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Blood Transfusion in Knee Arthroplasty

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1. Introduction

Orthopedic surgery is one of most blood-consuming surgical specialties since it is associated with a significant preoperative hemorrhage requiring frequent allogeneic blood transfusions. A special mention needs to be done to hip and knee arthroplasty, complex rachis arthrodesis and tumor-pathology removal. The intervention on older and higher-risk patients has raised the demand on allogeneic blood to such levels that even Blood Banks are unable to attend. Besides the high cost, using allogeneic blood has its risks, such as immunosuppression, patient's wrong identification, transfusion reactions or the possibility of infectious disease transmission. This imbalance between blood demand and availability, together with the awareness about potential risks of blood transfusions and the continuous advances both in technology and pharmaceutics, should lead us to extreme changes in transfusion politics; developing a series of therapeutic measures to reduce blood transfusion to minimum, leaving its use only when it is strictly necessary, especially in scheduled surgery.

PREOPERATIVE STRATEGIES
- Correction of preoperative anemia: iron supplements, erythropoietin, vitamin B12 and folic acid
- Autologous blood pre-donation
INTRAOPERATIVE STRATEGIES
- Individualize transfusion threshold
- Anesthetic measures
- Surgical technique
- Erythrocytes' substitutes
- Pharmaceutical measurements
- Autotransfusion:
• Intraoperative blood savers
• Normovolemic hemodilution
POSTOPERATIVE STRATEGIES
- Autotransfusion of blood from postsurgical drainage
- Iron supplements

Table 1. Blood-saving techniques during perioperative time.

The aim of this chapter is to inform on saving techniques of hematic components and its implantation in scheduled orthopedic surgery, summarized in table 1.

2. Preoperative strategies

2.1 Correction of preoperative anemia

In the preanesthetic evaluation we will provide a guideline for preoperative evaluation and preparation of the patient, and we will include him/she to a **blood-saving program** by stimulating their erythropoietin (EPO) production, giving iron (Fe) or autologous blood predonation. It is important to check on hemoglobin levels, as well as iron deposits (ferritin, soluble transferrin receptor and transferrin saturation) and associated pathologies (comorbidity).

Hemoglobin concentration is one of the most predictive factors for autologous blood transfusion (ABT). Patients with preoperative anemia show an increase in postoperative morbimortality and a decrease in quality of life (Shander et al., 2004). Age is a predisposing factor for anemia and the prevalence of postoperative anemia increases with age (Goodnough et al., 2005; Rosencher et al., 2003). Iron deficiency and chronic inflammation, with or without iron deficiency, are the most frequent causes of preoperative anemia in these patients. Folic acid and vitamin B12 deficiency can also be present, especially in elderly people.

A preoperative anemia must be treated before undergoing surgery, if it is possible, limiting exposure risk to allogeneic blood.

- **Human recombinant erythropoietin (rhEPO) –** For the past several years, we have at our disposal the human recombinant erythropoietin (rhEPO), obtained from genetic engineering, identical to the endogenous, which stimulates erythrocyte production in a dose-dependent way. It was considered that its use in surgical patients would arise preoperative hemoglobin values and/or facilitate autologous blood predonation, and this way decreasing the chances of an allogeneic transfusion. It is used in programmed patients undergoing major orthopedic surgeries in which initial hemoglobin is between 10 and 13 g/dl, and the prediction of perioperative blood loss is significant (Laupacis & Fergusson, 1998).

  Its main function is stimulating the bone marrow's erythropoietic activity, acting on specific receptors of erythrocyte-formation precursor target cells. Plasma levels of EPO do not vary with age or sex. In healthy individuals the rank goes from 5 – 25 mU/ml. EPO's dosage varies according to its indication and it must be supplemented with iron to avoid stimulating an iron-deficient erythropoiesis. After undergoing a preoperative treatment with EPO, ferritin concentration decreases to half. The speed at which iron from this deposits can be activated becomes a limiting factor. Patients with serious cardiovascular disease, poorly controlled hypertension and history of thromboembolic disease or deep vein thrombosis cannot be treated with EPO.
- **Iron, vitamin B12 and folic acid –** So that erythropoiesis works properly, besides EPO, it is necessary an appropriate iron intake (fundamental component in the hemoglobin molecule), as well as vitamin B12 and folic acid. Its deficiency affects the proliferation and cellular differentiation in erythropoiesis resulting in central arregenerative anemia (decreased reticulocytes). Total amount of iron in our organism is approximately 4-5 grams. 65% is found as hemoglobin, whereas 15-30% is stored in the hepatic parenchyma and rethiculoendotelial system as ferritin and the rest of it binds to transferrin in blood plasma. It is absorbed in the small intestine.

Iron-deficiency anemia affects approximately 25% of world population. Furthermore, there is a status defined as 'functional iron-deficient states', which is described as a situation where iron deposits are normal (or even increased), but iron supply to bone marrow is inadequate to satisfy the erythroid precursor demands; and another anemia associated to 'chronic processes' where erythropoiesis is deficient because of proinflammatory cytokines-mediated mechanisms.

