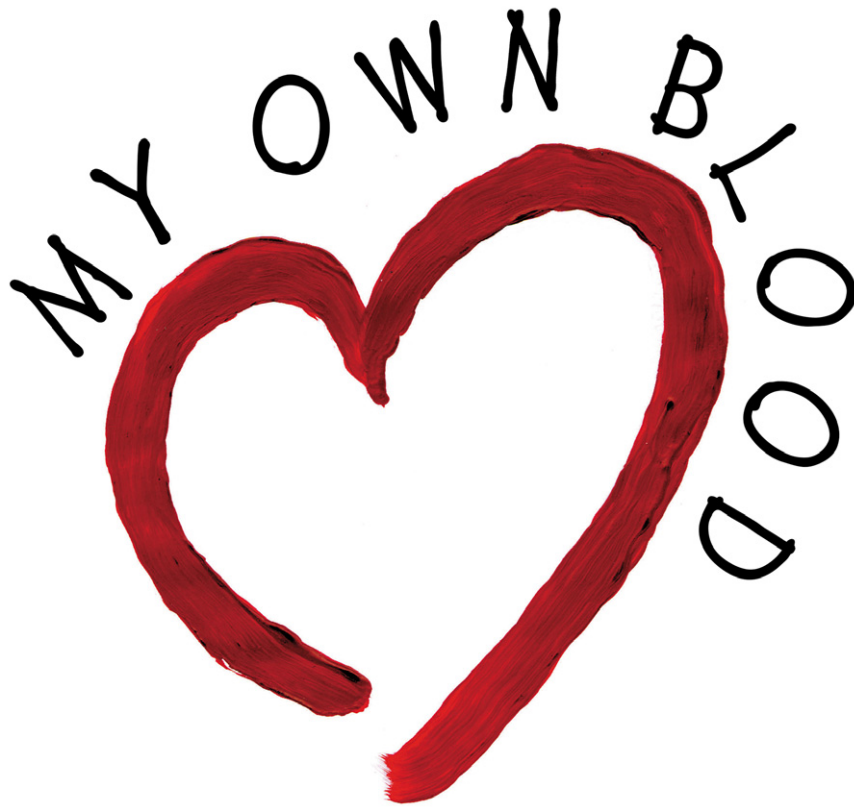


# Autologous Blood Transfusion

A review of opinions concerning autotransfusion of shed unwashed blood



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## **Autologous blood transfusion**

There are many opinions concerning autotransfusion of shed unwashed blood. Below I have compiled part of the extensive literature in this field. I have searched for recent articles in an attempt to cover the most up to date and important research. The investigators in the studies presented below persuasively argue against, as well as for the use, of this method and it is my hope that this compilation will provide a balanced picture of the differing current views in this field.

In summary, it may be said that washed autologous blood will contain lower levels of breakdown products and complement factors than shed, unwashed autologous blood. It seems to be a consistent finding that patients receiving unwashed blood cells will exhibit elevated levels of FSP and D-dimers but that these are normalised within the course of 24 hours and are not a sign of DIC nor lead to clinically significant coagulopathies. An activation of the complement cascade and interleukins in the shed unwashed blood is also a common finding.

However, the clinical risks in autotransfusion of unwashed shed blood seem to be very limited when the amount of reinfused blood is not excessive and the reinfusion is performed within 6 hours. The potential drawbacks of a system using unwashed blood should be compared to the costs and relatively complex handling of systems for washing shed blood.

It is, as always, ultimately up to the clinician in charge to use whatever she or he thinks is the optimal system in any given situation.

Mölndal, September 2001  
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## **Aortic and Cardiac Surgery**

**Schaff and co-workers (1978)** conducted a randomised prospective study of patients undergoing cardiac surgery. Sixty-three patients received autologous shed mediastinal blood post-operatively and 51 patients, who served as controls, received bank blood. No difference was found between the groups with respect to total post-operative bleeding but requirements for transfusion of stored bank blood were reduced by 50% in the autologous group. The shed blood was defibrinogenated but contained significantly more platelets and clotting factors than bank blood. No differences were seen between the two groups in PT, PTT, euglobulinlysis or levels of factors VII and IX. At 2 to 4 hours after transfusion the plasma fibrinogen levels were decreased in the study group compared to controls, but still remained within the normal range. However, this difference was not seen immediately after transfusion or at 24 hours after operation. Plasma haemoglobin levels were similar in both groups. No evidence of DIC was found in the autologous patients.

**Johnson and partners (1983)** found that patients undergoing cardiac surgery required significantly less banked blood if they underwent autologous transfusion of unwashed shed mediastinal blood post-operatively. A group of 168 patients who received autologous blood transfusion was compared to a group of similar size that did not.

**Hartz and colleagues (1988)** investigated the use of cardiectomy reservoirs as a post-operative blood collection system for autotransfusion in coronary bypass surgery in a group of 21 patients. The concentration of fibrinopeptide A (released as thrombin cleaves fibrinogen), was elevated and fibrinogen, factor VIII and platelets were depleted. The level of B $\beta$ -15-42 peptides (generated when fibrin is lysed by plasmin) was also increased in the reservoir blood. After infusion of the shed blood, the blood samples showed no signs of DIC (i.e. no increased fibrinopeptide levels or reduced levels of fibrinogen or factor VIII). Neither was there an induction of fibrinolysis as there was no increase in B $\beta$ -15-42 peptides in the patients' blood. The authors conclude that the procedure is safe and practical.

**Griffith and collaborators (1989)** recommend the washing of blood before autologous reinfusion as unwashed blood may confuse the interpretation of tests for DIC and that this may lead to unnecessary blood component use. They had found an increase in serum FDP but no other differences in coagulation tests in a study where 21 patients received unwashed and another 17 patients received washed shed mediastinal blood after cardiac surgery. No clinical problems of increased bleeding were observed, but the authors maintain that this is difficult to demonstrate in any study because of patient variability.

**Lawrence-Brown and colleagues (1989)** undertook a study of unwashed and washed shed blood from 10 patients undergoing aortic surgery for abdominal aneurysms and aorto-iliac bypasses. The D-dimer levels were increased 85 times in unwashed blood whereas they were normal in washed blood. It was interpreted as an indication of activation of the coagulation and fibrinolytic systems. It is argued that the markedly elevated D-dimer levels may be a risk factor precipitating disseminated intravascular coagulation (DIC). Coagulopathy is a common complication with larger volumes of blood transfusion and the argument for filtered, unwashed blood or washed blood is confused by other factors. The question of whether to use washed or unwashed autologous blood therefore remains open, according to the authors. They conclude by stating that because fibrin degradation products interfere with the aggregation of platelets and the polymerisation of fibrin, they may have the potential to cause a coagulopathy. They therefore suggest that the use of washed autologous blood increase safety.

