Hemolysis and Survival of Autologous Red Blood Cells Salvaged After Cemented and Uncemented Total Hip Arthroplasty

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Abstract

Autotransfusion is widely used after total hip arthroplasty (THA), but there are concerns about damage of red blood cells (RBCs) collected after surgery. In this study, we wanted to determine the damage and survival of RBCs salvaged after cemented THA and after uncemented THA and to compare the results.

In this prospective study of 60 patients—30 who underwent cemented THA and 30 who underwent uncemented THA—postoperative autotransfusion systems (BIODREN; B.E.R.C.O., Modena, Italy) were used. Levels of potassium and free hemoglobin in the postoperative blood samples were analyzed. Before transfusion, salvaged RBCs were labeled with radioactive chromium-51, and their survival was measured.

In blood salvaged after cemented THA, medium potassium level was 4.1 mmol/L (range, 3.2-5.6 mmol/L), and mean free hemoglobin level was 327 mg% (range, 120-410 mg%). In blood salvaged after uncemented THA, mean potassium level was 4.2 mmol/L (range, 3.1-5.5 mmol/L), and mean free hemoglobin level was 296 mg% (range, 130-402 mg%). In the cemented group, RBC survival was 73% at 48 hours after transfusion (range, 61%-79%), and mean time from 100% activity to 50% activity was 21 days (range, 14.2-28.2 days). In the uncemented group, RBC survival was 75% at 48 hours after transfusion (range, 68%-82%), and mean time from 100% to 50% activity of radio-labeled RBCs was 22 days (range, 16.2-29.4 days).

There were no statistically significant differences in potassium levels, free hemoglobin levels, or RBC survival between the cemented and uncemented groups. Blood salvaged after surgery was not significantly damaged. Our study results confirmed that washing blood collected after surgery is not necessary. Not washing this blood is safe and decreases allogeneic transfusion in orthopedic procedures.

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Postoperative blood transfusion is a common method of reducing the need for allogeneic transfusion after orthopedic operations.[1,2] During collection of shed blood, there is the possibility of red blood cell (RBC) damage. Levels of potassium and free hemoglobin are signs of RBC lysis. Survival of damaged RBCs is shortened. RBC survival has been reported by several authors.[3] The most common method of analyzing RBC survival is an isotope-labeling technique that uses chromium-51 (^{51}Cr). Survival studies of RBCs collected during orthopedic procedures have estimated their life span to be normal. Several studies have analyzed RBC survival after hip and knee arthroplasty, but no study has compared RBC damage and survival after cemented versus uncemented total hip arthroplasty (THA).

With cemented THA, there is concern that RBCs may be damaged from exposure to polymethylacrylate (methylmethacrylate monomer, MMA) and the high temperature created during the procedure. In the study reported here, we wanted to determine the damage and survival of RBCs salvaged after cemented THA and after uncemented THA and to compare the results.

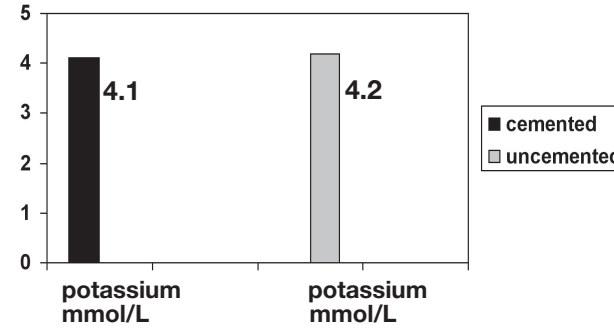

Figure 1. Levels of potassium in blood collected after surgery are in normal range. The difference between the 2 groups is not statistically significant ($P>.05$).

