Survival of autotransfused red cells

^{51}Cr studies in 10 knee arthroplasty patients

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We determined the long-term survival of red blood cells collected postoperatively from the surgical drains, filtered and autotransfused with the Constavac™ Blood Conservation System. 10 patients with knee arthrosis were treated with cementless total knee arthroplasty and postoperatively connected to the autotransfusion system. Shed blood was collected for 6 hours postoperatively and then reinfused. Before reinfusion, a fraction of the blood shed was radiolabeled with chromium-51 (^{51}Cr). For a postoperative minimum period of 40 days the activity of ^{51}Cr was measured in frequent venous blood samples. The time from 100% to 50% activity of the isotope (T_{50}Cr) was 21 days, equal to that reported for banked autologous blood.

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Autotransfusion (AT) can be done with cell-savers to reduce blood loss intraoperatively, and collection systems (Constavac™/CBC, Solcotrans®, OrthEvac®) salvaging postoperatively shed blood.

Comparing autotransfused and non-autotransfused patients, most studies (Bovill et al. 1986, Groh et al. 1990) concentrate on analyses of the number of homologous transfusions (HT). However, the need for HT following surgery is multifactorial. As yet, few studies have addressed the quality of the autotransfused blood itself.

Survival studies on red blood cells (RBC) collected intraoperatively with cell-savers have estimated the lifespan to be normal (Ray et al. 1986, Thorley et al. 1990).

We studied the long term survival of autotransfused RBCs from shed blood following a unilateral total knee replacement (TKR).

Patients

Inclusion

The experimental protocol was approved by the local Ethics Committee. Written and informed consent was obtained from patients, according to the Declaration of Helsinki-II and recommendations from the International Commission on Radiological Protection (ICRP 1988). The inclusion criterion was: primary arthrosis of the knee, scheduled for unilateral, cementless total knee arthroplasty. The exclusion criteria were: malignant disease of any kind, hematological diseases, including coagulopathy, rheumatoid arthritis, previous fracture involving the knee joint, previous tibial osteotomy. 12 patients entered and 10 patients completed the study: 5 men and 5 women, median age 71 (60–78) years. 1 patient was excluded within the first 24 hours because of continuous bleeding from the wound and the need for surgery and HT. One other patient had 2 HTs within the first 48 hours.

Preoperative evaluation

Preoperative screening for bleeding disorders was performed by monitoring APTT, bleeding time, Factors II-VII-X and thrombocyte count. Screening for cold agglutinins (4 °C) was also done, as salvaged blood was stored in the CBC collection reservoir at room temperature and the presence of cold agglutinins might lead to complications.

Methods

Surgery

All patients were treated with unilateral, cementless TKR, using the AGC-2000™ Total Knee System without resurfacing of the patella (Biomet Inc®, USA). 8 patients had spinal anesthesia, 2 underwent general anesthesia. Surgery was performed using laminar air flow and antibiotic prophylaxis was given as a single preoperative intravenous dose of dicloxacillin (1.0 g), approximately 30 minutes before ap-

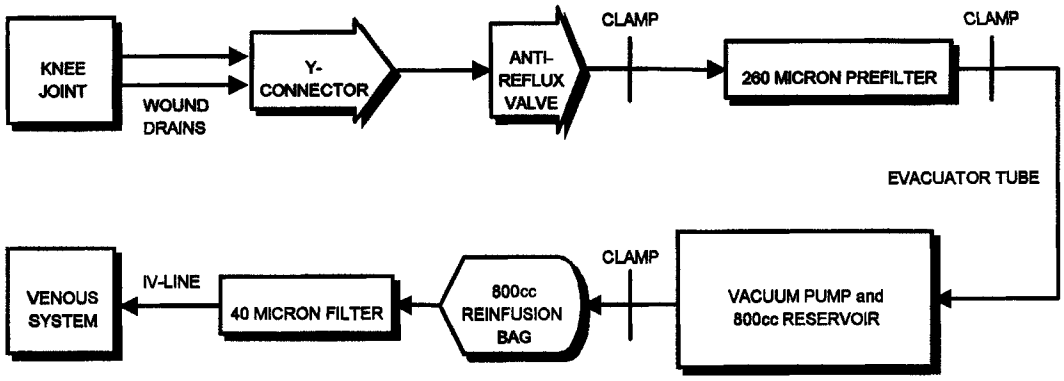

Figure 1. The ConstaVac™ Blood Conservation System.

plication of the tourniquet. The tourniquet was deflated after skin closure and application of circular bandages. Low molecular weight heparin (Logiparin®) was used as thromboprophylaxis. Volume deficits were substituted with normal saline. Homologous transfusions were given only when severe signs of anemia were present, not on the basis of a low hemoglobin level alone. No continuous passive motion apparatus was used. Both surgical drains were removed 24 hours postoperatively.

