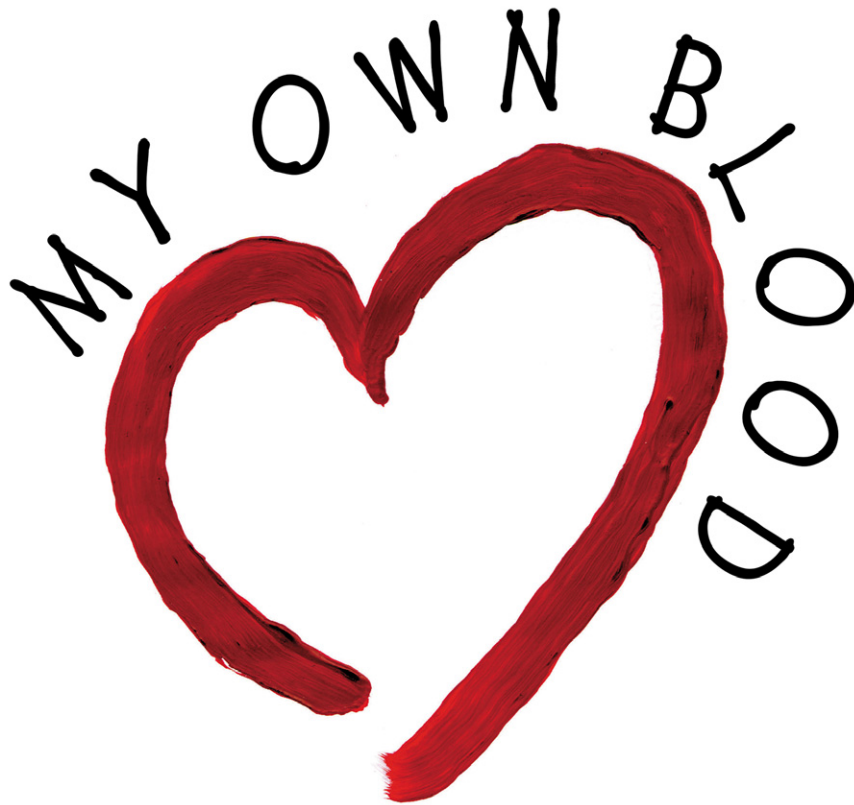


# Fat Embolization and Autologous Transfusion of Shed and Filtered Blood



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# **Fat Embolization and Autologous Transfusion of Shed and Filtered Blood**

## **1. Clinical studies and discussions on fat embolization in orthopaedic surgery**

The release of fat into the general circulation from the bone marrow cavities during hip and knee arthroplasty, is a well-known phenomenon, particularly if bone cement is used.

Kim (2001) presented a prospective study of 100 patients undergoing unilateral total knee arthroplasty and 100 patients undergoing bilateral total knee arthroplasty. Arterial and right atrial blood samples were obtained before and at short time intervals after insertion of the tibial component broach. The presence of fat was determined by staining with Oil Red O fat staining and marrow cells with Wright-Giemsa stain. It was found that 65% of the patients undergoing bilateral TKA had fat embolism compared to 46% of the unilateral cases. Bone marrow cell embolism was seen in 12% of the bilateral cases and in 4% of the unilateral cases. Six patients with positive bone marrow cells had neurologic manifestations.

Pitto, Schramm & al (1999) studied patients with femoral neck fractures undergoing cemented THA, using transesophageal echocardiography and blood gas analysis. They found that (85%) developed severe embolic events. Significant decreases in arterial oxygen saturation were also seen.

Pitto & al (2000) in another study using transesophageal echocardiography investigated patients undergoing cemented THR and found evidence of massive emboli of small particles in 19 patients (95%) during cement injection and stem insertion.

Koessler & al (2001) with the aid of transesophageal echocardiography detected embolism in 93.3% of 60 patients undergoing conventional cemented THR.

Hofmann and co-workers (1999) performed in-vivo monitoring of intramedullary pressure during un-cemented THR. Baseline pressure was measured to be 5-25 mm Hg. During forced removal of the spongy bone in the femoral canal the average pressure for the group of 8 patients rose to circa 150 mm Hg, with one patient reaching 265 mm Hg and another 420 mm Hg.

During use of big rasps the average pressure was measured at circa 125 mm Hg.

Fahmy & al (1990) measured intramedullary pressure in the distal femur during insertion of alignment rods of various designs and sizes in connection with total knee arthroplasty. They found evidence of marrow fat in blood at intramedullary pressures of 184 mm Hg and above.

Cases of fat embolism, sometimes with fatal outcome, after THR, both cemented and un-cemented have been described in the literature (Patterson & al 1991; Arroyo & al 1994; Oxorn & Edelist 1998; Gelinas & al 2000; Ott & al 2000; Fallon & al 2001).

