid complications related to homologous transfusion as well as to conserve blood bank resources, autotransfusion was successfully adapted mainly in cardiovascular and orthopedic surgery.

In patients undergoing neurosurgical procedures, however, the use is not widely reported. The usefulness of the cell saver technique in autotransfusion was examined in this study, and we assessed its related complications and cost effectiveness in patients undergoing spinal fusion.

Clinical Material and Methods

We included 50 patients who underwent instrumentation-assisted lumbar and thoracic spinal fusions between January 1998 and June 2000. There were 32 male and 18 female patients who ranged in age from 13 to 73 years (mean 49.5 years). All surgeries were performed by the same neurosurgeon (D.R.S.), and EBL of more than 500 ml was expected. In cases in which thoracic or lumbar instrumentation-assisted fusion is performed, greater EBL is expected than in those in which instrumentation is not used. Although an EBL of 500 ml or more may occur in patients undergoing spinal fusion without instrumentation, the chance of blood loss is higher if instrumentation is placed. Additionally, for this reason, we did not consider enrolling any patient undergoing cervical spine fusion. All patients in this study underwent elective surgery.

During surgery, the Brat 2 Cell Saver system (Cobe Cardiovascular, Inc., Arvada, CO) was used to salvage the lost blood. Features of this system are shown in Fig. 1. A specially designed type of suction device was used to suc-
tion blood from the operative field. The suction line had an additional channel, which delivered heparinized normal saline, anticoagulating the blood as soon as it entered the line. The blood was transported to a reservoir where it was filtered through a 40-μm mesh (Fig. 1A). We used 30,000 units of heparin in 1000 ml of saline, and 3000 units of heparin were usually needed for anticoagulation of 500 ml of blood. When the blood reached a certain level in the reservoir, a roller pump transferred it to a spinning bowl, which was mounted in the centrifuge (Fig. 1B). In the bowl, red cells were separated from plasma containing heparin, hemolyzed cells, free hemoglobin, activated clotting factors, fat, excess potassium, and other waste products. As the RBC content increased, the plasma was superseded to the waste bag. When a certain level of RBCs was reached (hematocrit 55–65%), a cell wash was initiated. This was effected by passing normal saline through the spinning bowl until the effluent flowing to the waste bag was clear. The final product of packed cells was suspended in saline and finally pumped into a transfusion bag (Fig. 1C and D). The hematocrit of this blood (also known as cell saver blood or cell saver red cells) was approxi-

mately 55 to 65%. It had, however, no clotting activity and a minimum amount of anticoagulant.

Intraoperative blood loss was determined by the measurement of the volume of salvaged blood in the cell saver combined with EBL in sponges and drapes. The necessity of transfusion was decided jointly by the surgeon and the anesthesiologist based on blood loss, hematocrit, and clinical stability. In no patient was blood transfused simply because autologous blood was available. Usually blood was transfused when the blood loss was more than 20% of the circulating volume, if changes in the blood pressure or cardiac output warranted transfusion or in cases in which the hematocrit dropped below 20 to 25% in a young adult or below 25 to 30% in an elderly individual with cardiac/vascular compromise. Moderate hypotensive anesthesia was used unless contraindicated. Postoperative blood loss was measured in drain containers. During the postoperative period, transfusion was performed to maintain a hematocrit of 25% in young adults and 30% in older patients or those with a history of cardiac or vascular disease.

Several parameters such as hematocrit, platelet count, plasma and urine hemoglobin, coagulation profile, and serum bilirubin, which could undergo changes after autotransfusion in which the cell saver technique is used, were measured pre-, intra-, and postoperatively; the measurements were obtained 24 hours before surgery, during surgery, and 48 hours after surgery. Additionally, hematocrit was measured immediately before, and at 24 hours and 7 days after surgery to determine whether additional transfusion was required. Again, the determinant of additional transfusion was the decrease of hematocrit below approximately 25%. During the postoperative period, the patients’ progress and any possible complications were monitored closely.

The cost of the cell saver procedure, including the cost of liner/tubing, standby (including expenses for nurses and/or technician) and anticoagulant solution, and autotransfusion, was estimated. This cost was compared with that for homologous transfusion, which includes ABO and Rh blood typing, antibody screening, cross matching, packed RBCs, and administration expenses.

Results

Fifty patients were included in this study, all of whom underwent thoracic and/or lumbar fusion in which instrumentation was used. In 12 patients this was repeated surgery for recurrent problems. The number of levels fused ranged from one to five (mean 1.78 levels). The mean intraoperative blood loss in these 50 patients was 832.65 ml (range 200–2400 ml). Of 50 patients, 33 (66%) required cell saver transfusion. The mean intraoperative blood loss in these 33 patients was 1046 ml. In this latter group, the mean number of fused levels was 2.12. The postoperative EBL was within 200 ml in all patients, as determined by measuring that in the drainage bag. All of the drains were removed within 48 hours.

