ORIGINAL PAPER

Bloodless surgery total kree arthroplasty

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Introduction. The purpose of this study is to try to decrease the amounts of blood transfused in knee prosthetic surgery by using blood-saving methods. We consider that a realistic target would be reducing the transfusion rate to less than 10%.
Materials and methods. Cohort study made up of a current cohort of 105 patients (107 total knee arthroplasties) and a historical control cohort of 193 patients (197 total knee arthroplasties). The study period extended from May 2004 to August 2005.
Results. Transfusion rate: historical cohort: 57.3% (113 patients); current cohort: 7.5% (8 patients). Erythropoietin has led to an increase in preoperative hemoglobin levels (mean value: 2.3 g/dl higher than the initial level). In the historical cohort, 3 patients entered a predonation program. In the current group, 34/55 patients (61.8%) entered such a program. The mean preoperative hemoglobin level was 13.9 g/dl (range: 13-14.9 g/dl) and decreased to 12 (range: 10.6-13.6 g/dl) after extraction of the two blood units. Of the 67 blood bags extracted, only 45 (67.1%) were used and 22 were discarded (32.9%).
Conclusions. Erythropoietin and the autotransfusion program have shown their usefulness in reducing the amount of blood transfused in prosthetic knee surgery.

Key words: *total knee replacement, bloodless surgery.*

Cirugía sin sangre en las prótesis totales de rodilla

Introducción. El objetivo del trabajo es intentar disminuir el índice transfusional en cirugía de prótesis de rodilla aplicando métodos de ahorro de sangre. Consideramos un objetivo realista conseguir un índice transfusional por debajo del 10%.
Material y método. Estudio de cohortes: una cohorte actual, con 105 pacientes (107 prótesis totales de rodilla), y otra histórica de control con 193 (197 prótesis totales de rodilla). El período de estudio comprende desde mayo de 2004 hasta agosto de 2005.
Resultados. El índice transfusional en la cohorte histórica fue del 57,3% (113 pacientes), y en la cohorte actual del 7,5% (8 pacientes). La eritropoyetina ha conseguido una mejoría en el aumento de los niveles de hemoglobina preoperatorios: valor promedio de 2,3 g/dl más alto que el nivel inicial. En la cohorte histórica, 3 pacientes entraron en un programa de predonación; en el grupo actual, 34/55 pacientes (61,8%). El promedio del nivel de hemoglobina preoperatoria fue de 13,9 g/dl (rango: 13-14,9 g/dl) y pasó a 12 (rango: 10,6-13,6 g/dl) tras la extracción de las dos unidades de sangre. De las 67 bolsas de sangre extraídas, sólo han sido utilizadas 45 (67,1%) y 22 se han desechado (32,9%).
Conclusiones. El empleo de eritropoyetina y el programa de autotransfusión han demostrado su utilidad en el ahorro de sangre a transfundir en la cirugía de prótesis total de rodilla.

Palabras clave: *prótesis total de rodilla, cirugía sin sangre.*

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INTRODUCTION

Bloodless surgery is a proponed therapeutic option that consists in minimizing the use of allogenic blood transfusions. In 1977 Ott and Cooley[1] published the results of their experience of 20 years of open heart surgery with 542 Jehovah's Witnesses. This idea was subsequently taken up by other surgeons and grew progressively, with multiple references in the literature to the treatment of these patients by different medical and surgical specialists.

Currently every year 75 million blood units are donated worldwide. The expression «safe blood» is relative, since blood transfusions in first-world countries also have a risk of disease transmission

Probably the highest risk is in relation to human immunodeficiency virus (HIV (1:1.5-2 million), hepatitis B virus (HBV) (1:100.000) and hepatitis C virus (VHC) (1:60.000). Moreover, there are other diseases with currently unknown incidences of transmission by transfusion (Creutzfeld-Jakobs, cytomegalovirus, simian foamy virus [SFV], West Nile virus [WNV], etc.).