Nowadays it has been proven its high profitability and efficiency index, mainly to optimize or as support in the erythropoietin treatment and autologous predonation. Administration of oral iron is effective in decreasing allogeneic blood transfusions and/or the number of transfused patients in orthopedic major surgery (Okuyama et al., 2005). Orally or intravenous use of iron will depend at the moment in which the treatment is taking place, oral iron absorptive capacity and existence of any gastric disease that could contraindicate oral iron treatment (Cuenca et al., 2004). If treatment is done with intravenous iron, once it is finished we must prescribe oral iron.

The total amount of administered iron will depend on initial hemoglobin value and existence of an iron-deficient condition. If using saccharose iron, dosage varies from 100 to 200 mg in alternate days, with a maximum dose of 600 mg per week and 200 mg every 2 days. At present there is also carboxymaltose iron, which contains greater amounts of iron (500-1000 mg) to administer in a single dose. In case of a folic acid and/or vitamin B12 deficiency we must supply substitutive treatment to correct it.

2.2 Autologous blood predonation

This means the presurgical patient's blood predonation or autodonation. Some weeks prior to intervention, a blood extraction (one or more units of blood) is performed to the patient to be used at his/her surgery or postoperatively.

To be included in the program the patient must fulfill both medical and analytical special requirements; hemoglobin levels before starting predonation process above 11 mg/dl, as well as an appropriate programming of surgery to avoid expiration of the predonated units (35 days - maximum time permitted for storage). Due to this fact, quite a reasonable amount of patients who have undergone autologous blood donation preoperatively, reach surgery time with hemoglobin values under their initial levels (before predonation), therefore increasing transfusion requirements. The patient carries out the donations once or more times during the days and weeks prior to intervention. 350-400 mL extractions are made not less than 3-day intervals, which is the time needed for protein synthesis and mobilization and to return to normal. This way, they can benefit from erythropoiesis stimulation with erythropoietin. All patients must receive an appropriate iron supplement.

Despite the fact that this technique was at its peak during the nineties, its use has been diminishing progressively for several reasons. In first place, the high number of blood bags that were dismissed because of an imbalance between extracted bags and transfusion requirements, since a good coordination in surgery programming and between all professionals taking part is needed. This difficulty has made this method a very expensive one in resource-consumption and less effective than it was thought to be at first. On the other hand, the establishment of intravenous iron and erythropoietin, decrease in transfusion threshold and improvement of the surgical method too, have pushed into the background autologous donation preoperatively, leaving it as last option in some cases such as complex spinal surgery with a mass blood loss forecast and those patients whose blood group have compatibility difficulties.

The existence of predonation units increases the likelihood of transfusion, as perception of risk decrease; there is less chance of rejection or blood incompatibility, as well as less infections. Moreover, it is exposed to the same errors in the processes of extraction, storage, identification and reinfusion to the autologous blood transfusion. Predonation of autologous blood has the following contraindications: serious cardiac disease, hepatitis B history and positive markers for HCV, HIV-I/II, HTLV-I/II and active bacterial infection.

3. Intraoperative strategies

To improve its efficiency, they must be associated to a blood-saving protocol during perioperative time.

3.1 Individualize transfusion threshold

A restrictive transfusion strategy (transfusion threshold at hemoglobin 7 g/dl) must be used, taking into consideration anemia risks and the benefits from a transfusion in an individualized way for every patient. Nowadays, rarely does hemoglobin over 10 g/dl get considered for transfusion, whereas it is believed to be strictly necessary when hemoglobin is less than 6 g/dl. In either case, the transfusion threshold must be lowered to try and delay the start of blood transfusion until the surgery ends, making a new assessment after each transfused packed red blood cells. Moreover, the usual practice of transfusing always two units of packed red blood cells (PRBC) is considered incorrect; as to raise the hemoglobin concentration 1 g/dl it takes about 4 ml/kg PRBC, being enough one PRBC.

3.2 Anesthetic measures

These include appropriate blood volume maintenance, dealing with pain, tachycardia and high blood pressure, hyperoxic ventilation to improve oxygen transport in patients with low hemoglobin and maintenance of normothermia. As specific actions in orthopedics we include:

- Regional anesthesia, as several studies have demonstrated decrease of perioperative bleeding when comparing with general anesthesia, which appears to be related to lower blood pressure.
- Optimal position of the patient to reduce venous congestion at the surgical field
- Monitoring low blood pressure is a controversial anesthetic measure, with a relative effectiveness amongst bleeding, used to lower down blood pressure and thus reducing blood loss during surgery. In orthopedic surgery, its use gets relegated to high intraoperative bleeding interventions. Relative contraindications include untreated severe high blood pressure, coronary disease, serious lung disease, severe anemia or significant polycythemia, cerebrovascular disease, pregnancy, considerable hypovolemia and serious kidney or liver dysfunction. There are numerous drugs used to control hypertension. Most frequently used in clinical practice are inhalators (isoflurane, sevoflurane), direct acting vasodilators (nitroglycerin, sodium nitroprusside), beta blockers (labetalol, esmolol), others (urapidil, captopril, etc.)