**Roberts et al. (1991)** investigated 96 consecutive patients undergoing aortocoronary bypass operation who were autotransfused with unwashed shed mediastinal blood post-operatively. The control group was made up of 78 consecutive historical cases that had not received autotransfusion. The authors found no decrease in the amount of banked blood required or percentage of patients who received transfusions in the autologous group. Serum creatinine levels were not different between the two groups at 7 days post-operatively, nor were haemoglobin levels at 4 and 7 days post-operatively.

**de Haan and collaborators (1993)** did a combined prospective randomised clinical study and an *in vitro* study in connection with autologous transfusion of shed mediastinal unwashed blood. They found that retransfusion of shed blood increased the total post-operative blood loss by 43%. Increasing concentrations of both fibrinogen degradation products and tissue-type plasminogen activator stimulating activity in shed blood correlated significantly with higher post-operative bleeding tendency. Fibrin monomers can bind to platelets and cause a high level of plasmin activity localised on the platelet surface resulting in platelet dysfunction and damage. The authors recommend that blood from the wound area, which is the main source for fibrin monomers should be retransfused in limited quantities, not retransfused at all or washed by a cell saver.

**Long and associates (1993)** present the results of a study of reinfusion of washed versus unwashed blood intra-operatively during abdominal aortic aneurysm repair in 26 prospectively randomised patients. Registration of clinical and haematologic parameters was undertaken pre-operatively and directly post-operatively and at 12 and 18 hours. Peri-operative survival was 100% for both groups. Total blood loss and volume autotransfused was significantly greater in the unwashed cell group. (In a discussion following the article, Dr Long writes

that the unwashed blood was anticoagulated twice, which may be the reason for the prolonged bleeding, whereas in the washed group the heparin was washed out). No difference between the groups was seen at any time regarding haemoglobin, fibrinogen, prothrombin time and partial prothrombin time. In the unwashed cell group fibrin split products and Di-dimer levels were significantly higher post-operatively. The serum free haemoglobin levels were higher in the unwashed cell group immediately post-operative but this difference was not seen at 12 and 18 hours. In spite of haptoglobin levels being low in the unwashed group post-operatively, no peri-operative renal failure was noted. Homologous blood use was not significantly different between the two groups. One patient in the unwashed cell group developed DIC after reinfusion of more than 3000 ml shed blood. The authors speculate that the occurrence of DIC could be the consequence of the large volume reinfused, but at the same time say that such changes have been reported at larger volumes of autotransfused washed blood, since this is devoid of coagulation factors and platelets and may produce dilutational coagulopathy. In spite of the elevated levels of FSP and D-dimers in the unwashed cell group, this was not associated with clinical bleeding and thought not to constitute a clinical diagnosis of DIC in the absence of bleeding, and the authors do not think this is an adequate reason to advocate cell washing over direct reinfusion of shed blood.

**Axford and collaborators (1994)** undertook a prospective study of 32 patients, undergoing open heart surgery, who were randomised to either of two groups. The groups were followed until 7 days post-operatively. Group 1 received non-washed mediastinal blood and group 2 received liquid preserved packed red blood cells for transfusion therapy post-operatively. The authors found no difference between the groups with respect to patient age, type of procedure performed, pre-operative or post-operative left ventricular ejection fraction, duration of the cardio-pulmonary bypass, frequency of post-operative myocardial infarction, need for post-operative ventilatory support, frequency of low cardiac output syndrome, post-transfusion febrile reactions or serum creatinine levels. The average volume of shed mediastinal blood was  $710 \pm 90$  ml. Analysis of the blood to be infused demonstrated that hematocrit value, cellular haemoglobin content and platelet count were all significantly greater in banked blood. Shed blood contained more factor VIIIc activity, antithrombin III activity, higher protein C levels, more plasminogen activity and more antiplasmin activity. No differences were noted with respect to plasma haemoglobin, fibrinogen, fibronectin or the amount of particular microaggregates. The shed blood, in addition, had elevated levels of fibrin degradation products and D-dimer. Analysis of the patients' haematologic variables demonstrated no difference between the groups with respect to hematocrit, haemoglobin level, plasma haemoglobin level, white cell blood count, platelet count or plasma microaggregate level either at baseline or any other subsequent time point in the study. No significant differences between the groups were noted with respect to

the patients' plasma protein variables, including factor V, factor VIIIc, antithrombin III activity, fibrinogen or fibronectin levels. The level of protein C was significantly greater in the group receiving shed blood until the first post-operative day, but after that no difference was noted. The bleeding time was never significantly different between the two groups at any time throughout the study and was not affected by transfusion with either unwashed shed mediastinal or banked blood. The same was true for plasminogen levels and antiplasmin levels. Finally there was no difference between the groups with respect to blood loss. The authors conclude that shed mediastinal blood undergoes extensive coagulation and clot lysis within the mediastinum and pleural spaces before collection but that the transfusion of approximately 700 ml of unwashed shed mediastinal blood is safe. They recommend that modest amounts of mediastinal blood be used routinely as the simplest and first source of blood for transfusion and blood volume support in the post-operative management of all cardiac surgery patients.

**Bartels et al (1996)** undertook a prospective randomised study of 32 patients undergoing elective major aortic surgery, receiving intra-operative autotransfusion of either filtered unwashed blood or washed blood. Coagulation, haematologic and clinical parameters were followed pre-operatively and until 24 hours after autologous transfusion. Levels of haemolytic degradation products (bilirubin, free haemoglobin, and lactic dehydrogenase) were also measured. The authors found no differences between the two groups concerning intra-operative blood loss, amount of retransfused blood, intra-operative transfusions or requirement of either homologous or pre-donated autologous blood. No negative effects on the functions of vital organs (renal, pulmonary, and cardiac) were observed in the studied population. Analysis revealed more haemolysis, higher levels of platelets, D-dimers and FDP and lower haematocrit and haemoglobin levels in the unwashed blood. No further differences regarding other coagulation parameters (fibrinogen, partial thromboplastin time, and prothrombin time) were observed. Samples taken from the patients' blood revealed no differences concerning erythrocyte count, platelet count, and haemoglobin or serum creatinine at any time. Levels of free haemoglobin and lactic dehydrogenase were higher in the group retransfused with unwashed blood at 1 hour after retransfusion, but this difference was not seen during the rest of the follow-up period of 24 hours. The D-dimer levels were higher in the group receiving unwashed blood at 1 and 6 hours after retransfusion but not at later observation times. The levels of FDP were not different between the groups. The authors state that only a low volume was retransfused in this study and that clinical, haematologic or haemostatic disturbances may manifest themselves only if larger volumes of blood are retransfused. It was concluded that washed blood seems to be of better quality regarding levels of haemolytic degradation products and coagulation disturbances, but that larger studies are necessary to evaluate the significance of these results on mortality and morbidity after retransfusion.