The autotransfusion system

The Constavac™ Blood Conservation (CBC) System (Stryker® Instruments, USA) is a closed, autologous blood recovery system designed for postoperative collection, filtering and reinfusion of shed blood (Figure 1). The vacuum pump provides an adjustable constant vacuum, kept below 100 mmHg to avoid excessive hemolysis, according to the recommendations of the American Association of Blood Banks (AABB 1990).

The CBC system is connected to two CH14 intraarticular drains during the finishing stage of the operation and active suction is not initiated until after postoperative removal of the tourniquet.

When collection of shed blood in the reservoir is completed, the blood flows through a 260 micron filter to the blood bag, from which autotransfusion through a 40 micron filter (Codan, Germany) is done. Within the 6-hour collection time-limit, collection and autotransfusion cycles can be performed simultaneously. In our study, no patient bled more than the collective capacity of the reservoir and bag allowed (1.6 L) during the first 6 postoperative hours, which permitted equal collection periods for all patients.

Chromium-51 labeling of erythrocytes

Labeling of the erythrocytes with chromium-51 was done according to the recommendations of the International Committee for Standardization in Hematology (ICSH 1971). Before the labeling started, 10 mL of venous blood were drawn from the patient. The hematocrit was measured and the sample was labeled "Zero".

From the CBC transfusion line, 17.4 mL of shed blood ready for autotransfusion were drawn into a 20 syringe containing 2.6 mL of glucose citrate and mixed gently. The 20 mL of citrated blood were centrifuged at 2800 RPM for 7 minutes. The volume of the plasma fraction was measured and the plasma was subsequently discarded. Radioactive sodium chromate (5.6 MBq of $Na_2Cr^{51}O_4$ in an isotonic sodium chloride solution, Amersham, Denmark) was added to the packed erythrocytes and the mixture was incubated at 37 °C for 15 minutes. The volume deficit compared to that before discarding the plasma was compensated for by adding isotonic sodium chloride, followed by gentle mixing, centrifugation and discarding of the supernatant. This saline washing was repeated twice. After a subsequent fourth addition of isotonic sodium chloride, 10 mL of the ^{51}Cr-labeled RBCs were weighed and reinjected intravenously (autotransfused). An additional 1 mL was weighed and mixed with 499 mL of isotonic sodium chloride. This sample was saved and labeled "Standard".

20 minutes after reinjection of the radiolabeled RBCs, 20 mL of venous blood were drawn (heparinized) from the patient (sample labeled "100%"). 10 mL were used for measuring the hematocrit and an additional 10 mL for counting emission of gamma-photons. The "100%" and subsequent samples were analyzed in the gamma-counter after lysis with saponin. All samples were counted at one setting for each patient after the last blood sample was taken, thus obviating the need to correct for physical decay.

Venous blood samples were drawn 20 minutes after reinfusion of the radiolabeled erythrocytes (100%). Blood samples were drawn 3 times weekly until 50%

Table 1. Hourly drainage volumes during the first 6 postoperative hours. The drainage volumes from t = 6 hours (collection for reinfusion terminated) and until t = 24 hours (drains removed), median (range), are also shown

Drainage	Volume (mL)
0–1 h	210 (0–360)
1–2 h	155 (20–340)
2–3 h	90 (20–200)
3–4 h	75 (20–160)
4–5 h	50 (20–110)
5–6 h	40 (10–80)
0–6 h	660 (210–1020)
0–24 h	910 (310–1520)
Autotransfused	560 (110–920)
Retrieval fraction (%) [a]	58.1 (35.5–67.3)

[a] Retrieval fraction: Reinfused volume as percentage of total drainage (0–24 hours)

activity of ^{51}Cr was reached, followed by samples drawn weekly until less than 33% activity remained in the blood.

The physical half-life of ^{51}Cr is 27.7 days. The effective dose-equivalent was estimated as less than half of the radiation dose sustained during an ordinary radiograph of the spinal column (0.4 mSivert) (Amersham 1985).

Results

Hourly drainage volumes decreased from more than 200 mL to approximately 40 mL during the first 6 postoperative hours (Table 1), the maximum collection period allowed for the CBC (American Association of Blood Banks 1990). Note that the autotransfused volume is 100 mL less than the total volume collected, since the collection reservoir retains 100 mL (including the fat-containing supernatant) when emptied into the blood bag.

Less than 33% chromium activity in the blood was reached only after more than 40 days postoperatively (Figure 2). The time until 50% activity of ^{51}Cr in blood (corrected for physical decay, but not for elution) was determined by monoexponential fitting (Figure 3). The time from 100% activity to 50% activity was 21 days.