3.3 Surgical technique

This includes an adequate ischemia (use of tourniquet), adequate hemostasis, minimally invasive surgery, etc. The most important factors are surgical time reduction and well-cared

hemostasis. There is a straightforward relationship between hematic loss and surgical time; a longer surgical time is associated to a greater hematic loss. During surgery, local hemostatic agents, such as fibrin sealants, which reduce surgical bleeding, can be used. We will develop this part further on.

3.4 Erythrocytes' substitutes

These are substances able to replace the use of allogeneic blood components. They are obtained from human blood, transgenic animals or recombinant technology. Currently still under development. There are hemoglobin solutions and perfluorocarbonate emulsion.

3.5 Pharmaceutical measurements

Several prohemostatic drugs have been used in order to try reducing or preventing intraoperative bleeding. In orthopedic surgery, antifibrinolytic and desmopressin are the mainly used.

3.5.1 Antifibrinolytics

Perioperative bleeding is partially attributed to the fibrinolytic system activation. Several work groups have administered antifibrinolytics, and as a result observed a decrease in perioperative bleeding and blood bags transfused (Henry et al., 2001). In other recent revisions, which evaluate antifibrinolytics drugs in orthopedic surgery (Kagoma et al., 2009; Zufferey et al., 2006), they conclude that using tranexamic acid or aprotinin reduces the percentage of patients requiring blood transfusions and also are efficient decreasing bleeding. When using epsilon-aminocaproic acid (EACA) there are no signs of a significant reduction in hemorrhagic risk, although not many studies have been done. All of them can have relatively infrequent but very serious side effects, such as arterial thrombosis, renal failure or rhabdomyolysis.

3.5.1.1 Aprotinin

It is a 58 amino acid polypeptide. It is found mainly in mammalian mastocytes and it is commercialized from bovine lung. Aprotinin works inhibiting trypsin, plasmin and tissue and plasma kallikrein. In addition to this, it holds an anti-inflammatory effect attenuating inflammatory response in major surgery, particularly at high-doses. It is the antifibrinolytic drug most widely studied to reduce bleeding and diminish transfusion needs. However, in comparison to tranexamic acid or EACA, it increases mortality risk. After the adverse results in mortality in patients who had undergone cardiac surgery in an observational study over more than 4000 patients (Mangano et al., 2006), and in a randomized double blind trial with over 3000 patients (Fergusson et al., 2008), the drug was withdrawn worldwide.

3.5.1.2 *Synthetic antifibrinolytics*

Synthetic analogs of lysine. Tranexamic acid and EACA are able to block fibrinolysis by competitively antagonizing the binding of plasminogen to fibrin.

Tranexamic acid is 10 times stronger in vitro than EACA. In total knee arthroplasty, prophylactic administration significantly reduces blood loss up to 50% and decreases transfusion requirements without increasing the risk of thromboembolic signs (Alvarez et al., 2008; Cid & Lozano, 2005; Lozano et al., 2008). Optimal technique would be with two tranexamic acid bolus (each of them 10-15 mg/Kg), one before surgery and another when letting the air out of the tourniquet. In total hip prosthesis, tranexamic acid results in a

decrease of intraoperative bleeding when administered prophylactically (Benoni et al., 2001), with no raise in thromboembolic complications incidence (Johansson et al., 2005b). However, it must only be used in those patients of whom a significant blood loss is expected. In spinal surgery, its administration is associated with considerable decrease in perioperative blood loss without side effects coming out (Elwatidy et al., 1976).
The rapid administration causes hypotension and its use is not recommended in patients with thromboembolic history although there is no evidence of an association with thromboembolic complications arising.
Epsilon-aminocaproic acid (EACA), in addition to its antifibrinolytic effect, prevents from platelet receptor degradation by plasmin, preserving platelet function. On the whole, recommended dose is a 150-mg/Kg bolus before surgery, followed by a 15-mg/Kg/h infusion during surgery. In a 2008-published meta-analysis they concluded that it is the most effective antifibrinolytic drug in spinal surgery (Gill et al., 2008). Nevertheless, not many studies have been done regarding this drug as to obtain conclusions. The most frequent side effect is hypotension, which is usually associated to a rapid intravenous administration. There is no evidence that EACA would raise thromboembolic episodes.

3.5.2 Desmopressin acetate

Desmopressin acetate is an antidiuretic hormone synthetic analogue. Besides its antidiuretic effect, it has a hemostatic action that would be based in factor VIII and Von Willebrand factor release to the circulatory system from the existent deposits at the vascular endothelium cells, and its ability for increasing platelet adhesion. In orthopedic surgery its use has been reduced mainly to spinal surgery, with initial encouraging results (Kobrinsky et al., 1987), although not proved in subsequent studies. In hip and knee orthopedic surgery there is no evidence of a decrease in blood loss or erythrocyte volume transfusion. Dose for intravenous administration is 0.3 μg/Kg and its main use would be for Von Willebrand syndrome. Desmopressin side effects include facial redness, severe headache, hypotension and high-speed beating. Its strong antidiuretic effect can produce water retention, hyponatremia and convulsions.