**Schulze and co-workers (1996)** studied blood from chest drains after cardiac surgery and compared this to systemic blood. No autotransfusion was undertaken. Patients were divided into two groups: Group A with low blood loss post-operatively (up to 300 ml) and group B with high blood loss (up to 1000 ml). Haemolysis was twice as pronounced in group A. PMN elastase levels increased steadily up to 4 hours after surgery and were twice as great in group A. A decrease in factor XII was noted both in systemic blood and in drainage blood, but was more pronounced in the former at 2 hours. Kallikrein-like activity in the chest-drainage blood had doubled in both groups but was more pronounced in group A. Thrombin-antithrombin III complexes were very high in drainage blood from both groups. This was also the case for D-dimers. In systemic blood the levels of these parameters were normal. The values for tissue-plasminogen activator (t-PA) were normal in both systemic and drainage blood. In their final conclusion the authors state that the results pointed to high haemolysis and high activation of granulocytes; an increased activation of the contact-phase system through the consumption of factor XII and an increase in kallikrein-like activity; a great increase in the thrombin-antithrombin III complex as a marker for advanced coagulation and high fibrinolytic activity as measured by increased D-dimer levels. They recommend autotransfusion only in cases of high blood loss and that it should be limited to the first 4 post-operative hours.

**Vertrees and co-workers (1996)** studied the effects of post-operative infusion of shed mediastinal blood in a prospective, randomised study of 40 patients. Twenty of the patients received filtered shed mediastinal blood and 20 patients washed shed mediastinal blood (if sufficient volume was present) post-operatively. The follow-up period was 5 hours post-operatively. The authors found that blood lost post-operatively at 3, 4 and 5 hours was significantly greater for the patients receiving unwashed blood, and they concluded that there may be increased bleeding after infusion of unwashed blood. Patients in this group also had elevated levels of FSP (fibrin split products) and D-dimer after infusion. It was attributed to, in part the high levels infused with the shed blood but may also be explained by increased fibrinolytic activity. Thromboelastography (TEG) indicated abnormal coagulation in that clotting was prolonged and a softer clot was formed after direct infusion of unprocessed shed mediastinal blood. However, prothrombin time, partial prothrombin time and platelet count remained normal. Increases were noted for neutrophils, creatine kinase, lactate dehydrogenase and plasma free haemoglobin as well as more febrile episodes (55% vs. 20%) in the unwashed group. The researchers conclude that, although post-operative blood loss was not excessively high in either group, they saw a definite tendency for increased blood loss and derangement of the coagulation mechanism, as evidenced by TEG, in patients reinfused with unwashed blood. The most likely explanation for this, the authors think, is excessive fibrinolytic activity induced by the increased levels of D-dimers and FSP as a result of direct infusion of unwashed shed mediastinal blood.

**Flom-Halvorsen and collaborators (1999)** present a series of 40 patients undergoing coronary bypass surgery with extensive blood laboratory investigations in connection with autologous transfusion of shed mediastinal blood. Another series of 4916 patients has been followed clinically after autologous transfusion using the same protocol as the 40 patients. In some cases large amounts were autotransfused, in one patient up to 5375 ml. A total absence of fibrinogen was noted in the shed mediastinal blood and taken as a sign of complete coagulation. An extreme thrombin formation was seen in the shed mediastinal blood together with a reduced level of antithrombin. This might indicate an insufficient clotting inhibition, but the test for thrombin, however, was negative. There was a presence of protein C that might add to the safety of the autotransfusion of shed mediastinal blood. In circulating plasma after autotransfusion high levels of TAT (thrombin-antithrombin complexes), PF<sub>1,2</sub> (prothrombin fragment 1.2),  $\beta$ -TG ( $\beta$ -thromboglobulin, indicative of platelet activation) and PAP (plasmin- $\alpha_2$ -antiplasmin) were seen. However PF<sub>1,2</sub> and TAT levels returned to nearly pre-operative levels 18 hours after surgery. The inflammatory markers in plasma, C3bc (C3 activation products), TCC (terminal complement complex) and TNF- $\alpha$  (tumour necrosis factor  $\alpha$ ; may impair wound healing over time by suppressing collagen synthesis and collagen gene expression) and IL-6 (interleukin-6) were all elevated after autotransfusion. However all had returned to pre-operative levels at 18 hours post-operatively, except IL-6. Despite the high levels of fibrinolytic parameters in the shed blood, like PAP and D-dimer, disturbing bleeding problems were rare. No correlation was found between the plasma free haemoglobin concentration in the patients and in the mediastinal shed blood. The authors recorded no problems with impaired wound healing or increased infection rate despite the elevated levels of TNF- $\alpha$ . It is suggested that regulatory mechanisms may neutralise the infusion of these components. The authors conclude by stating that “the present experience with nearly 5000 consecutive patients undergoing coronary bypass with a consistent autotransfusion protocol could demonstrate a high level of safety without any significant transfusion-related side effects...”

**Martin et al. (2000)** performed a prospective randomised study on 198 patients undergoing open heart surgery with CPB (cardio-pulmonary bypass) who were divided into 2 groups. One group received autotransfusion of shed mediastinal blood after the operation and the other group did not. Among the autotransfused patients 55% needed homologous blood after surgery compared to 73% in the other group. However, the amount of blood collected post-operatively was higher in the autotransfused group. Coagulation parameters (platelet count, prothrombin time and partial thromboplastin time) and complication rates were similar for both groups. Wound infections were not observed in the autotransfused group, nor were any other significant side effects noted. The authors suggest that 1 in 2 patients undergoing this type of surgery would benefit from reinfusion of shed mediastinal blood. The patients who

would benefit most from autotransfusion are male, anaemic and with lower body surface area. The authors hypothesise that the cause of increased shed blood in the autotransfused patients could be related to the greater mechanical efficacy of the autotransfusion closed drainage system compared with the effect of soft sump drains used in the control group of patients.