To be able to calculate the transfusion needs of each patient various studies were carried out in the 90s assessing different variables. For example, Nelson et al suggested the following formula:

$$EBL = \frac{[VOL \times (Hmt\ pre - Hmt\ pos)]}{Hmt\ pre}$$

In which EBL = estimated blood loss, VOL = total blood volume and Hmt = hematocrit.

In another study, Larocque classified patients by assessing a series of variables such as preoperative hemoglobin (Hb) levels, weight, type of surgery (knee, hip), uni- or bilateral, primary or revision surgery; in an attempt to predict the probability of transfusions in knee and hip replacement using a score system. Moreover, it is known that allogenic transfusion causes immunomodulatión[2]. This was described by Opelz, who showed an improvement in survival in patients who underwent kidney transplant and received a transfusion.

Undoubtedly, this is beneficial in some diseases and negative in others[3]. An increase in recurrence in colorectal cancer has been seen in patients that underwent resection surgery and that received allogenic transfusion.

However, the only unanimous conclusion in all the studies published is that the main predictive value of the need for transfusions is preoperative levels of hemoglobin[4,5].

All other variables (weight, height, age, sex) are of questionable value.

In our specialty we have begun to see that patients who receive allogenic transfusions have a higher rate of postoperative infection (nosocomial and postoperative)[6]. Blood donation in our country is completely altruistic, as also in another 80 countries, amongst which are practically all European countries, and the number of active donors is around 90 million worldwide.

The aims of this study are the following:

1) Main objective: to decrease the transfusion rate seen in historic cohorts (57.3%), using blood-saving methods. We consider a realistic objective would be to achieve a transfusion rate below 10%.

2) Operative objectives: a) to assess the efficacy of each of the blood-saving methods used: erythropoeitin (EPO), predonation-autotransfusion and Redon recovery and transfusion threshold; and b) to assess the cost/benefit ratio of blood-saving techniques in a tertiary hospital.

MATERIALS AND METHODS

We carried out a cohort study, comparing a current cohort and a historic control cohort. The historic cohort included 193 patients that received 197 total knee replacements during 2002. All the patients were operated in the Donostia Hospital. The current cohort included 105 patients, which received 107 total knee replacements from May 2004 to August 2005. All the patients were operated in the Donostia Hospital. The study had the approval of the Ethics Committee of our hospital.

Inclusion and exclusion criteria were applied to both groups. In the historic group we included all patients who came for consultation to the Trauma and Orthopedic Surgery Service of Donostia Hospital who had undergone total knee replacement and were operated on in the year 2002. In the current group we included all patients seen in consultation by the surgeons who participated in the study and who underwent surgery between May 2004 and August 2005.

The exclusion criteria were: over 80 of age and treatment with coumarin derivatives.

Three models of prostheses were used: Duracon, Genesis II and LCS (in 5 cases and only in the current group). In both cohorts, we carried out antibiotic prophylaxis with cefazoline IV, administering 2 g before induction of anesthesia (one dose). Prophylaxis to prevent thromboembolism was carried out in both cohorts with 40 mg of enoxaparin administered subcutaneously (sc) every 24 hours for 4 weeks.

In the historic cohort the types of prostheses used were the following: Duracon: 152 implants (134 with preserved PCL [88.1%] and 18 without preserved PCL [11.9%]); and Genesis: 45 implants (26 with preserved PCL [57.7%] and 19 without preserved PCL [22.3%]).

The following prostheses have been used in the current cohort: Duracon: 79 implants (43 with preserved PCL [54.4%] and 36 without preserved PCL [45.6%]); and Gen-

esis: 23 implants (8 with preserved PCL [34.8%] and 5 without preserved PCL [65.2%]); and LCS: 5 implants, all with preserved PCL.

In the historic cohort, 190 prostheses were cemented and 7 were non-cemented. In the current cohort, the 107 prostheses were cemented.