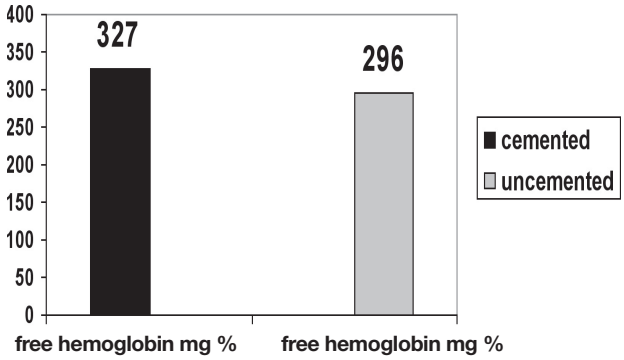

Figure 2. Levels of free hemoglobin in blood collected after surgery: 327 mg% after cemented arthroplasty, 296 mg% after uncemented arthroplasty. The difference between the 2 groups is not statistically significant (*P*>.05).

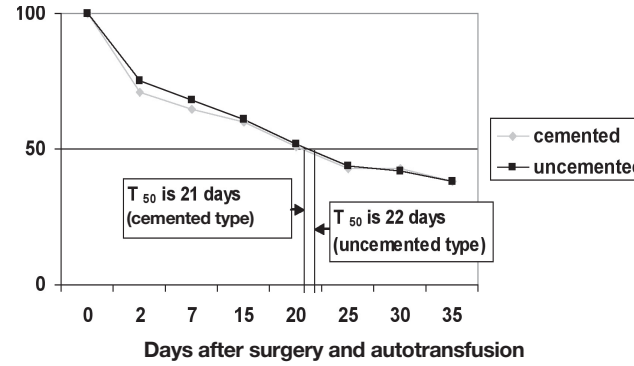

Figure 3. Chromium-51 activity in postoperative venous blood samples after reinfusion of radiolabeled shed blood. T_{50} (time from 100% activity to 50% activity) ^{51}Cr of labeled red blood cells is 21 days (cemented group) and 22 days (uncemented group).

In this prospective study, we analyzed the levels of potassium and free hemoglobin and the long-term survival and half-life of RBCs collected after surgery from surgical drains and autotransfused with the BIODREN conservation system (B.E.R.C.O., Modena, Italy). We compared our results with those of other studies of the survival and half-life of autologous and allogeneic sources of transfused blood.

Materials and Methods

This prospective, controlled study, which received hospital ethics committee approval, involved 60 patients scheduled for primary THA—30 who underwent cemented THA and 30 who underwent uncemented THA. All patients underwent spinal anesthesia with 0.5% bupivacaine. Low-molecular-weight heparin (Fraxiparine), started the evening before surgery, was used for thromboprophylaxis. Prophylactic antibiotics (first-generation cephalosporins) were administered to all patients before the induction of anesthesia and were continued for 24 hours after surgery. Volume deficits were substituted with crystalloid and colloid solutions during surgery and the day after surgery. Both surgical drains were removed 48 hours after surgery.

Autotransfusion System

The BIODREN system is a closed, autologous blood recovery system designed for postoperative collection, filtering, and reinfusion of shed blood. The vacuum pump provides an adjustable constant vacuum, kept below 100 mm Hg to avoid excessive hemolysis, according to recommendations of the American Association of Blood Banks (1990).[4] The system is connected to 2 drains during the finishing stage of the operation, and active suction is initiated after closure of the skin. When collection of shed blood in the reservoir is completed (ie, 600 mL of blood has been collected or a maximum of 360 minutes of collection has elapsed), the blood flows through a 260-micron filter to the blood bag, from which autotransfusion through a 40-micron filter blood transfusion set (Pall Corporation, Ann Arbor, MI) occurs.

Before reinfusion, blood samples were drawn to analyze the levels of potassium and free hemoglobin, and salvaged RBCs were labeled with radioactive ^{51}Cr. Fifteen minutes after the start of reinfusion, the first measurement of radioactivity in peripheral blood was made. This level is expressed as 100%. Reinfused RBCs were then monitored serially at determined intervals. Their radioactivity is expressed as a percentage of first postinfusion activity.