**Schmidt (2000)** in his PhD thesis presents a thorough literature review on autologous blood transfusion after coronary bypass surgery as well as his own results from several studies. Among the advantages of autologous blood transfusion the author lists elimination of risk of transfusion reactions, disease transmission and alloimmunisation, safe transfusion in patients with alloantibodies or rare blood subgroups and a reduction in demand for allogeneic blood. The observed variability in post-operative bleeding in the literature on blood transfusion requirements may reflect surgical technique and meticulousness in surgical haemostasis. Post-operative bleeding is the largest source of blood loss following cardiac surgery. When blood is shed clot formation is initiated with consumption of coagulation factors followed by fibrinolysis due to activation of kallikrein, factor XII and tissue-plasminogen activators. This means that the defibrinogenated mediastinal blood can be autotransfused without the addition of anticoagulants. In studying autologous transfusion of unwashed shed mediastinal blood, several aspects of this practice were evaluated. He found that autologous transfusion of unwashed shed mediastinal blood reduced the risk of receiving allogeneic blood from 55% in the controls to 28% in the study group. In connection with this the author has calculated that the type II error (accepting a false difference) may amount to about 50% in studies with sample sizes of less than 50 patients. It was found that RBCs in shed mediastinal blood have normal morphology and that the osmotic resistance of RBCs was not different from those in circulating blood, whereas osmotic resistance in stored SAGM (Saline, Adenine, Glucose, Mannitol) blood was much lower, suggesting that salvaged RBCs have been less damaged than stored RBCs. The survival of <sup>51</sup>Cr-labelled shed mediastinal RBCs and circulating RBCs did not differ. Stored blood undergoes depletion of 2,3-DPG. This substance regulates the affinity for oxygen to RBCs so that a decrease will cause increased affinity for oxygen and consequently the ability to release oxygen to the tissues is reduced. The author showed that the oxygen affinity of shed mediastinal blood does not differ from the patients' circulating blood. This was in contrast to the patients in the control group where a decrease in 2,3-DPG levels was seen following transfusion of stored blood. In critically ill patients (i.e. coronary artery disease) transfusion of RBCs with normal oxygen affinity may be important. No increase in free haemoglobin (FHB; which is filtered by the kidney and may lead to renal dysfunction) was observed after autologous transfusion. A decrease in haptoglobin (which binds FHB and transports it to the liver) levels was seen in both the study group and controls (but more pronounced in the former) at 18 hours post-operatively but not after the 2<sup>nd</sup> post-operative day.

Renal function, as measured by creatinine and urea levels in serum, remained normal in both groups. High levels of D-dimer were found in the shed mediastinal blood. Regression analysis demonstrated linearity between the serum D-dimer levels and the amount of autotransfused shed mediastinal blood in the study group. No changes were found in clotting factors or coagulation tests (platelet count; factor II, VII and X; fibrinogen; modified thrombin time; APTT) but thrombin time was greater in the autotransfusion group, probably due to the fact that this test is more sensitive to heparin than is APTT, which, as stated above, remained normal. The author believes that the high plasma levels of D-dimer in the autotransfused patients simply indicate the high content of D-dimer in the shed blood and are not a sign of fibrinolysis in the patients, as no signs of coagulopathy or fibrinolysis were found. High levels of IL-6 were found in shed mediastinal blood, but no subsequent rise in plasma levels were seen, nor were there any cases of body temperature rise or any other adverse effects that have been attributed to IL-6. An *in vitro* analysis showed activation of the leukocytes in the shed mediastinal blood but this was not detectable in patients *in vivo*. Shed mediastinal blood contains high levels of creatinine kinase (CK). These cardiac enzymes were elevated in patients receiving autologous transfusion but using a cut-off point of CK-MB of 100 µg/l for diagnosis of acute myocardial infarction it was still possible to use CK-MB as a diagnostic tool for this condition.

## **Orthopaedic Surgery**

**Duncan (1886)** described a successful case of autotransfusion in a patient who had sustained a crushed left leg in a railway accident and had to undergo amputation. Blood was collected in a bowl during amputation and mixed with phosphate of soda and distilled water and then injected. After surgery the patient was put to bed, placed in front of the fire and given teaspoonfuls of weak brandy and water frequently. The man recuperated completely.

**Groh and collaborators (1990)** performed 25 consecutive TKAs with post-operative autotransfusion of unwashed shed blood from the wound drainage (test group). The results were compared to 25 previous arthroplasties performed without the use of the autologous blood transfusion equipment (control group). It was found that pre-operative haematocrit, blood loss and fluid replacement were similar in both groups. Ten patients in the control group required transfusion of packed red blood cells compared to only 2 patients in the test group. Microbiological cultures of samples from the autotransfusions yielded no microbe growth after 14 days. Serial post-operative haematocrits, platelet counts, prothrombin, partial prothromboplastin, blood urea nitrogen and creatinine levels were similar in both groups. No evidence of coagulopathy, thrombocytopenia or renal dysfunction was found.

**Faris and colleagues (1991)** studied 99 patients who received shed blood after total joint arthroplasties. They suggest that although there was no evidence that fibrinogen-fibrin products in unwashed shed blood produced a coagulopathy, the possibility remains a cause for concern. Shed blood may contain methylmethacrylate monomer, locally administered antibiotics, fat and chips of bone. They found no adverse effects except for febrile reactions, particularly if the reinfused blood was collected more than six hours after the operation.

**Gannon and co-workers (1991)** in a randomised study of 239 consecutive patients undergoing TKA and THA sought to assess the efficacy of post-operative blood salvage. The median amount of homologous blood required was reduced by 74% if shed unwashed blood was autotransfused, compared to controls. Thirteen percent in the study group required homologous blood transfusion compared to 39% in the control group. The authors consider post-operative blood salvage safe and effective in reducing the requirements for homologous blood transfusion.

**Behrman and Kiem (1992)** studied reinfusion of shed blood in 150 patients undergoing spinal surgery. Fifty patients had no blood salvage and served as controls (Group A), 50 patients had intra-operative blood salvage with Cell Saver (Group B) and 50 patients had Cell Saver intra-operatively and post-operative

salvage of post-operative drainage (Group C). There were statistically significant reductions in the requirement for homologous and pre-banked autologous in Group B (by 35%) and Group C (by 68%) compared to control Group A. IT was concluded that the combination of intra-operative and post-operative blood salvage was highly effective in reducing the need for transfused blood.

**Clements et al (1992)** did a prospective, randomised study on 35 patients receiving either washed or unwashed shed autologous blood from post-operative wound drainage, following THA, TKA or posterior spinal arthrodesis. No complications were noted in the patients receiving washed blood. In the group that had unwashed blood reinfused, 2 patients had a hypotensive reaction immediately on reinfusion of the drainage, which ceased once reinfusion was discontinued. One patient, with a history of hypotension, developed hypotension and ST segment depression five hours after completion of reinfusion, in connection with venography of the lower extremities, with iodinated contrast medium, being performed as part of a protocol for DVT. The patient developed a massive myocardial infarction and died 4 days post-operatively. The authors discuss whether the hypotension in these cases might be caused by the addition of acid citrate dextrose as an anticoagulant, chelating circulating ionised calcium, thereby reducing its availability for cardiac contractility. In the case of the patient who died of myocardial infarction, a reaction to the contrast medium used during venography is discussed, as it is known that reactions are not uncommon and sometimes fatal. The authors conclude by stating that their current practice is to reinfuse only washed drainage in their patients.