Orsini & al (1987) in animal (dogs) experiments showed bone marrow release into the circulation occurs already below 150 mm Hg.

Byrick (2001) in an editorial discusses fat embolism and postoperative coagulopathy. Three factors are required for “intravasation” of fat and marrow during orthopaedic surgery, namely:

1. disruption of vessels within the marrow cavity,
2. presence of particulate fat and marrow within the cavity,
3. pressurisation of the canal.

The author also notes that echocardiography cannot distinguish between marrow debris, fat, air or other particulate matter. It is possible that activation of the intravascular coagulation system is required for an increase in lung vascular permeability and pulmonary oedema. The question is raised whether intravascular fat is sufficient or even necessary, to cause coagulopathy.

Lewallen (1997) reviews fat embolization in THR. A patent foramen ovale, allowing the passage of emboli from the right heart to the left heart, and thus out into the arterial circulation, was stated to have been found in circa 25% of normal hearts in an autopsy material. The author in this review further state that paradoxical embolization has been reckoned to be possible in 10% of normal patients.

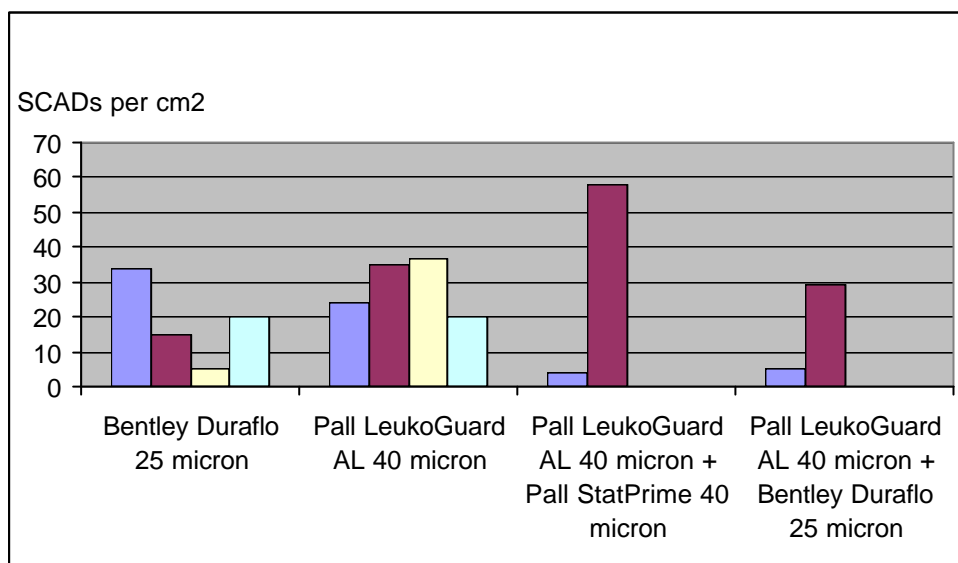
## **2. Experimental studies on autotransfusion and fat embolism**

Several experimental studies address the issue of fat embolization and autotransfusion.

Kincaid & al (2000) studied reinfusion of scavenged blood in an experimental investigation in dogs undergoing thoracotomy with the use of CPB. The dogs received scavenged blood that had passed through no or different arterial filters with or without the use of an intermittent or continuous cell saver device. Brain tissue was then examined by histology for the presence of small capillary and arteriolar dilatations (SCADs), indicative of microembolization.

It was found that SCAD density for the cell saver group was significantly less than for the arterial filtration group. There were no significant differences within each group. The authors were surprised to find that the use of Pall LeukoGuard AL filter (which removes leukocytes as well as lipid, by electrostatic attraction) resulted in the highest SCAD density of any method tested.

Obviously, there was no statistically significant difference between the 25 µm filter and the 40 µm filter. The rather limited number of animals, of course, makes this open to discussion.



Brooker & al (1998) performed a similar experimental investigation in dogs. They found  $46.5 \pm 14.5$  SCADs/cm<sup>2</sup> after hypothermic CPB with cardiotomy suction (with a 150-200 µm filter and a 25 µm filter) in 5 animals.

Henn-Beilharz & al (1990) studied fat in blood in connection with intra- and postoperatively collected blood for autotransfusion using a cell saver device with a 40 µm filter (Sangopur) during primary and revision hip arthroplasty. The amount of fat in the retrieved blood was classified into 3 groups: 1) No fat; 2) 1-2 ml fat; 3) >2 ml fat. It was found that the amount of fat in the retrieved blood increased with the retransfused volume and that primary THRs tended to yield more fat into the retrieved blood. The 40 µm filter did not eliminate the fat from the blood. With a 20 µm filter (Microsept), however, fat from the drained blood was eliminated. In another part of the study intra-operatively retrieved blood from abdominal aneurysm surgery was analysed, and found to contain no fat.