3.6 Autotransfusion

It includes all the procedures by which a patient is transfused with his own blood. These methods have a number of advantages such as lack of infectious diseases transmission, avoids hemolytic disease incidence and several different transfusion reactions, it has immediate availability, as well as compatibility, avoids categorization and cross-matching mistakes, and last of all, decreases hypothermal risk of stored blood. It can be performed by two different methods:

3.6.1 Normovolemic hemodilution

Normovolemic hemodilution consists in extraction and anticoagulation of an established blood volume (4 units maximum) after anesthetic induction and its simultaneous substitution for crystalloids and/or colloids to maintain normovolemia, and thus causing dilutional anemia. Reinfusion is done later on when surgical hemorrhage is under control or even before if necessary. Extracted blood is then anticoagulated at room temperature, which preserves platelet functions. Despite these theoretical benefits, dissolving coagulation factors, hematocrit and platelets causes a microvascular bleeding. Furthermore, excessive

crystalloid contribution leads to their accumulation on the interstitial space during postoperative time and it is currently considered as an obsolete technique, mostly because of its inefficiency as a blood-saver method. Nowadays the use of normovolemic hemodilution is not recommended for decreasing allogeneic blood transfusion, nor transfused patient number or bags transfused.

3.6.2 Intraoperative blood savers

Retrieving intraoperative blood involves autologous collection and infusion of autologous red blood cells, which is done by means of a device known as cell saver. It is commonly used in orthopedic surgery (spinal surgery and replacement of hip prosthesis) and provides significant autologous blood volumes. In major orthopedic surgery, perioperative blood retrieval reduces the probability of receiving autologous blood transfusion by 65% (Carless et al., 2004). The devices used recover only 50-60% of lost blood during surgery, which together with the high cost of consumables, makes its use only indicated to those procedures in which intraoperative hemorrhage is predicted to be over 1,000-1,500 ml, or else when it is possible to recover at least one packed red blood cells. This method would also be indicated in those patients whose religious believes contraindicates a blood donor transfusion but permits an autologous transfusion, when no compatible blood donor is available or when the patient is not capable of donating enough amount of autologous blood before surgery.

Despite the devices' costs, retrieved and processed blood can be less expensive than allogeneic blood (Gardner et al., 2000). A clear benefit from perioperative blood reinfusion is the erythrocyte viability in collected blood, which is higher than that from allogeneic blood and oxygen transport capacity, being better than in stored blood (Colwell, Jr. et al., 2002). However, autotransfusion programs are associated with certain organization complexity and a weak cost-benefit relationship when used indiscriminately.

This procedure is contraindicated when there is bacterial contamination at the operating field, neoplastic disease, patients with positive viral-markers, sickle-cell anemia and when certain local hemostatics have been used or else when blood is found to be hemolyzed. Different procedures are available for intraoperative blood recovery. Semicontinuous-flow blood centrifugation system is one of the most commonly used, where blood is retrieved by aspiration, anticoagulated, filtered and sent to a reservoir from where it is pumped to a centrifuge bell which divides and washes the cells to return them to the patient as a saline suspended red blood cells, with a hematocrit value around 50-70%. During this process, plasma is dismissed, as well as toxic products from hemolysis, coagulation factors, platelets and fat.

OrthoPAT® (Orthopedic Perioperative Autotransfusion System, Haemonetics), is an autologous blood retrieval, specifically designed for adapting to intermittent bleeding during and after programmed orthopedic surgery, reducing unnecessary allogeneic transfusions. It is a small device, easy to operate and completely automatized. In prosthetic-hip and spinal surgery it is commonly used for intra and postoperative retrieval, whereas in prosthetic-knee surgery it is preferably used postoperatively. Perioperative use of blood retrievals may significantly reduce allogeneic transfusion risks in a not inconsiderable number of patients with high-risk of being transfused (Pola et al., 2004).

4. Postoperative strategies

4.1 Postoperative autotransfusion

There are certain orthopedic surgical procedures (such as knee arthroplasty), in which postoperative bleeding through postsurgical drainages is very significant due to the

completion of most of the surgery with lower extremity ischemia, so that bleeding occurs primarily in the early hours of the postoperative period. For this reason, in this type of surgeries, blood retrieval during postoperative time has been the main instruction and the one that has achieved major performance. Several devices for postoperative blood retrieval have been designed, in order to aspirate, store and retransfuse lost blood through postsurgical drainages.

Reinfused blood is often filtered rather than washed. It would be restricted to orthopedic programmed surgeries where estimated postoperative bleeding is between 750 and 1000 mL, and at least the equivalent to one packed red blood cells can be retrieved. Autotransfused blood must be collected and reinfused within a 4-6 hour-period. Stored blood in surgical drainage holds a better oxygen release to tissues than that from blood bank, although having a lower hematocrit. Furthermore, it owns better rheological characteristics and fewer ionic disturbances than blood bank. Hematocrit is low because it is total blood, which means that with this blood reinfusion we will not be able to raise hematocrit, but we will succeed in not diminishing its value.