**Martin et al. (1992)** studied autotransfusion of unwashed shed blood from wound drainage after cementless TKA in 197 patients. The study was not controlled or randomised. Drainage collection was less than 8 hours in all patients. Transfusion of banked blood was also performed. Complications (4%) included wound haematoma in 5 patients, DVT in 2 patients and transient chills, fever or tachycardia at the time of transfusion in 4 patients. The authors state that no known complications could be attributed directly to the reinfusion process. There were no cases of peri-operative mortality, coagulopathy, pulmonary embolism or fat embolism syndrome. It is concluded that whole-blood salvage by this method is safe.

**Robbins et al. (1992)** investigated 11 patients who received transfusion of autologous unwashed blood after joint replacement surgery (8 THAs and 3 TKAs). Microparticulate matter was analysed before and after micro-aggregate filtration. The effect of shed blood on coagulation of venous blood was also measured. Particulate matter of diameter 10-20  $\mu\text{m}$  was found in only 2 of 10 collections at an average concentration of  $33 \times 10^3 / \text{l}$ . All transfusion devices contained blood that would not coagulate but partial thromboplastin time was shortened when the filtrate was mixed with paired post-operative venous blood

samples. The authors consider it likely that activated coagulation factors present in the transfused blood will be neutralised on re-infusion by the patient's liver.

**Woda and Tetzlaff (1992)** report of a case of upper airway oedema (including the epiglottis and laryngeal structures) immediately following transfusion of unwashed autologous blood after THA in a 70-year-old woman. Prothrombin time and partial thromboplastin time were increased, fibrinogen decreased, bleeding time was greater than 20 minutes and fibrin split products were moderately elevated. The patient recovered after intensive care including administration of fresh frozen plasma, cryoprecipitate and pooled platelets. The authors view the incident as a case of acute transfusion reaction, which may have been related to the administration of unwashed shed blood. They further speculate that the numerous silicone-coated components and filters may have activated the complement cascade.

**Blevins and co-workers (1993)** undertook a prospective study of reinfusion of shed blood on 26 young patients undergoing spine and hip surgery. They found that the D-dimer levels increased significantly at one hour after the transfusion and that it returned to baseline level 12 – 18 hours after the transfusion. The authors concluded that the reinfusion of unwashed, filtered, shed blood up to 15% of the patient's total blood volume is safe.

**Arnestad et al (1994)** investigated shed unwashed blood after THA in 10 patients and plasma changes after reinfusion with regard to cytokines. Plasma concentrations of IL-6 increased 1 and 60 minutes after retransfusion. Plasma concentrations of TNF- $\alpha$ , IL-1 $\alpha$ , IL-1 $\beta$ , IL-4 and IL-8 did not change significantly after reinfusion. This was despite the fact that raised levels of IL-1 $\alpha$ , IL-1 $\beta$ , IL-6 and IL-8 were seen in the collected shed blood. The filtration procedure did not reduce the concentrations of these factors. The authors conclude that whole blood collected from a surgical wound contains large concentrations of cytokines and that retransfusion caused increased plasma concentrations of IL-6. The authors state that large concentrations of IL-6 in plasma were to be expected as tissue damage is the major determinant of circulating concentration of IL-6.

**Blaylock and associates (1994)**, in an *in vitro* study investigated the washed and unwashed supernatant of blood collected from joint spaces of seven patients during TKA. The unwashed supernatant showed elevated levels of FDP (fibrin(ogen) degradation products) and D-dimer. The unwashed samples initiated clot formation in normal plasma, whereas the washed samples did not. Corrected PT and APTT were below the normal range, while it was normal for the washed samples. The authors contend that although shed unwashed blood is being used without widespread reports of clinical complications, patients are not receiving the safest blood product available. However, the researchers write that while washing shed blood removes most of the components and by-products of

the fibrinolytic and coagulation systems, the study had not ascertained the in vivo effects on the systemic and thrombotic systems.

**Healy and co-workers (1994)** did a prospective, randomised study on autotransfusion of autologous shed blood after hip or knee replacement or spine fusion in 128 patients. They observed an increase of fibrin degradation products to double pre-operative value for patients who did not receive shed autologous blood compared to a tenfold increase in patients receiving shed autologous blood. These values returned to equal levels 24 hours after transfusion. The increase in D-dimer levels was also greater for the group who received shed autologous blood but also these values were the same in all groups 24 hours after transfusion. Clotting studies, including prothrombin time, partial thromboplastin time and thrombin time showed no significant differences between patients who received shed blood and patients who received liquid-preserved red blood cells. The authors concluded that reinfusion of autologous, unwashed, filtered, post-operative drainage blood from orthopaedic wounds is an acceptable alternative to the transfusion of liquid-preserved red blood cells.

**Simpson and colleagues (1994)** conducted a prospective randomised study on 24 patients undergoing total joint arthroplasty. The patients receiving reinfusion of shed blood post-operatively required blood transfusion in 25% of the cases versus 83% in the control group. For the TKAs, the percentages were 11% and 78% respectively. No transfusion reactions were seen. It was concluded that post-operative blood salvage is a safe and effective source of autologous blood.

**Wixson et al. (1994)** in a study of 50 patients with total joint arthroplasties, investigated autotransfusion from post-operative wound drainages. A mean of 450 ml was given to these patients. The collected blood was analysed and found to be completely defibrinated but contained fibrin degradation products (increased D-dimer levels) and haemolysed blood (reduced haptoglobin levels). No clinical manifestations of disseminated intravascular coagulation were observed. The body subsequently cleared both the haemolysed and defibrinated products. The D-dimer level was elevated in only 7 of 15 patients and 5 remained elevated 24 hours later. They noted that the source of the D-dimer and fibrin degradation products included the surgical wound, in addition to the re-infused blood.

**Arnestad and colleagues (1995)** studied 25 patients undergoing THA. Fifteen patients received autotransfusion with washed wound drainage blood and 10 patients received unwashed wound drainage blood. Cytokine release (IL-1 $\beta$ , IL-6, IL-8 and TNF- $\alpha$ ), PMN elastase and terminal C5b-9 complement complexes (TCC) were measured in the shed washed and unwashed blood as well as in the patients' plasma. In the washed shed blood there were no elevations in the concentrations of cytokines, TNF- $\alpha$ , PMN elastase or TCC. Nor was there an

increase in the plasma levels of these variables after autotransfusion. In the unwashed shed blood there were high levels of cytokines, PMN elastase and TCC. Filtration did not lower the concentrations of these factors, except for TCC. After reinfusion there was an increase in the plasma concentrations of IL-6, IL-8 and PMN elastase 1 and 60 minutes after completion of the reinfusion. The authors found no differences regarding blood pressure, oxygen saturation or haemoglobin concentration between the groups. One of the patients transfused with unwashed blood had a febrile reaction. The authors conclude by recommending a centrifuge-based cell salvage device when there is need for transfusion of large volumes.