The data were analyzed using the SPSS system. Uni-
A. Chanda, D. R. Smith, and A. Nanda

TABLE 1
Summary of reported studies in which autologous blood is used in spinal surgery

<table>
<thead>
<tr>
<th>Authors &amp; Year</th>
<th>No. of Patients</th>
<th>Mean Age (yrs)</th>
<th>Hemoglobin/Hematocrit Preop</th>
<th>Hemoglobin/Hematocrit Postop</th>
<th>Mean Blood Loss (ml)</th>
<th>Autologous Blood Only</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flynn, et al., 1982*</td>
<td>55</td>
<td>13.8</td>
<td>37.8%</td>
<td>NA</td>
<td>1082</td>
<td>NA</td>
</tr>
<tr>
<td>Kruger &amp; Colbert, 1985</td>
<td>30</td>
<td>44</td>
<td>36.3%</td>
<td>NA</td>
<td>1350</td>
<td>84</td>
</tr>
<tr>
<td>Bailey &amp; Mahoney, 1987</td>
<td>52</td>
<td>18</td>
<td>13.1 g</td>
<td>10.6 g</td>
<td>791</td>
<td>85</td>
</tr>
<tr>
<td>Thomson, et al., 1987*</td>
<td>13</td>
<td>20</td>
<td>37.5%</td>
<td>32%</td>
<td>1200</td>
<td>100</td>
</tr>
<tr>
<td>Johnson, et al., 1989</td>
<td>55</td>
<td>38.4</td>
<td>34.2%</td>
<td>30.6%</td>
<td>2722</td>
<td>0</td>
</tr>
<tr>
<td>present study</td>
<td>50</td>
<td>49.5</td>
<td>42.28%</td>
<td>35.58%</td>
<td>832.65</td>
<td>96.4</td>
</tr>
<tr>
<td></td>
<td>33</td>
<td>49.5</td>
<td>42.85%</td>
<td>34.88%</td>
<td>1046</td>
<td>96.7</td>
</tr>
</tbody>
</table>

* Multiple entries denote more than one group of patients. Abbreviation: NA = not available.

variates and multivariate analyses of variance test were performed to assess the data. The cost of the cell saver procedure was analyzed. It was found that the most significant factor in determining the amount of blood loss was the number of levels fused (p < 0.0001); however, multivariate analysis revealed that repeated surgery had no statistical contribution to the amount of blood loss (p = 0.494) in this study.

Only two patients required postoperative homologous transfusion. The first patient was a 78-year-old man who presented with a traumatic compression fracture of the T3 vertebral body. He underwent surgery in May 1999. Brakedown of the fractured vertebral body with T2–3 and T3–4 disectomy was performed. Four-level fusion was achieved using a titanium cage, posterolateral rods, and sublaminar hooks; each level was fused in one stage. The intraoperative EBL was 2000 ml. His preoperative hematocrit was 43%. One thousand two hundred milliliters of cell saver RBCs were transfused intraoperatively. His postoperative hematocrit after 48 hours was 25%. He underwent transfusion with two units of homologous packed red blood cells. After 7 days, the hematocrit was 33%.

The second patient was a 54-year-old woman who presented with recurrent prolapsed intervertebral L4–5 and L5–S1 discs for which she underwent surgery in April 2000. Discectomy was performed, and posterior lumbar interbody fusion was undertaken using Branigan cages with transpedicular screw and rod fixation. Her preoperative hematocrit was 43%. One thousand two hundred milliliters of cell saver RBCs were transfused. Twenty-four hours after surgery, however, the hematocrit was 23%, and 1 U of homologous packed RBCs was transfused on the 2nd postoperative day. At the time of discharge, the hematocrit was 29%.

The mean preoperative hematocrit was 42.28% in all 50 patients and 42.85% in the patients who received transfusions. After 7 days, the mean hematocrit was 35.58% in 50 patients and 34.88% in the 33 patients who received transfusion. The mean decrease in hematocrit in these 33 patients was 7.82%. The other parameters (platelet count, activated partial thromboplastin time, PT, plasma and urine hemoglobin, and serum bilirubin) were measured. Although traces of hemoglobin were detected in the plasma and urine, there were no clinical manifestations. A slight increase of indirect bilirubin was detected in the serum, but it remained consistently below 3 mg/dl. The maximum decrease in the platelet count was found to be up to 80,000/mm³.