Booke & al (2001) in an in-vitro study investigated fat elimination from autologous blood. Packed RBCs of a volume of 250 ml were diluted with 250 ml saline and 200 ml of soybean oil was added. Soybean oil was chosen since gas chromatography had shown that its spectrum of fatty acids is comparable to the spectrum of fatty acids found in bone marrow and salvaged autologous

blood. The blood was filtered through one of three filters: 1) LipiGuard (especially designed to remove fat), 2) Microfilter Sangopur 40  $\mu\text{m}$  (blood filter) and 3) Purecell RC 400 (leukocyte removal filter). It was found that LipiGuard removed 62% of the fat versus 69% of the fat for Sangopur. Purecell RC 400, on the other hand, removed 99% of the fat. The authors conclude that although the tested filters removed some of the fat, none of them was capable of total fat elimination. They also found it surprising that LipiGuard, especially designed for fat filtration, was only as effective in fat removal as the ordinary blood filter, Sangopur, with a pore size of 40  $\mu\text{m}$ .

Goodman and co-workers (1978) in an experimental study investigated fat embolism and autotransfusion in dogs. Experimental soft tissue contusion and femoral fractures were produced. The fat and bone marrow thus produced was bathed in arterial blood for 60 minutes and the blood and fat continually aspirated by the autotransfusion sucker. The shed blood/fat/marrow mixture was then reinfused intravenously on the contralateral side. This procedure was followed in animal groups 2, 3 and 4. Animal group 1 served as a control group in which the animals were not autotransfused, but with similar soft tissue and femoral lesions.

Groups 2, 3 and 4 had heparin added to the shed blood in doses of 100, 300 and 100 USP units of heparin, respectively, before autotransfusion. The shed blood for groups 2 and 3 was filtered through 125  $\mu\text{m}$  filters, whereas the shed blood in group 4 was filtered through a 20  $\mu\text{m}$  filter.

It was found that mean pulmonary dead space increased and arterial oxygen levels decreased after autotransfusion in-groups 2 and 3, whereas in groups 1 and 4 the values were virtually unchanged. Arterial blood pressure remained stable in all groups but pulmonary arterial pressures rose in groups 2 and 3 compared to groups 1 and 4 which had normal values.

Lung biopsies revealed 4-5  $\mu\text{m}$  fat emboli occluding only the smaller intra-alveolar capillaries and precapillary arterioles 15 minutes after autotransfusion in groups 2 and 3. At 30 and 60 minutes the number and size of the fat emboli had increased, including also larger arterioles, and formation of amorphous thrombi around fat droplets as well as perivascular and interstitial oedema in groups 2 and 3. Lung biopsies from groups 1 and 4 revealed no intravascular thrombi, embolized fat or platelet clots. Biopsies from brain, heart and kidney demonstrated evidence of embolized fat in groups 2 and 3 whereas this was not noted in groups 1 and 4.

The authors conclude that sufficient fat is available within the femur to produce a haemodynamic and cardiorespiratory pattern similar to that, which occurs clinically. It is suggested that extremely small fat droplets may pass through the lungs and coalesce into larger droplets, which may occlude vessels of a significant size.

### **3. Clinical experience of autotransfusion and the issue of fat embolization**

A thorough literature search yields relatively few studies focusing on fat embolization in connection with reinfusion of shed blood. Two studies mention the fact that intra-operative autotransfusion of shed blood was performed, but do not mention this as contributing to fat embolization.

Heine & al (1998) in a case report describe fatal pulmonary embolism in the early postoperative period following revision THR (it is not stated whether this was a cemented or uncemented procedure). Intra-operative fluid replacement consisted of 5 units of packed RBCs, 1,400 ml of autologous salvaged blood, 6 l of crystalloid and 1 l of hetastarch solution. Autopsy revealed massive, diffuse osmium tetroxide-stained fat embolization in all pulmonary capillaries and several larger pulmonary vessels. The embolism was attributed to fat from the marrow cavity reaching the pulmonary vasculature during surgery secondary to preparation and insertion of the hip prosthesis.

Pitto, Koessler & Kuehle (1999) investigated fat embolism during THR using, among other methods, echocardiography. Lost blood was replaced with predonated autologous blood and with blood salvaged intra-operatively with a cell saver device. During the whole operation embolism to the heart was continuously monitored with a transesophageal echocardiography probe and videotaped. In conventionally cemented THRs embolic cascades were registered during preparation of the femoral canal, implantation of stem and relocation of hip joint. Emboli were not registered during any other period of the surgical procedure, although it is highly likely that salvaged blood was reinfused also during surgery. None of the patients experienced neurological alterations nor showed signs of a respiratory distress syndrome.

A few studies address, more or less specifically, the issue of fat content and risk of embolization in shed and retrieved blood.

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.

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.