**Ayers and co-workers (1995)** did a prospective, randomised study on the collection and reinfusion of unwashed, filtered, salvaged blood in total hip replacement on 232 patients. They recorded no complications or episodes of hypotension, confusion, tachycardia, cardiac or pulmonary compromise or febrile reaction in the patients who had received reinfused autologous blood.

**Southern and co-workers (1995)** investigated 13 consecutive patients who underwent total joint arthroplasty and received reinfusion of unwashed drainage blood. No control group was used and the study thus was not randomised. The levels of TNF- $\alpha$ , IL-1 $\alpha$ , IL-6 and IL-8 were measured from the shed blood as well as from peripheral blood samples in the recovery room and at 6 hours post-operatively. The patients also all received washed shed blood intra-operatively. It was found that IL-6 was elevated in serum at 6 hours, but the other substances remained at control levels. In shed unwashed blood, on the other hand, the levels of TNF- $\alpha$ , IL-1 $\alpha$ , IL-6 and IL-8 were all elevated. The plasma levels of FDP were elevated at 6 hours post-operatively and the prothrombin time increased at the same point in time, however fibrinogen levels remained unchanged.

**Grønberg and collaborators (1996)** in a study of red cell survival (using  $^{51}\text{Cr}$  labelling technique) after autologous blood transfusion following 10 cases of cementless TKA found the RBC survival to be equal to that reported for banked autologous blood and probably longer than the survival of homologous banked RBCs.

**Han and co-workers (1997)** studied 135 primary total joint arthroplasties using reinfusion of shed blood. They found no complications related to air embolism, coagulopathy, renal failure or sepsis.

**Kristiansson et al. (1997)** undertook a study of patients undergoing total hip arthroplasty (THA) in which 10 patients had only a drain inserted in the wound and 12 patients had blood from the drain reinfused. One aim of the study was to compare the systemic concentrations of anti-thrombin, soluble fibrin and D-dimer in patients receiving allogeneic blood to those receiving autologous blood.

They concluded that transfusion of non-anticoagulated retrieved blood did not influence the coagulation/fibrinolysis profile as measured by plasma concentrations of anti-thrombin, soluble fibrin and D-dimer, compared to patients not receiving retrieved blood. They suggested that the changes in systemic concentrations of anti-thrombin, soluble fibrin and D-dimer might be caused by the trauma response to orthopaedic surgery.

**McKie and Herzenberg (1997)** describe a case of disseminated intravascular inflammation (also known as salvaged-blood syndrome or haemodilution-induced platelet-and-leukocyte activation syndrome) in a 17-year-old girl undergoing surgery for idiopathic scoliosis where autotransfusion with washed blood was employed. The authors believe the disseminated intravascular coagulation was caused by a combination of factors such as the salvage of extremely dilute blood which was then spun in the Cell Saver causing activation of platelets and leukocytes during the spin cycle, and possibly the use of absorbable gelatine sponges soaked in topical thrombin during surgery. The authors warn against salvaging blood that has been diluted either during irrigation or during infusion of crystalloid.

**Newman et al. (1997)** carried out a randomised, controlled trial on 70 patients undergoing TKA. One group received homologous bank blood and the other group reinfused autologous blood. They found no complications or adverse effects from reinfusion and the number of infective episodes was significantly less when the use of bank blood was avoided.

**Xenakis and associates (1997)** evaluated the efficacy of autotransfusion of post-operative drainage blood alone (208 patients) or in combination with pre-donation of autologous blood (50 patients) or transfusion of homologous blood alone (117 patients which served as controls) in a total of 375 patients treated with THA or TKA in a prospective study. It was found that post-operative reinfusion of salvaged blood decreased the need for homologous blood transfusion compared to controls. The combination of post-operative reinfusion of salvaged blood and pre-deposited autologous blood was associated with the lowest requirements for homologous blood transfusion. No complications from reinfusion of salvaged blood were reported in this study.

**Dalén (1998)** concludes that the clinical complication rate with retransfusion of filtered drain blood in TKA was low and no serious side effects noted. A temperature rise after total knee replacement was seen both after ABT, homologous blood transfusion and also when no blood was given to the patient. Dalén, in the Discussion part of the thesis, gives a review of information in the literature concerning the amount of drain blood that can be retransfused. Obviously, large amounts of blood have been retransfused in many cases (1685 –

3190 ml) without any side effects, but it he recommended that careful monitoring and coagulation factor replacement be undertaken in such cases.

**Goodnough and Brecher (1998)**, in a review article on autologous blood procurement, state that the safety of using unwashed wound drainage in orthopaedic surgery has been controversial. Theoretical concerns have been raised regarding the infusion of potentially harmful materials and although complications have been reported in a few cases in a few small studies, several larger studies have reported no serious adverse effects when drainage was passed through a standard 40 µm filter.

**Hand and co-workers (1998)** investigated methyl methacrylate (MMA) levels in serum and shed blood in 8 consecutive patients undergoing TKA and transfusion of unwashed autologous blood. The authors found that MMA monomer is present in salvaged blood but is undetectable in systemic blood before or after re-infusion. They further concluded that the MMA monomer levels in salvaged blood makes it safe to re-infuse the shed blood. Elimination of MMA is dependent on factors in the blood and not on filtration. They recommend the method as being safe in TKA.

**Mottl-Link et al (1998)** in a randomised study of 28 patients undergoing total hip arthroplasty studied the wound drainage collection equipment from different manufacturers. They found increased levels of histamine and prostaglandin E<sub>2</sub> (PGE<sub>2</sub>) but no difference in serotonin in unwashed shed blood. The authors state that the elevated levels of histamine and PGE<sub>2</sub> could not explain the development of fever 8 hours after autotransfusion reported elsewhere in the literature. However, they suggest that the results of this study should discourage the use of retransfusion even though further clinical studies are necessary.

**Sculco (1998)** did a review of blood management in orthopaedic surgery. The author was a co-author of Clements et al. (1992). The author in this article states that there seems to be a role for post-operative drainage reinfusion in patients with significant blood loss but that the patients must be carefully monitored to identify untoward hyperthermic or hypotensive reactions.

**Henderson et al. (1999)** did a prospective study on the ability of post-operative salvage and reinfusion of unwashed blood after TKA (uni-/bilateral, primary and revision) to reduce homologous blood transfusion requirements in 339 patients (159 retransfused and 180 not transfused). No adverse effects were detected with reinfusion up to 2.5 litres of salvaged unwashed blood. The number of patients requiring homologous blood transfusion in connection with unilateral primary TKA was reduced from 68% to 15%. The overall reduction in the study was from 74% to 22%.