Variables studied

1) Identification variables: name, surname and clinical history number.

2) Quantitative variables: Hb (g/dl), blood pressure (mmHg), anemia indicators (folic acid [ng/ml], iron [Ìg/dl], transferrin [mg/dl], ferritin [ng/ml], vitamin B12 [pg/dl], transferrin saturation [%]) and age.

3) Category variables: sex (man: 0, woman: 1), type of previous disease (yes: 0, no: 1), administration of EPO (yes: 0, no: 1), allogenic transfusion (yes: 0, no: 1), predonation transfusion (yes: 0, no: 1), incidence during surgery (yes: 0, no: 1), complications with Redon recovery (yes 0, no: 1), complications during evolution (yes: 0, no: 1), type of pathological condition (arthritis: 1, rheumatoid arthritis: 2, others: 3), type of anesthesia (regional + sedation: 1, regional + sedation + epidural catheter: 2, general: 3), classification according to the *American Society of Anesthesiology* (ASA I: 1, ASA II: 2, ASA III: 3, ASA IV: 4, ASA V: 5).

Distribution into groups

As preoperative HB levels are the most important known predictive factor for assessing the probability of allogenic transfusion, we divided the patients of each cohort into 3 groups.

1) Group A: level of Hb < 13 mg/dl.
2) Group B: level of Hb between 13-15 mg/dl.
3) Group C: level of Hb > 15 mg/dl.

For each of the three groups of the current cohort we designed a protocol for the preoperative phase, one for the intraoperative phase and one for the postoperative phase[7,8].

Preoperative phase

1) Group A: as the probability of transfusion in this group of patients is very high, we gave them EPO. If there was any contraindication to this, we did not treat, but included them in the study. The dose of EPO was 40,000 UI/sc in 4 weekly doses, beginning on day 21 of the preoperative period, and continuing on days 14 and 7 of the same; the last dose was given on the day of surgery. If Hb levels were above 15 g/dl and there was still a dose of EPO scheduled this was suspended. Throughout treatment patients received a complement of 240 mg of iron sulfate daily.

2) Group B: These patients have a medium probability of transfusion and they are on a protocol to enter a program of predonation-autotransfusion. The level of Hb is determined during the preoperative study, the date for surgery is scheduled and, 3 weeks before that date, minimum, patients are sent to a blood bank for the extraction of 2 complete blood units. Moreover, they have to take 240 mg of iron sulfate daily.

3) Group C: as these patients have a low probability of transfusion, no action was indicated during this phase.

Surgical phase

During this phase we used a protocol for the application of ischemia from the beginning to the end of surgery in all patients. Ischemia was suspended once the Redon recovery drainage was in place[9,10].

We recommended that an electrical scalpel be used once the skin incision was made, and also that the surgical incision should be as small as possible in all patients. A minimally invasive technique (MIT) was not used in any patient.

Postoperative phase

In this phase all groups had to follow the same protocol guidelines.

1) Redon recovery: we drew up a protocol for the use of the Consta VacTM CBC II Stryker® model. The recovery drainage has a filter to retransfuse blood, this is the conventional 200 micron filter, we substituted it for one of 40 microns for greater safety to recover and transfuse the blood from the drainage during the first 4-6 hours of the postoperative period[9].

2) Transfusion threshold*:* the appropriate level is between 7-10 g/dl Hb and, when this is reached, based on the clinical situation of each patient[11], a decision is made whether to carry out a transfusion. Health status is determined according to the ASA[12] classification. All patients took 240 mg of iron sulfate daily fasting (two tablets at breakfast and one at dinner), for 3 weeks after surgery.

Statistical methods

All data included in the Systat statistical package editor was assessed by means of a preliminary analysis to detect incongruence, values out of logical range, alteration of recruitment criteria, etc. Error detection and subse-quent correction was carried out by checking clinical histories.

Category variables are in absolute frequency values and relative frequency values (%). Quantitative variables are in mean and standard deviation values.