Chromium-51 Labeling of Red Blood Cells

Labeling of RBCs with ^{51}Cr was done according to the recommendations of the International Committee for Standardisation in Haematology (1971).[1] After blood collection was completed, 10 mL of blood was drawn from the autotransfusion system. This fraction of the shed blood was sent to the laboratory for RBC labeling. Labeled RBCs were then transfused to the patient. Twenty minutes after reinjection of radiolabeled RBCs, 10 mL of venous blood was drawn from the patient; the RBCs were used for counting emission of gamma photons (sample labeled *100%*). This "100%" sample and subsequent samples were analyzed in the gamma counter after lysis with a saponin. Blood samples were drawn 3 times weekly until 50% activity of ^{51}Cr was reached.

Results are presented using descriptive statistics. Student *t* test was used to compare the cemented and uncemented THA groups. *P*<.05 was considered statistically significant.

Results

Mean total amount of salvaged blood transfused was 605 mL in the cemented THA group and 695 mL in the uncemented THA (control) group (*P*<.05). Total blood loss was 1075 mL in the cemented group and 1105 mL in the uncemented group (*P*>.05). None of the 60 patients needed allogeneic transfusion.

Patients' potassium and free hemoglobin levels are listed in Figures 1 and 2. In the cemented group, mean potassium level was 4.1 mmol/L (range, 3.2-5.6 mmol/L), and mean free hemoglobin level was 327 mg% (range, 120-410 mg%).

Table. T_{50} Cr^{51} From Autologous Blood

Blood Source	T_{50} Cr^{51} (Days)	Study
Intraoperative autologous, spine	21	Ray et al[9] (1986)
Intraoperative autologous, aortic surgery	23	Thorley et al[10] (1990)
Postoperative autologous, knee arthroplasty	21	Grønborg et al[11] (1996)
Peripheral red blood cells	15-24	Umlas et al[12] (1993)

Abbreviation: T_{50}, time from 100% activity to 50% activity.

In the uncemented group, mean potassium level was 4.2 mmol/L (range, 3.1-5.5 mmol/L), and mean free hemoglobin level was 296 mg% (range, 130-402 mg%). There were no statistically significant differences between the groups.

Results of measurements of ^{51}Cr activity are presented in Figure 3. In the cemented group, RBC survival was 73% at 48 hours after transfusion (range, 61%-79%), 65% on day 7 after transfusion (range, 54%-72%), and 60% on day 15 after transfusion (range, 44%-62%). Time from 100% activity to 50% activity was 21 days (range, 14.2-28.2 days).

In the uncemented group, RBC survival was 75% at 48 hours after transfusion (range, 68%-82%), 67% on day 7 after transfusion (range, 57%-79%), and 61% on day 15 after transfusion (range, 49%-65%). Time from 100% activity to 50% activity was 22 days (range, 16.2-29.4 days).

"Blood salvaged after surgery is not significantly damaged."

Discussion

During lysis of RBCs, intracellular potassium is released, and the extracellular level increases. In addition, the level of free hemoglobin increases when the membrane of RBCs is destroyed. When free hemoglobin levels are high, hemoglobinuria and renal damage can occur. No statistically significant differences in potassium and free hemoglobin levels were found between the cemented and uncemented THA groups. The literature has no data on the levels of potassium in blood collected after surgery, but many studies have confirmed an increase in potassium level during storage of allogeneic or preoperatively donated autologous blood.[3,4] Serum potassium levels may be as high as 19 to 30 mmol/L in blood stored for 21 days.[4,5] Our patients' levels were in the normal range, confirming a low level of hemolysis of RBCs collected after surgery.

There are many studies of free hemoglobin in blood collected during and after THA and total knee arthroplasty.[2-4] In blood collected during surgery, these levels are increased and can become very high.[4] The level reported for blood collected after THA surgery is 236 mg/dL (range, 97-422 mg/dL), and the level reported after other orthopedic procedures is 152 mg/dL (31-298 mg/dL).[3,4] Our patients' levels of free hemoglobin fall in this range, and none of our patients developed hemoglobinuria or renal damage.