**Huët et al (1999)** undertook a meta-analysis of cell salvage procedures in cardiac and orthopaedic surgery. They state that cell salvage did not appear to increase the frequency of adverse events. They further maintain, comparing devices that wash blood and that do not wash blood: “Nevertheless, our results suggest that, in orthopaedic surgery, the two types of devices appeared to decrease the frequency of exposure to allogeneic blood to a similar degree, when compared with a control. This finding is important, because devices that wash salvaged blood can be more cumbersome to use and more expensive than those that do not. Although unwashed blood contains factors that can cause an increase in peri-operative bleeding, this did not translate into an obvious difference in effectiveness between the two types of devices. However, all of the trials evaluating devices that do not wash blood used the devices post-operatively in orthopaedic patients. The method of unwashed cell salvage is not advocated for intra-operative use, because serious side effects have been described.”

**Krohn and associates (1999 #1)** in nine patients after infusion of post-operatively drained untreated blood noted an increase in pulmonary and systemic vascular resistance that they suggested might be caused by activated complement.

**Krohn et al (1999 #2)** compared arterial blood pre-operatively and at wound closure with samples of drained blood from the wound at closure and from a collection system for autologous transfusion of unwashed shed blood in connection with scoliosis surgery in 10 young, otherwise healthy patients. The patients' blood was not sampled following reinfusion of the drained unwashed blood. Drained blood contained high levels of D-dimer, both from the wound and the collection system but no clottable fibrinogen. In the drained blood there were split products, mainly from cross-linked fibrin, in contrast to arterial blood which contained normal fibrinogen. The authors take this to be a sign of pronounced fibrinolysis in the wound after closure. They conclude that the concentrations of FDP may impair local coagulation and might interfere with general haemostasis if infused. However, the high levels of FDP and D-dimers infused in these young, otherwise healthy patients seemed to be tolerated well.

**Krohn and co-workers (1999 #3)** studied cytokines and the modulators of their function in systemic and drained blood during a six-hour period after surgery for thoracic scoliosis in 8 patients. A Cell Saver was used intra-operatively. The results showed that IL-1 $\beta$  and IL-6 concentrations increased in drained blood while TNF- $\alpha$  increased only in systemic blood. IL-1Ra, sTNFR-I and IL-10, which are modulating factors, increased both in drained and systemic blood. At 6 hours IL-6sR had decreased slightly in drained blood. IL-2 was not found. The level of IL-2 sR $\alpha$  was reduced in parallel with the haemodilution.

**Krohn and collaborators (2000)** investigated autotransfusion in 9 patients after surgery for idiopathic thoracic scoliosis. Arterial TF (tissue factor) antigen levels

were 3 times higher than post-operatively (128 pg/ml vs. 40 pg/ml). During reinfusion of shed blood the blood levels of TF antigen rose to 96 pg/ml and then dropped to 64 pg/ml. Serum of drained blood contained high levels of TF antigen (773 pg/ml) but no TF activity was seen. The authors conclude that the high levels of TF antigen are devoid of procoagulant activity and suggest that the TF antigen in plasma is a soluble, proteolysed TF-apoprotein or an inactivated TF complex.

**Munk Jensen and co-workers (1999)** studied reinfusion of drainage blood after TKA. The patients all received more than 250 ml of drainage blood. The authors noted a gradual increase in D-dimer post-operatively, but thought that this is a normal post-operative finding. They concluded that reinfusion appears to be safe without disturbing the immune and coagulative capacity of the patients.

**Åvall (1999)** concluded that reinfusion of unwashed, filtered blood leads to increased systemic concentrations of IL-6, but does not affect the post-operative haemoglobin recovery after hip or knee replacement surgery.

**Åvall et al. (1999)** studied autotransfusion of washed and unwashed drainage blood after TKA in a randomised study in 27 patients. The controls received no autotransfusions. They reported significantly increased levels of IL-6 in all 3 groups, a fact they attributed to the surgical trauma. The increase was significantly greater in the group that received unwashed blood at one minute after autotransfusion. IL-8 levels remained far below the reference values in all groups. On day 4 post-operatively C3a-levels in the unwashed group were higher than pre-operatively, but there were no differences between the groups. C5b-9 did not show any significant changes in any of the groups. The plasma haemoglobin levels decreased significantly in all 3 groups, but there were no differences between the groups. The authors discuss whether the activation of the complement cascade, resulting in the formation of the anaphylatoxins C3a and C5a and of the C5b-9 terminal complement complexes, might have been caused by the surgical trauma. Trauma is also known to activate neutrophils with secondary release of cytokines. The major effects of IL-6 are the induction of acute-phase proteins in hepatocytes and stimulation of the B-cell antibody production. The fact that there was a difference between the groups with respect to IL-6 levels only at 1 minute after autotransfusion might be explained by the fact that it was a dilutational effect of the reinfused blood. The authors speculate that IL-6 might have a stimulating effect on hypoxic induction of erythropoietin. In spite of the post-transfusion difference in IL-6, the authors found no difference in haemoglobin recovery.

**Breakwell and colleagues (2000)** undertook a randomised study on 33 patients undergoing bilateral TKA: One group was randomised to receive allogeneic blood (control group) and the other to receive collected and re-infused blood

(study group) during the initial 8 hours post-operatively. In the study group there was a significant reduction in allogeneic blood requirements from 6.3 to 3.8 units in total. No transfusion reactions were seen. There was no difference in either pre-operative or post-operative haemoglobin between the groups. The authors recommend the use of autologous reinfusion of shed unwashed blood.

**Earnshaw (2000)**, in an editorial, discusses the problems of blood management in connection with TKA. He points to the risks of immunomodulation and transmission of CJD with allogeneic blood transfusion. The author points out that about a third of patients are unable to pre-donate blood and of the units pre-donated about half are discarded unused. Complications in the form of infections and receiving the wrongs units of blood can still occur.

**Grosvenor and colleagues (2000)** studied the efficacy of post-operative blood salvage in THAs. The study was a retrospective case-control investigation. Of the initial 180 case records, 156 met the criteria for inclusion in the study. Half of the patients had post-operative blood salvage and the other half served as controls. It was found that there was a significantly increased risk of allogeneic transfusion among patients who had undergone THA without post-operative blood salvage and without having pre-donated autologous blood. The risk for allogeneic transfusion was significantly reduced whether or not they had pre-donated autologous blood. The authors recommend the use of post-operative blood salvage in THAs regardless of the availability of pre-donated autologous blood.

**Rosolski et al (2000)** investigated drained unwashed blood salvaged after TKA in 3 different makes of autotransfusion equipment. They found decreased haematocrit and thrombocyte levels in the shed blood. The blood was unable to coagulate and was defibrinated and with activated coagulation, fibrinolysis and complement reactions (TAT, PAP, FDP levels elevated, C<sub>3</sub> reduced). The shed blood further contained cell remnants as evidenced by released intra-cellular enzymes (LDH, elastase and  $\beta$ -thromboglobulin). The authors cannot therefore recommend autotransfusion with shed unwashed blood.