Table 1. Transfusion rate in the historical cohort

	Total nr. of patients	Patients transfused
Group A	53	38 (65,5%)
Group B	105	62 (59%)
Grupo C	39	13 (33,3%)

Group A: hemoglobin level (Hb) < 13 mg/dl; group B: Hb between 13 and 15 mg/dl; group C: level of Hb > 15 mg/dl.

Table 3. Average age according to sex in both cohorts in the 3 groups

	Historic cohort		Current cohort	
	Females	Males	Females	Males
Group A	67,9	77,5	73	68,5
Group B	70,3	69,3	71	65,3
Group C	68,2	63,1	77	78,1

Group A: hemoglobin level (Hb) < 13 mg/dl; group B: Hb between 13 and 15 mg/dl; group C: level of Hb > 15 mg/dl.

X^2 was used to compare qualitative variables in different groups, collapsing categories if the final calculated value was < 5, or using Fischer's test when necessary.

We used t Student or ANOVA to compare the distribution of quantitative variables in different groups if the number of groups was greater than 2.

In all cases we established a significance of ·=0.05. Statistical analysis was carried out using version 8 of the STATA statistical package in a Windows XP environment.

RESULTS

Transfusion rate

Having analyzed the data from both cohorts it is possible to see that the result obtained was a decrease in the transfusion rate. In the historic cohort the transfusion rate was 57.3% (113 patients) and in the current cohort it was 7.5% (8 patients). This difference is statistically significant ($X^2 = 34.4$, df = 1, $p < 0.05$). If we analyze this based on Hb values, and, therefore by groups, we see a variation in transfusion rate which we have detailed in Tables 1 and 2.

Sex

We found a clear predominance of women over men in both cohorts, with the exception of both C groups, in which this woman/man ratio was inverted.

1) Historic cohort: 142 women/55 men (72.1/ 27.9%).

2) Current cohort: 76 women/31 men (71.1/ 28.9%).

There is no statistically significant difference in sex distribution in both cohorts.

Age

We did not include patients over 80 years of age in this study (supposed to be 9.3% of the historic cohort). What we have seen over a 2 year interval is an increase in patient age in 5.1 years for women and 3.2 years for men. However, this difference is not statistically significant.

Average age in both cohorts was:

1) Historic cohort: women 67.9 years, with a range of 40 to 79; men 65.3 years, with a range of 49 to 79 (Table 3).

2) Current cohort: women 73 years, with a range of 50 to 79; men 68.5 years, with a range of 58 to 79.

ASA assessment

Assessment of patients' health status for anesthesia was performed according to ASA and it is possible to see that in both cohorts most patients were ASA II and III. As we have seen when detailing previous diseases, the patients in the current cohort are less healthy (Table 4).

If we compare both cohorts and asses, on one hand, patients ASA I and II, and on the other hand, patients ASA III, IV and V we find that the index for severity of disease is greater in the current cohort, and this difference is statistically significant ($X^2 = 6.16$, df = 1, $p < 0.05$).

Table 2. Transfusion rate in the current cohort

	Total nr. of patients	Patients transfused
Group A	33	4 (12,1%)
Group B	55	3 (5,4%)
Group C	19	1 (0,9%)

Group A: hemoglobin level (Hb) < 13 mg/dl; group B: Hb between 13 and 15 mg/dl; group C: level of Hb > 15 mg/dl

Table 4. Number and percentage of patients in each ASA category (*American Society of Anesthesiology*)

	Historic cohort	Current cohort
ASA I	4	0
ASA II	144	65
ASA III	45	40
ASA IV	4	2
ASA V	0	0