Discussion

A retrieval fraction of 58% is somewhat lower than fractions reported by some (Kristensen et al. 1992) using Solcotrans® and equal to that reported by others using Constavac™/CBC (Martin et al. 1992). A lower retrieval fraction can be explained in part by the 100 mL retained in the CBC-system.

We followed the RBCs for at least 40 days and found $T_{50}Cr$ for autotransfused erythrocytes from unwashed shed blood to be 21 days, which is equal to $T_{50}Cr$ reported for banked autologous blood (Högman et al. 1983) (Figure 3). However, $T_{50}Cr$ for both are slightly shorter than the normal values of 25–33 days reported for autologous RBCs that have not been exposed to the collection, filtering and reinfusion procedure of an autotransfusion device (Peters and Lewis 1991). In contrast, Wixson et al. (1994) estimated a $T_{50}Cr$ of 40 days. Their results, however, were based on studies in 16 patients followed for only 2 weeks,

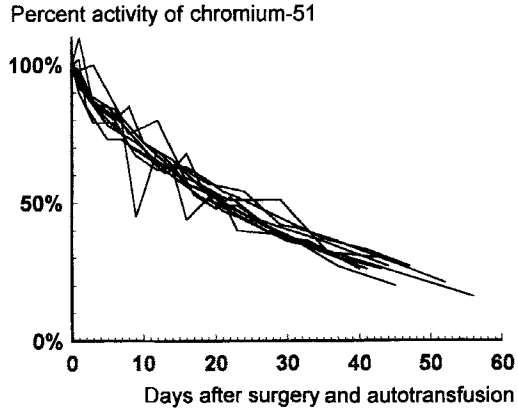

Figure 2. Chromium-51 activity in postoperative venous blood samples following reinfusion of radiolabeled shed blood. Activity corrected for physical decay, but not for elution.

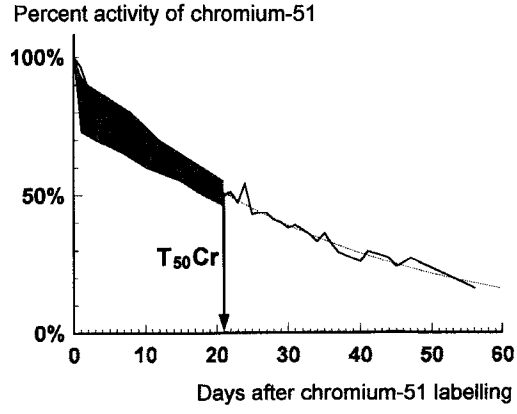

Figure 3. Exponential fit on the median curve ($T_{50}Cr$ = 21 days) for the autotransfused red cells, compared to the normal range of survival curves for chromium-labeled autologous erythrocytes stored in SAGM solution for 35 days. Activity of chromium-51 corrected for physical decay, but not for elution.

having various types of joint replacements (hip, knee, bilateral knee) and supplemental autologous transfusions of preoperatively donated and intraoperatively collected blood.

Correction for physical decay was done by simultaneous analysis of all samples from a patient. At the end of their life span, RBCs release their content of ^{51}Cr when they hemolyze, but a small fraction of ^{51}Cr leaks from intact and living RBCs. This elution occurs continuously and at a constant rate at approximately 1% per day (Peters and Lewis 1991). In addition to this elution, an additional fraction of up to 10% of the ^{51}Cr may be lost within the first 24 h. This early loss has not been explained. If it does not continue beyond the first 2 days, it is often viewed as an artefact, in the sense that it does not denote an increased rate of lysis in vivo, and it can usually be ignored (Peters and Lewis 1991). We have chosen not to correct for an initial steep drop in the survival curve (Figures 2 and 3), which could be explained as an early loss of the type described.

RBCs labeled and reinfused in our study are distributed in 3 compartments: (1) The bloodstream, i.e., the living cells analyzed in the gamma-counter by frequent venous blood samples throughout the study; (2) the drainage reservoir, i.e., the cells lost via the surgical drains from the 6th postoperative hour until the drains were removed 24 hours postoperatively. We found that a (small) continued loss of labeled RBCs takes place after the first 6 postoperative hours. (3) Finally, it is highly likely that labeled RBCs are also trapped in the wound hematoma in the knee region. These cells are lost to further measurements by the gamma-counter and are consequently assumed to be dead, following a shortened life-span. The quantity of this initial trapping of RBCs is not known.

In conclusion, a $T_{50}Cr$ of a minimum of 21 days is likely, for salvaged and filtered RBCs from unwashed shed blood stored for up to 6 hours at room temperature prior to reinfusion. Correction for a possible "early loss" elution phenomenon, the initial trapping and the extracorporal loss of labeled cells could lead to an increase in the $T_{50}Cr$. Consequently we find that the survival of autotransfused RBCs is about the same as the survival of autologous banked RBCs and probably longer than the survival of homologous banked RBCs.

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