Blevins & al (1993) studied reinfusion of shed blood after orthopaedic surgical procedures in children and adolescents. The number of fat particles per ml blood was counted. They found  $23,643 \pm 56,965$  fat particles  $< 9 \mu\text{m}$  in shed blood. In patients' blood before transfusion the corresponding numbers were  $1 \pm 1$  and at 1-2 hours after surgery the corresponding numbers were  $142 \pm 405$  and at 12-18 hours after surgery  $21 \pm 59$ . Particles measuring 9-40  $\mu\text{m}$  in diameter numbered  $24 \pm 36$  in shed blood and could not be found in the patients' blood following transfusion. Particles  $>40 \mu\text{m}$  were not detected. The authors conclude that although the presence of fat particles  $< 9 \mu\text{m}$  in reinfused blood is of concern, the data of their study indicate that the particles were rapidly cleared from the circulation.

Healy and co-workers (1994) did a prospective, randomised study on autotransfusion of autologous shed blood after hip or knee replacement or spinal fusion in 128 patients. The shed blood to be reinfused was filtered through either a RC-100 polyester leukocyte filter or a  $40 \mu\text{m}$  filter. The number of fat particles of the two size ranges studied (diameters  $<10 \mu\text{m}$  and 10-40  $\mu\text{m}$ ) were substantially elevated in postoperative shed blood compared to liquid-preserved RBCs. The RC100 filter seemed to be more effective in removing fat particles and white blood cells than the  $40 \mu\text{m}$  filter. In systemic blood samples, however, the amount of fat particles of both size groups was similar in patients who had received shed blood and patients who received liquid-preserved RBCs. Also, the patients receiving shed blood by autotransfusion showed a similar clinical course as patients who were not autotransfused.

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.

#### **4. CONCLUSION**

A thorough literature search using Premedline, Medline, Science Citation Index and PubMed, from 1986 to present date, has been undertaken to find all relevant literature on fat embolization and autotransfusion and the potential risks involved.

The literature search was done using the following search combinations:

fat AND transfusion

fat embol\* AND transfusion

fat embol\* AND salvage  
fat embol\* AND infusion  
fat embol\* AND blood AND autologous  
fat AND filter AND transfusion  
fat AND filter AND salvage  
fat AND filter AND infusion  
fat embol\* AND filter AND blood AND autologous

In addition, relevant references from the retrieved articles were also included.

The relevant literature that was retrieved, in combination with recent articles on fat embolization in orthopaedic surgery, is presented in the previous sections of this commentary on fat embolization and autotransfusion.

Henn-Beilharz & al (1990) demonstrated that 20 µm filters remove the fat from from drained blood. In an experimental study (Goodman & al 1978) with infusion of large amounts of collected marrow fat mixed with arterial blood, it was shown that 20 µm blood filters prevented fat embolism in this extreme situation. A similar scenario is unlikely in a clinical setting with postoperative collection of shed blood from a wound where the bone marrow cavity has been closed off by the implanted orthopaedic device and the surgical wound thoroughly rinsed before closure to remove debris and fat. Kincaid & al (2000), in an animal experiment with intra-operative blood collection, saw histologic evidence of brain damage from emboli after filtration with a 25 µm arterial filter, the extent of which was no less than with a 40 µm arterial filter or a combination of two 40 µm arterial filters, or a combination of a 25 µm arterial filter and a two 40 µm arterial filter. Also Brooker & al (1998) found evidence of brain damage from emboli after filtration with a 150-200 µm filter and a 25 µm filter. Even specially designed fat filters seem to be no more effective in removing fat from blood than conventional 40 µm blood filters, which both remove circa 2/3 of the lipids (Booke & al 2001).

The major risk for fat embolization seems to occur at the time of marrow cavity preparation and insertion of an orthopaedic implant. The literature reports of emboli in over 90% of the cases in one series (Pitto & Koessler 1999).

Two clinical reports (Heine & al 1996; Pitto, Koessler & Kuehle (1999) describe cases of fat embolism in connection with THR and mention that shed blood was retrieved intra-operatively and reinfused, but do not attribute the fat embolism to this fact, but rather to the surgical procedure.

The other clinical reports that at all mention fat in connection with autotransfusion (Faris & al 1991; Martin & al. 1992; Blevins & al 1993; Healy & al 1994) conclude that autotransfusion of autologous, unwashed, filtered, post-operative drainage blood from orthopaedic wounds, is an acceptable method and that no clinical manifestations of fat embolization were observed.

In conclusion it may be stated, that to our knowledge, there are no reports of clinical manifestations of fat embolism being attributed to autotransfusion of autologous, unwashed, filtered, post-operative drainage blood from orthopaedic surgical wounds. Furthermore, the greatest risk of fat embolization seems to be the orthopaedic surgical procedure as such, not the postoperative collection, filtration and reinfusion of shed blood.

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