At the end of their life span, when they hemolyze, RBCs release their content of ^{51}Cr, but a small fraction of ^{51}Cr leaks from intact and living RBCs. This elution occurs continuously and at a constant rate, approximately 1% per day.[5] An additional fraction, up to 10% of ^{51}Cr, may be lost within the first 24 hours. This early loss has not been explained.

Our results show a large decrease in ^{51}Cr activity during postoperative days 1 and 2. The THA groups did not differ in their ^{51}Cr activity levels 48 hours after reinfusion of shed blood—RBC survival was 73% in the cemented group and 75% in the uncemented group—and there was no statistically significant difference after 7 and 15 days of reinfusion. The groups' time from 100% activity to 50% activity (T_{50}) was also similar, which can be explained with data of elution of ^{51}Cr, but we also assume that some RBCs are destroyed during surgery. These RBCs are also collected and reinfused, but they are fragile, and their lysis could cause early loss in ^{51}Cr activity. Their lysis could also increase the levels of potassium and free hemoglobin.

In both groups of patients, RBCs were exposed to the trauma associated with motorized instruments as well as the suction produced by the vacuum pump. In the cemented group, RBCs were also exposed to MMA. During MMA insertion, local temperature may exceed 100°C, but this increased temperature is thought not to cause postoperative damage to RBCs collected in the autotransfusion system. The literature has no data that can be used to analyze what effect local temperature during cement insertion may have on RBC damage, but the effects of short heat exposure on human RBCs are known. In one study, lethal injury did not occur until exposure at 70°C for 300 milliseconds or more, and sublethal injury did not occur until exposure at 60°C for 1200 milliseconds.[6] In vitro studies have also shown that MMA concentration above 5 mg/mL caused leukocyte disintegration within 1 minute.[7]

These high temperatures do not cause injury of RBCs collected after surgery. No study in the literature has compared survival of RBCs collected during cemented or uncemented THA.

The effect of MMA on RBCs is unknown. MMA levels in shed blood are highest 5 minutes after drain insertion.[8] MMA probably causes RBCs to become more fragile, and their survival (measured with ^{51}Cr activity) might be lower 48 hours after reinfusion of shed blood. Our study results confirmed that MMA in shed blood after THA may cause RBC damage, but the difference in ^{51}Cr activity levels after

7 and 15 days of reinfusion was not statistically significant. The T_{50} was also similar.

We followed the activity of labeled RBCs for at least 20 days. We found that T_{50} for autotransfused RBCs from unwashed shed blood was 21 days (cemented group) and 22 days (uncemented group), which equal the T_{50} ^{51}Cr reported for banked autologous blood, shed mediastinal blood, and homologous blood (Table). However, T_{50} ^{51}Cr is slightly shorter than the time (25-33 days) reported for autologous RBCs that have not been exposed to operative trauma, suction, collection, filtering, and reinfusion.

Conclusions

The T_{50} ^{51}Cr of 21 or 22 days is likely for RBCs salvaged from post-THA unwashed shed blood stored for up to 6 hours at room temperature before reinfusion. Correction for a possible "early loss" elution phenomenon could lead to an increase in T_{50} ^{51}Cr. Our results are similar to those in the literature for autologous blood collected during or after surgery and for peripheral blood.[9-12] Two studies have analyzed RBC viability and survival after total joint arthroplasty, but each involved only a few patients (3 in one case, 5 in the other).[13,14] RBC viability was normal according to one of these studies,[13] and, according to the other,[14] the half-life of ^{51}Cr-labeled RBCs estimated before joint arthroplasty did not change after surgery.

Blood salvaged after surgery is not significantly damaged. In the case of THA, survival of RBCs from blood salvaged and reinfused after surgery is similar to survival of RBCs from other autologous and allogeneic blood sources. In this study, there were no statistically significant differences in potassium levels, free hemoglobin levels, or RBC survival between cemented and uncemented THA groups. Our study results confirmed that washing blood collected after surgery is not necessary.