The activated partial thromboplastin time and PT were measured in each patient, and the mean International Normalized Ratio was 1.2. The International Normalized Ratio was never higher than 1.5 in any patient. None of the patients in this study suffered any of the major complications that have been reported in the literature to occur after autotransfusion, such as hemoglobinuria, coagulopathy, cardiopulmonary problems, air embolism, and major sepsis. The available results reported in other major studies are compared in Table 1.

The cost of each procedure was analyzed. The cost of each unit of homologous packed RBCs in our institution is $559 (Table 2). The cost of cell saver autotransfusion was $1014 for the first 1000 ml and $715 for each subsequent 1000 ml (Table 3). There was no cost related to the machine used for cell saver procedure. Although autotransfusion was performed using the cell saver technique in all patients, as many as 34% required no transfusion. Considering that we would have arranged for at least one unit of packed RBCs for transfusion in these patients, we analyzed these data.

The cost of transfusing cell saver RBCs was compared with that of transfusing a comparable amount of homologous packed RBCs. It was found that the costs of these two modalities were statistically comparable in cases requiring transfusion of at least 500 ml of packed RBCs. If a patient required less than 500 ml of packed RBCs for transfusion, the cost of cell saver autotransfusion was much higher than that of homologous transfusion.

Discussion
The use of autotransfusion has been well documented as a valuable method of recycling blood in a safe and effective manner. The benefits of decreased homologous transfusions to the patient and blood bank services are easily recognized.

The major adverse effects of homologous blood transfusions are transmission of infectious disease and immune reactions. Although the incidence of posttransfusion viral
Cell saver autotransfusion in spinal fusion

The risks of immune reactions must also be considered. Transfusion of ABO-incompatible blood is the most significant risk associated with homologous transfusion. Hemolytic reactions caused by mismatched blood transfusion (mostly due to errors in patient identification) occur. In France between 1991 and 1994, 126 hemolytic transfusion reactions were reported, including six cases of ABO-incompatible transfusions that led to death. The risk of transmission of parasitic disease, although possible, is low in the US. Bacterial sepsis transmitted by transfusion, however, may be life threatening. Although autologous blood may demonstrate a small bacteriological contamination, there is usually no significant risk of infection directly associated with reinfused autologous blood.

The amounts of ABO blood group antigens on red blood cells are not fixed and vary among individuals. Consequently, ABO-incompatible blood for transfusion can be obtained from multiple donors, but it is not as common as autologous blood.

The major advantages of autologous blood transfusion are the elimination of the aforementioned problems. In autotransfusions, there is no possibility of an ABO-incompatible transfusion. Moreover, there is no risk of immunization to RBCs, white blood cells, platelets, and protein antigens. Systemic anticoagulation is not required because heparin is added at the suction tip. All anticoagulant is then removed by the cell washing procedure so that very little is reinfused in the patient. Although minimal anticoagulant is reinfused, no coagulation factors are available in the transfused blood. Therefore, coagulopathy is directly related to the quantity of blood transfused. When the quantity of autotransfused blood exceeds 3.5 l, predictable dilutional coagulopathy occurs.

Coagulopathy, if it occurs, can be managed by transfusing fresh-frozen plasma. Usually PT 1.5-fold longer than the control values has been suggested as an indicator of the need for replacement of the coagulation factors in cases of massive blood loss and transfusion. Hemolysis, however, caused mostly by turbulence resulting from excessive vacuum levels of suctioning blood mixed with air, occurs in 10 to 30% of patients undergoing autologous blood transfusion. In the mid-1990s, hepatitis GB and hepatitis G viruses associated with blood transfusion were isolated. In France between 1991 and 1994, 126 hemolytic transfusion reactions were reported, including six cases of ABO-incompatible transfusions that led to death. Similar incidences have been reported in France except for hepatitis B virus. In the mid-1990s, hepatitis GB and hepatitis G viruses associated with blood transfusion were isolated. The amount of blood loss, as has been observed, varies from patient to patient and procedure to procedure. In this study we found the most significant factor determining the amount of blood loss to be the number of levels fused (p < 0.0001).

In a study conducted by Johnson, et al., the authors reported the following risk factors for blood loss: 1) posterior approach, 2) three-level fusion, 3) the use of instrumentation, 4) two stage 360° fusions, and 5) male sex. In our study, the number of anterior approach procedures was not sufficient to make a comparison with those of posterior approach, which would have been statistically viable. In their comparable study, Johnson, et al., showed that posterior approaches cause greater blood loss because of the dissection of muscle layers. Similar to our study, they also found that blood loss depended on the number of levels fused. We cannot comment on the difference between using and not using instrumentation because we analyzed data obtained in only those patients in whom instrumentation was placed. We found no statistically significant difference between male and female patients. Johnson, et al., reported a greater blood loss in male patients, which may be due to the effects of greater body mass. Normally, there is less blood loss in fusion procedures than in surgery to correct spinal deformity. Similar to the results reported by Johnson, et al., we found no statistically significant difference of blood loss in cases of repeated surgeries. Additionally, we have analyzed the cost effectiveness of this method.