Comparison analysis from obtained data in several studies shows that, regarding blood bank, blood from postsurgical drainage in orthopedic surgery, even with lower hematocrit and hemoglobin (8-10 g/dL), has higher concentrations of erythrocytic ATP and 2,3-BPG, less ionic disturbances and possibly, less immunosuppressive action. This blood includes too activated coagulation factors and fibrinogen degradation products, which could be the cause of coagulopathies. However, no significant increase in bleeding has been found, neither coagulation disorders clinically expressive There are no differences in perioperative inflammatory mediators levels between patients receiving unwashed retrieved blood from those who do not get it (Munoz et al., 2005b). Fat particles content, which is the main cause of fat embolism and respiratory distress syndrome, is controlled using a filter between collection and reinfusion container, and dismissing the last 80-100 cc. These methods allow removal of 90% of fat particles in the retrieved blood. The remaining 10% is eliminated by leukodepletion filter. These filters have shown to be effective in dismissing bacteria and tumor cells. In accordance with the abovementioned, unwashed blood must be limited to a maximum 1000 ml reinfusion. This collecting system brings advantages such as minimum contamination risk as it is a closed circuit and greater hemodynamic stability during postoperative period due to the disposal of blood volume, which is reinfunded if necessary. Moreover, it is cheap and can be used in Jehovah's Witnesses, as it is a closed circuit in which blood does not lose total contact with the patient's body.

Contraindications for using postsurgical drains' blood are: renal failure, altered hepatic function, coagulation disorders, infusion of hemostatic agents or inadequate solutions (topic antibiotics, antiseptics, oxygenated water) and neoplastic or septic disease. Retrieval of postoperative blood reduces both patients' percentage that would receive allogeneic blood transfusion and volume of transfusion (Carless et al., 2004).

4.2 Iron supplements

The use of intravenous iron during postoperative of orthopedic-surgical patients, is an effective treatment to increase hemoglobin levels, as shown in five clinical trials randomized controlled; unlike oral iron supply.

5. Surgical aspects and its relationship with bleeding

5.1 Introduction

Transfusion requirements are a matter that concerns doctors not only for disease transmission risk but also for transmission complications and the high-cost of the procedure (Garcia-Erce et al., 2002). There has been a recent trend towards developing a protocol in order to decrease transfusion requirements (Garcia-Erce et al., 2002; Kourtzis et al., 2004). Several options have come up, pharmaceutical as well as transfusion options alternatively to allogeneic transfusion, summed up in table 2.

According to different studies who have studied predictive factors in trauma surgeries, preoperative hemoglobin level and levels of red cell mass are predictors of transfusion needs. The higher the levels of hemoglobin and red cell mass, the less need to transfuse (Garcia-Erce et al., 2002; Lozano et al., 2008).

Occult blood has an outstanding paper regarding blood management in the patient being operated of arthroplastic surgery. Occult blood can reach 50% of the missed blood perioperatively (Sehat et al., 2000).

During surgery there are several options to consider in order of preventing bleeding, such as: use or not have drainages, aspiration pressure and time of aspiration of drainages and the use of ischemia during prosthetic surgery.

SURGICAL VARIABLES
1. Drainages and non-infectious complications
2. Relation between drainage and infection
3. Use of postoperative blood retrieval
4. Number of drainages
5. Aspiration pressure
6. Start / Opening-up / End of drainage
7. Tourniquet
8. Surgical technique

Table 2. Different surgical options to reduce bleeding

5.2 Drainages and non-infectious complications

The use of drainages in orthopedic surgery is a matter of tradition. Its use prevents postoperative hematomas and diminishes postoperative pain, but its use is still controversial (Corpe et al., 2000). Despite several evidence-based medical studies, British orthopedists were not following their recommendations in 2003 (Canty et al., 2003).

Drains have been related to the transfusion necessity and infection rate, among others. But some studies, such as Seyfert's et al (Seyfert et al., 2002), prove that placing drainages with suction does not increase transfusion requirements or postoperative course.

On the other hand, there are studies whose results highlight that not using drainages does not avoid transfusions nor does it reduce blood loss. Padala et al. find questionable the use of drainages in primary knee surgery as it increases transfusions (Padala et al., 2004). Some studies hold on to the fact that it is not necessary their use in primary knee arthroplasty (Adalberth et al., 1998; Corpe et al., 2000; Jenny et al., 2001), nor hip or knee (Crevoisier et al., 1998; Niskanen et al., 2000), nor primary hip (Acus, III et al., 1992; Beer et al., 1991; Hadden & McFarlane, 1990; Kumar et al., 2006). Della Valle et al found out in their study