**Sebastián et al. (2000)** studied autologous transfusion of shed blood after spinal surgery. In the study group 28 consecutive patients receiving autotransfusion were compared to a previous series of 31 patients not receiving autotransfusion. It was found that autologous transfusion reduced allogeneic blood requirements by almost 30% compared with controls. Post-operative shed blood had higher levels of plasma-free haemoglobin (PFHB) than pre-operative blood samples. However, there was no change in RBC morphology, median corpuscular fragility (MCF) or RBC adenosine triphosphate (ATP) or diphosphoglycerate (DPG; it is a RBC metabolite derived from glucose metabolism and functions to reduce haemoglobin-O<sub>2</sub> affinity and to modulate the mechanical properties of the RBC membrane) content. Concentrations of enzymes (GOT, GPT, CK and LDH) and

inflammatory cytokines (IL-1 $\beta$  , IL-6) were elevated in shed blood. Following transfusion of unwashed shed blood there were no alterations in coagulation parameters (prothrombin time (PT), activated partial thromboplastin time (APTT), prothrombin activity (PA)). Similarly, there were no differences in IL-1 $\beta$  or IL-6 levels between the groups and the values were within normal range from post-operative day 1. PFHB and haptoglobin concentrations displayed almost identical profiles in the two study groups. Serum enzyme levels were elevated for CK (day 2) and GOT and LDH (day 7) in both groups, but more pronounced in the autologous group. The authors therefore encourage caution when using these enzymes for diagnosis of post-operative myocardial or hepatic injury. Elevations in the levels of these enzymes probably reflect enzyme release from damaged muscles and inflammation-induced post-operative intravascular haemolysis. Furthermore, the idea is put forth that there seems to be enough haptoglobin in the general circulation to bind free haemoglobin, avoiding possible renal damage. The authors conclude by stating that post-operative salvage of blood seems to be an excellent resource of functional and viable RBCs without many of the transfusion-related risks.

**Andersson and collaborators (2001)** in 58 consecutive patients studied complement split products (SC5b-9) and pro-inflammatory cytokines (IL-6 and IL-8) in patients autotransfused with shed blood after THA and TKA. No differences were found in the volumes of collected blood during THA and TKA. Higher concentrations of free haemoglobin were found in the collected blood than in the circulating blood. No differences between THA and TKA were noted with respect to haemoglobin, hematocrit or free haemoglobin. The concentrations of SC5b-9, IL-6, IL-8 and PMN elastase were higher in salvaged blood compared with systemic blood. The IL-6 and IL-8 levels were elevated at both 60 minutes and at 12-18 hours compared with pre-operative levels. However, the plasma levels of SC5b-9 and PMN elastase remained unchanged. No signs of adverse reactions were found that could be attributed to salvaged blood infusion. Despite the fact that salvaged blood contained high concentrations of free haemoglobin, the level of this substance in the circulation did not increase after infusion of salvaged blood. The reasons for the increased concentrations of IL-6 and IL-8 are discussed. The authors believe that they may be due to either the infusion itself or the surgical trauma. It was not possible to draw any conclusions regarding the reason for the activation. It is pointed out that the salvaged blood has been exposed to tissue factors in the wound, to air and to the synthetic material of the collection equipment and that all of these factors may contribute to the activation. The authors conclude that there are few side effects if small amounts of salvaged blood are infused but if large volumes are needed the procedure might be dangerous due to the activation of the complement cascade and the release of pro-inflammatory cytokines.

**Krohn and co-workers (2001)** did a study on nine patients operated on for thoracic scoliosis. The authors write that the concentrations of plasmin-antiplasmin complexes and D-dimers indicate activated coagulation and fibroinolysis, not systemically but rather the activity locally in the wound. They concluded that there is extensive fibrinolytic activity in the closed wound after major orthopaedic surgery and that the systemic concentration of fibrin(ogen) degradation products, indicated by D-dimers, after recirculation of drained, untreated blood might impair coagulation.

## **Other Articles of Interest**

**Kingsley et al. (1976)** in an experimental study on baboons compared reinfusion of unwashed with washed blood. All animals survived. The unwashed group was less stable after the procedure and showed seizure activity and cardiac arrhythmias, but no signs of abnormal bleeding from the surgical wound were seen. A decrease in hematocrit was observed in all animals. A significant increase was seen in free haemoglobin levels in the unwashed group after 1 and 2 litres autotransfusion, but this difference had disappeared at 24 hours. The increase in fibrinogen was significantly greater at 7 days in the washed group. The levels of fibrin split products were significantly increased in the unwashed group after 2 litres autotransfusion and at 24 hours, but not at 7 days. After 2 litres of autotransfusion the platelet count was higher in the washed group but this difference had disappeared at 24 hours. The authors interpret these laboratory values to indicate that the unwashed group showed a typical pattern of DIC.

**Lemos et al. (1996)** in a review article discuss the pros and cons of different blood substitution systems and provide an instructive summary on the issue of reinfusion of shed autologous blood.

**Stowell et al. (1997) for the The American Association of Blood Banks** in its publication "Guidelines for Blood Recovery and Reinfusion in Surgery and Trauma" bring up several issues in connection with autologous transfusion of unwashed blood. The issue of contaminants is discussed. Such contaminants may be made up of tissue fragments, activated clotting factors, complement proteins, lymphokines and exogenous materials, such as antibiotics and topical clotting agents. Hypocalcemia in connection with reinfusion of large volumes of unwashed, citrated, recovered blood to patients with severe liver disease has been reported. The Association brings up relative contraindications to collection and reinfusion. Among these are contaminated wounds, and wounds with malignant cells, surgery for pheochromocytoma (which might induce malignant hypertension), and homozygotic sickle cell anaemia and risk for contamination with amniotic fluid in obstetric practice. Further, the significant elevation in cytokine levels in unwashed blood that increases over 6 hours may be a source of concern in some patients.

**Faught and coworkers (1998)** in a review article state that the fibrinolysis and free haemoglobin in shed blood is reduced by washing but the clinical importance of this is not clear because most patients appear to suffer no serious adverse clinical effects from the transfused unwashed blood. Although the post-operative bleeding has been reported to increase in some studies, it is likely that in operations with large intra-operative blood losses any increase in post-

operative bleeding is balanced by the large amount of autologous blood that can be salvaged and transfused.

**Keating (1998)** in a review article on blood management in orthopaedic surgery discusses the different options for blood salvage. He states that that filtering alone does not markedly reduce cytokine concentrations in the processed blood. The cost-effectiveness of using washed blood is questioned since it requires an expensive device and technical expertise to operate it and may thus be too costly to recommend as a standard procedure.. The use of unwashed blood, on the other hand, is considered cost-effective in decreasing the need for allogeneic blood transfusion.

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