Another issue is when transfusion should be performed. This will remain a controversial issue. There is no uniform indication, and the decision varies from physician to physician. To unify the indication in our study, we chose cases in which the same surgeon and team of anesthesiologists performed the surgeries. Bailey and Mahoney performed intraoperative transfusion in cases in which blood loss of 20 to 25% of the patient’s blood volume occurred. They undertook postoperative transfusion with autologous

\[\text{ TABLE 2 }\]

\text{Cost analysis of homologous transfusion}\(^*\)

<table>
<thead>
<tr>
<th>Expenditure</th>
<th>Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABO &amp; Rh typing</td>
<td>76</td>
</tr>
<tr>
<td>antibody screen</td>
<td>56</td>
</tr>
<tr>
<td>cross match</td>
<td>133</td>
</tr>
<tr>
<td>packed RBCs</td>
<td>208</td>
</tr>
<tr>
<td>administration</td>
<td>86</td>
</tr>
<tr>
<td>total</td>
<td>559</td>
</tr>
</tbody>
</table>

\(^*\) Data obtained from the blood bank at Louisiana State University Health Center, Shreveport.

\[\text{ TABLE 3 }\]

\text{Cost analysis of autotransfusion by cell saver technique}

<table>
<thead>
<tr>
<th>Expenditure</th>
<th>Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>liner/tubing/anticoagulants (to be changed after each cycle)</td>
<td>92.00</td>
</tr>
<tr>
<td>standby nurses &amp;/or technician (1 needed for 1 patient)</td>
<td>297.00</td>
</tr>
<tr>
<td>autotransfusion</td>
<td>625.00</td>
</tr>
<tr>
<td>total</td>
<td>1014.00*</td>
</tr>
</tbody>
</table>

\(^*\) The recurring cost in a single surgery: $1014 for the first 1000 ml, and additional cost of $715 for every subsequent 1000 ml.

\[J. \text{Neurosurg: Spine} / \text{Volume 96} / \text{April, 2002}\]
blood when hemoglobin was less than 10 g/dl and with homologous blood when hemoglobin was less than 7 g/dl. Thomson, et al., stated that decision was individualized, whereas Flynn, et al., and Kruger and Colbert did not mention the criteria of postoperative blood transfusion. Johnson, et al., performed intraoperative transfusion when blood loss exceeded 20% of the circulating blood volume or when hypotension or a decrease in cardiac output occurred. This is similar to our criteria. After a series of conferences, however, most of the authorities concluded that transfusion is rarely indicated when the hemoglobin concentration is greater than 10 g/dl and that transfusion is always indicated when it is less than 6 to 7 g/dl. Between these two parameters, the decision to transfuse depends on a patient’s clinical status.

The last important issue is that of cost effectiveness. Although costlier than homologous transfusion of smaller volumes, intraoperative autotransfusion in which the cell saver technique is used may be worth the expense because of its major advantage: total prevention of transfusion-transmitted diseases and immune reactions. The cost of the cell saver transfusion does not vary in multiples with the amount of blood transfused. Thus, it is more cost effective in cases in which larger blood losses occur. It is also expected that the cost of the cell saver procedure will decrease once its use becomes more widespread. In a study conducted in France in 1997, the authors mentioned that the cost of using the cell saver, including the servicing and depreciation of the machine as well as costs of disposable anticoagulant and saline solution, was $220 per patient. In that study, the authors demonstrated a total savings of $10,300 in 65 patients in whom the cell saver procedure was used instead of homologous transfusion. The authors of other studies have also confirmed the cost effectiveness of intraoperative cell saver autotransfusion.

Conclusions

The safety of autologous transfusion in which the cell saver technique is used is now well established. Although the risk of complications such as hemoglobinuria, coagulopathy, and sepsis are finite, the actual incidences are very low and, with the advancement of techniques, are approaching zero. Moreover, the enormous burden on blood bank services is drastically alleviated with the widespread use of the intraoperative cell saver procedure. The cost of cell saver autotransfusion becomes cost effective when the blood transfusion exceeds 500 ml of RBCs. With widespread use, the ultimate cost of autotransfusion is expected to become lower than that of homologous transfusion.

References


A. Chanda, D. R. Smith, and A. Nanda


Manuscript received May 14, 2001.
Accepted in final form November 15, 2001.
Address reprint requests to: Anil Nanda, M.D., Department of Neurosurgery, Louisiana State University Health Sciences Center, 1501 Kings Highway, P. O. Box 33932, Shreveport, Louisiana 71130-3932. email: ananda@lsuhsc.edu.