more complications in the group with drainages in comparison to the non-drainages group in primary hip arthroplasty (Gonzalez, V et al., 2004). Ovadia et al (Ovadia et al., 1997), as well as other work-groups (Hallstrom & Steele, 1992; Walmsley et al., 2005), find significant the premise that the use of drainages increases transfusion requirements (0.7 units per patient with drainage, in comparison to 0.2 unit per patient without, $p = 0.005$).
Widman et al.(Widman et al., 2002) reveal in their study that the use of drainages in hip surgery does not decrease postsurgical hematoma, analyzed with SPECT, but it does increase transfusion requirements.
Esler et al. (Esler et al., 2003) state that they cannot support the use of suction drainages as the group with suction drainages shows a greater blood loss than the non-drainages group. Nevertheless, they do give support to the use of drainages for reusing blood.
Some authors assert that the use of drainage is not harmful but it is of no use at all (Ashraf et al., 2001; Johansson et al., 2005a). Other authors do not see that using drainages in unicompartmental knee surgery has an adequate cost/benefit ratio, since it increases the cost of the procedure both in labor and equipment expenditure; and furthermore, avoiding postoperative drainage in this kind of procedures does not influence the outcome (Confalonieri et al., 2004).
In their meta-analysis, Parker et al. (Parker et al., 2004) find out that suction drainage increases transfusion requirements after a hip or knee arthroplasty, with no benefits contributed.
A mechanical complication that may occur with Redon-drains is that this can break, thus staying intra-articular. In the knee's joint we may keep an expectant management or else require surgical maneuvers such as arthrotomy (Marmor, 1990) or either arthroscopy surgery to remove the drainage (Kao et al., 2002).

5.3 Relation between drainage and infection

Once we reach the infectious complications, the debate remains open. On the one hand, the fact that drains decrease hematoma, knowing that hematoma is an enabling factor for infection, is an argument for its use. But on the other hand, drainages can increase retrograde infection (Mengal et al., 2001).
Regarding deep infections, studies are controversial. Some authors, e.g. Kim et al., defend that using drainages does not increase infections rate or it even decreases it. These associate drains' use with a non-significant decrease in deep infections (Kim et al., 1998).
On the other hand, many authors present results where drains' use has a positive relation to infection. Minnema et al. (Minnema et al., 2004)have linked the use of suction drains with an increasing rate of surgical wound infection after total knee arthroplasty.
Cultivating the drain's end is not a favorable practice in cost-benefit studies, according to the study published by Weinrauch et al. (Weinrauch, 2005). In spite of Weinrauch's study, several groups have cultivated the drain's tip. Zamora-Navas et al. (Zamora-Navas et al., 1999) analyze the drain's tip observing that drainages removed before 12 hours do not have any contamination, those retired at 24 hours show contamination in 2 out of 12 patients for *Staphylococcus epidermidis*, and those drains removed at 48 hours also present contamination for *S. epidermidis* in 2 out of 12 patients. Clinical evaluations of wound healing were similar in both groups. A different group of study, Willemen's et al. (Willemen et al., 1991), cultivated the catheter's tip of all groups and concluded that culture of the catheter's end that had been removed at 24 hours time, were all-negative cultures. A related study to the

abovementioned is that from Schmitt et al. (Schmitt & Weyand, 1997), in which a greater number of hours maintaining the drainage increases bacterial contamination of the drainage tip. Therefore, Willemen (Willemen et al., 1991), Drinkwater et al. (Drinkwater & Neil, 1995) and Rowe's et al. (Rowe et al., 1993) groups recommend use of drainages up to 24 hours, owing to the relationship between use of drains, microbial contamination in the catheter's tip, risk of prosthetic infection and comfort in early rehabilitation.
Regarding superficial infections, authors such as Saleh et al. (Saleh et al., 2002) and Ovadia et al. (Ovadia et al., 1997), find in their studies that superficial infection is significantly related to use and duration of drainages.

5.4 Use of postoperative blood retrieval

Within the options in saving blood we can use intraoperative and postoperative blood retrieval. Regarding the use of blood retrieval in total knee (Dalen et al., 1996; Gannon et al., 1991; Groh et al., 1990; Handel et al., 2006; Heddle et al., 1992; Hendrych, 2006; Kristensen et al., 1992; Majkowski et al., 1991; Martin et al., 1992; Munoz et al., 2005a; Noain et al., 2005; Simpson et al., 1994; Strumper et al., 2004; Thomas et al., 2001; Wojan et al., 2005; Xenakis et al., 1997) and hip (Gannon et al., 1991;Kristensen et al., 1992) arthroplasty, it is considered to be useful as it decreases blood transfusion necessity, reaching a 48% decrease transfusion requirements.
The use of postoperative retrieval in knee or hip primary surgery, analyzed from a cost-benefit point of view, is a profitable procedure (Dramis & Plewes, 2006; Jones et al., 2004; Thomas et al., 2001; Wojan et al., 2005). However, some authors like Umlas et al. show that the use of a retrieving instrument is not profitable due to its high cost and the small amount of blood retrieved (Umlas et al., 1994). Slagis' group (Slagis et al., 1991) find that using a retrieval is actually associated to a diminishment in costs, but it is not recommended as a systematic manner in all patients undergoing total knee arthroplasty as the amount of blood salvaged is low and they still need blood transfusions.
The amount of blood salvaged in hip arthroplasty surgery is 350-700 mL and 500-800 mL in knee arthroplasty (Dutka et al., 2002), although other groups state that the average transfused amount is around 1000 mL in knee arthroplasty (Breakwell et al., 2000). The study by Han et al. (Han & Shin, 1997) shows that using a retrieval is useful as it is possible to reinfuse 437 mL in hip, 883 mL in knee arthroplasty and 1713 mL in bilateral knee surgery without patients having any air embolism problem, coagulopathy, renal failure or sepsis.
The followed protocol in blood retrieval is the reinfusion of the collected blood within 6 first hours (Dalen et al., 1995). Using blood from postoperative drainage (blood retrieval) in knee arthroplasty does not show important complications (Groh et al., 1990; Sinardi et al., 2005; Wojan et al., 2005), neither inflammatory cell response increase (Altinel et al., 2006; Munoz et al., 2005b; Munoz et al., 2006). According to different studies there are no statistically significant differences within the studied parameters, except for IL-6, which could increase febrile reactions (Handel et al., 2006; Kristiansson et al., 1995). In the study by Bengtson et al. (Bengtson et al., 1990) they found a decrease of anaphylactic toxin and complement activation with no clinical impact. Woda et al. (Woda & Tetzlaff, 1992) describe a case with tracheal edema post-reinfusion of salvaged blood.
The recovered blood culture may be positive in some cases, for this reason Wollinsky et al. recommend antibiotic prophylaxis with cefuroxime to reduce contamination of suction tips and collection bags (Wollinsky et al., 1997). This same study shows that the use of prophylactic cefuroxime limits the transfer of autologous blood products.