There were no statistically significant differences in blood loss and blood transfusion rates between the cemented and uncemented groups. Six hours after THA, blood loss was increased in the uncemented group, but, after 48 hours (when postoperative drains were removed), there was no difference in total blood loss between the groups.

In this study, we compared postoperative autotransfusion in cemented versus uncemented THAs. Autologous blood collected after surgery was not washed. Although our results showed that washing blood collected after surgery is not necessary, definitive recommendations to wash or not to wash blood should be held until further investigations are conducted to compare potassium levels, free hemoglobin levels, and RBC survival in washed and unwashed blood.

Authors' Disclosure Statement

The authors report no actual or potential conflict of interest in relation to this article.

References

1. Grosvenor D, Goyal V, Goodman S. Efficacy of postoperative blood salvage following total hip arthroplasty in patients with and without deposited autologous units. *J Bone Joint Surg Am*. 2000;82(7):951-954.
2. Friederichs MG, Mariani EM, Bourne MH. Perioperative blood salvage as an alternative to predonating blood for primary total knee and hip arthroplasty. *J Arthroplasty*. 2002;17(3):298-303.
3. Blevins FT, Shaw B, Valeri CR, Kasser J, Hall J. Reinfusion of shed blood after orthopaedic procedures in children and adolescents. *J Bone Joint Surg Am*. 1993;75(3):363-371.
4. Faris PM, Ritter MA, Keating EM, Valeri CR. Unwashed filtered shed blood collected after knee and hip arthroplasties. A source of autologous red blood cells [published correction appears in *J Bone Joint Surg Am*. 1991;73(10);1580]. *J Bone Joint Surg Am*. 1991;73(8);1169-1178.
5. Mollison PL. Methods of determining the posttransfusion survival of stored red cells. *Transfusion*. 1984;24(2):93-96.
6. Fildes J, Fisher S, Sheaff CM, Barrett JA. Effects of short heat exposure on human red and white blood cells. *J Trauma*. 1998;45(3):479-484.
7. Dahl OE, Garvik LJ, Lyberg T. Toxic effects of methylmethacrylate monomer on leukocytes and endothelial cells in vitro [published correction appears in *Acta Orthop Scand*. 1995;66(4):387]. *Acta Orthop Scand*. 1994;65(2):147-153.
8. Healy WL, Wasilewski SA, Pfeifer BA, et al. Methylmethacrylate monomer and fat content in shed blood after total joint arthroplasty. *Clin Orthop*. 1993;(286):15-17.
9. Ray JM, Flynn JC, Bierman AH. Erythrocyte survival following intraoperative autotransfusion in spinal surgery: an in vivo comparative study and 5-year update. *Spine*. 1986;11(9):879-882.
10. Thorley PJ, Shaw A, Kent P, Ashley S, Parkin A, Kester RC. Dual tracer technique to measure salvaged red cell survival following autotransfusion in aortic surgery. *Nucl Med Commun*. 1990;11(5):369-374.
11. Grønborg H, Otte KS, Jensen TT, Marving J, Solgaard S, Rechnagel K. Survival of autotransfused red cells. 51Cr studies in 10 knee arthroplasty patients. *Acta Orthop Scand*. 1996;67(5):439-442.
12. Umlas J, Jacobson MS, Kevy SV. Survival and half-life of red cells salvaged after hip and knee replacement surgery. *Transfusion*. 1993;33(7):591-593.
13. Colwell CW Jr, Beutler E, West C, Hardwick ME, Morris BA. Erythrocyte viability in blood salvaged during total joint arthroplasty with cement. *J Bone Joint Surg Am*. 2002;84(1):23-25.
14. van Iperen CE, van de Wiel A, de Bruin M, Marx JJ. Total hip replacement surgery does not influence RBC survival. *Transfusion*. 2000;40(10):1235-1238.