Several studies compare the different blood retrievals, finding out that whereas some are easier to use, others have a better suction and that side effects do not present statistically significant differences (Trammell et al., 1991).
Another point of view to look at is that from Mauerhan et al. (Mauerhan et al., 1993) and other authors (Mac et al., 1993; Reize et al., 2006), who find that the use of a recovered blood is not necessary in hip and knee arthroplasty. Faraj et al. show in their study that cost/profit ratio is not profitable when using a blood retrieval (Evans et al., 1993; Faraj & Raghuvanshi, 2006; Jackson et al., 2000).

5.5 Number of drainages

The study by Labek et al. (Labek & Bohler, 1998) links the number of drainages with prosthetic hip bleeding. Their article studies the relationship between number of drainages, its positioning (deep and/or superficial) and its relationship with transfusions needed, wound's exudation, subcutaneous hematoma and thigh edema. Given the possibility of placing three drainages, two drainages, (subcutaneously and subfascial) or one drainage (subcutaneously or subfascial), the conclusion was that using two drainages alone is better rather than 3 drainages or no drainage as there are no more complications with respect to surgical injury and a 47% reduction of blood units was achieved.

5.6 Aspiration pressure

Aspiration pressure is one of many variables when using drains. Cheung et al. state that low suction drains do not increase the number of complications (Cheung & Chiu, 2006). Along the same lines, Benoni et al (Benoni & Fredin, 1997) show that a high aspiration pressure increases drained quantity after knee arthroplasty in a significant way with respect to low-pressure aspiration drainages. The average drained amount in 24 hours is 570 mL in high-pressure aspiration drains and 480 mL in low-pressure ones (p=0,03). At 48 hours, drained quantity had raised to 785 mL and 585 mL (p=0,002) respectively.
Another study regarding aspiration pressure is that from Kirschner et al. (Kirschner et al., 1989) where it is observed that the higher suction pressure increases the risk of secondary hematomas. Martin et al. (Martin et al., 2004), in their study with three groups (no drainages, suction drainages and a third group with non-suction drains), find that the group using non-suction drainages is that with fewer complications and less transfusion requirements.
When studying another variable such as time of aspiration (continuous or discontinuous), and according to Berman et al. (Berman et al., 1990), using continuous aspiration increases drained amount, however it also decreases complications from the surgical wound and transudation through surgical injury. Another study evaluating results from a discontinuous opening of the drain is that from Brueggemann, who shows that clamping the drainages during 55 minutes every hour for the first 6 postoperative hours decreases transfusion needs, without increasing the risk of hematomas or complications from the surgical wound (Brueggemann et al., 1999). Prasad et al. in their study show that an intermittent clamping of drains decreases bleeding, rather than clamping the drainage only initially for 2 hours (Prasad et al., 2005).
Seyfert et al. (Seyfert et al., 2002) compare a group with unicompartmental knee prosthesis with suction drainage and another one with no drainage. The study analyzes bleeding at 12, 24, 36 and 48 hours. Average bleeding in the suction-drainage group was

528 mL, whereas in the non-suction 436 mL. However, difference between both averages was not statistically significant.

5.7 Start/opening-up/end of drainage

If the opening-up of drainage is delayed, the obtained amount through drainage diminishes in a statistically significant manner (Roy et al., 2006; Tsumara et al., 2006). Along the same lines, another study states that delaying the opening-up of drainages 4 hours; drainage decreases in a statistically significant way (Shen et al., 2005).

On the other hand, some authors conclude that clamping drains during first 2 postoperative hours does not influence within drained quantity, nor transfusion number, or mobility, or surgical wound complications (Kiely et al., 2001). Study by Leemann et al. affirms that after 6 hours drainage can be removed as 78% of bleeding has been already drained (Leeman et al., 2006).

Senthil et al. (Senthil et al., 2005) state in their study that 84% of total drain was collected during first 12 hours, and 94% during first 24 hours. The study's conclusion is that articular drainages can be safely removed after first 12 postoperative hours.

The Spanish group headed by Zamora-Navas (Zamora-Navas et al., 1999) study bleeding features in three groups in which drainage is maintained 12, 24 and 48 hours. They observed that the group maintaining drainage for 24 hours had already drained 87% of the total amount at 12 hours time. In the last group (with drainage 48 hours), bleeding at 12 hours corresponded to 91% of the total amount, and bleeding at 24 hours was 97% of the total amount collected after 48 hours.

Regarding when to remove drainage, in the study by Benoni et al. (Benoni & Fredin, 1997) we can observe how the drained amount between 24 and 48 hours is only 215 mL in the high-pressure aspiration drainages, and 105 mL in those with low-pressure aspiration. In conclusion, we can see that aspiration pressure is not more than a variable, as previously seen, and that drained volume between 24 and 48 hours is not as far as important as the bleeding that occurs during first 24 hours.

In the study by Slagis et al., the conclusion of greater volume collected during first operative hours repeats (Slagis et al., 1991). The average collected volume was 493 mL, great part of it being collected during first 4 hours.

Another study showing that prosthetic bleeding is produced during first postsurgical hours is that from Willemen et al. (Willemen et al., 1991), in which they keep drains 48 hours and they observe that 85% of total volume was drained after 24 hours. Between 24 and 48 hours the drain was of only 50 mL.

In our own study (Ares-Rodriguez et al., 2008), we observed that mean of the survival curve for postoperative bleeding time was 16 hours for total knee arthroplasty, and we therefore concluded that drainage in total knee arthroplasty can be safely removed after 18 postoperative hours, with a safety margin.

5.8 Tourniquet

A first study shows that releasing the tourniquet intraoperative (before wound closure) and a correct hemostasis does not reduce total amount of blood lost in total knee arthroplasty (Hersekli et al., 2004). Barwell et al. (Barwell et al., 1997) present in their study that using tourniquet has some side effects and that these can be minimized if removal of tourniquet is done prematurely, together with a thoroughly hemostasis prior to surgical wound closing.

Lotke finds in his study that releasing tourniquet, together with coagulation and immediate start of continuous passive motion (CPM) therapy, increases arthroplasty bleeding (Lotke et al., 1991).

5.9 Surgical technique

Regarding which surgical technique would most reduce postoperative bleeding, several maneuvers have been discussed; such as navigation, sealing the intramedullary femoral canal during femoral preparation in total knee arthroplasty, different prosthetic models and using minimally invasive techniques.

The use of the navigator reduces bleeding through drainage in a statistically significant way, according to the studies by Kalairajah (Kalairajah et al., 2005) and Hinarejos (Hinarejos et al., 2009). On the other hand, groups such as Chang's (Chang CW et al., 2010) or Turajane's (Turajane T et al., 2009) do not find statistically significant differences between minimally invasive surgery with navigation and conventional surgery.

Sealing the intramedullary femoral canal in non-navigated surgery and with intramedullary femoral guide decreases both the fall in hemoglobin and transfusion requirements in a statistically significant way (Ko et al., 2003; Raut et al., 1993). Another study showed a decrease in bleeding through drainages with this technique (Kumar et al., 2000).

Porteous et al. (Garcia-Erce et al., 2002; Porteous and Bartlett, 2003) analyze postoperative drainage in three implant types; cemented, hybrid and uncemented total knee replacement. The statistically significant conclusion is that cemented prosthesis has a lesser bleeding with regard to other two groups during 8 first hours, but this difference decreases after 24-48 hours. Another study states that constrained arthroplasty increases blood loss (Berman et al., 1988).

6. References

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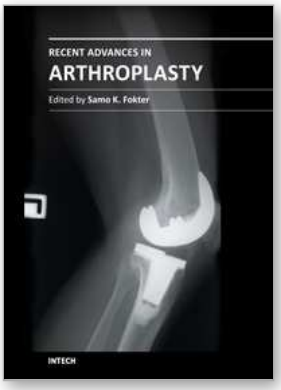

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The purpose of this book was to offer an overview of recent insights into the current state of arthroplasty. The tremendous long term success of Sir Charnley's total hip arthroplasty has encouraged many researchers to treat pain, improve function and create solutions for higher quality of life. Indeed and as described in a special chapter of this book, arthroplasty is an emerging field in the joints of upper extremity and spine. However, there are inborn complications in any foreign design brought to the human body. First, in the chapter on infections we endeavor to provide a comprehensive, up-to-date analysis and description of the management of this difficult problem. Second, the immune system is faced with a strange material coming in huge amounts of micro-particles from the tribology code. Therefore, great attention to the problem of aseptic loosening has been addressed in special chapters on loosening and on materials currently available for arthroplasty.

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