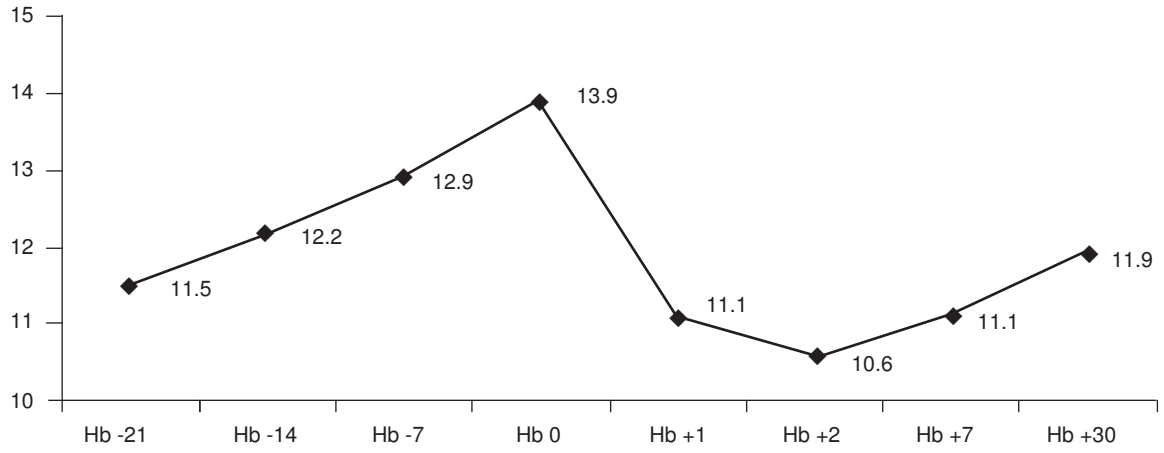

Figure 1. *Evolution of Hb levels in patients treated with erythropoeitin.*

ERYTHROPOEITIN

Patients with preoperative Hb levels below 13 g/dl were treated with EPO, therefore patients in both A groups. Treatment with EPO achieved a marked improvement in preoperative Hb levels, elevating them by an average 2.3 g/dl above initial levels. One week after surgery, patients' average levels of Hb were 0.4 g/dl lower than before surgery. One month after surgery, Hb levels were an average 0.3 g/dl above initial levels (Figure 1).

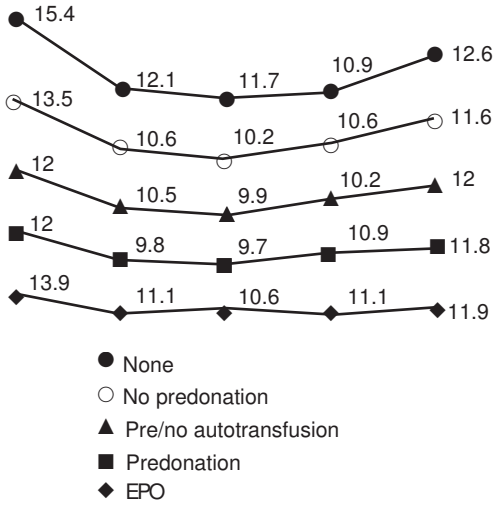

Figure 2. *Evolution of Hb levels in each of the groups (A, B and C) and in the 3 subgroups in group B from the day of surgery, and postoperatively days 1, 2 and 7, and 1 month. EPO erythropoeitin Group A: Hemoglobin level (Hb) < 13 mg/dl; group B: Hb between 13 and 15 mg/dl; group C: level of Hb > 15 mg/dl.*

Predonation-Autotransfusion

Included in this group are those patients with a preoperative Hb level of 13-15 g/dl. Due to these levels they are candidates for an autotransfusion program and are both B groups. In the historic cohort there were 3 patients in this group. In the current B group 34 patients of the 55 in the group (61.8%) followed the predonation protocol. Average preoperative Hb in the patients that followed the predonation protocol was 13.9 g/dl, with a range of 13 to 14.9 g/dl, and changed to 12 g/dl on the day of surgery, after extraction of two bags of blood, with a range of 10.6 to 13.6 g/dl. Of the 67 bags of blood extracted, only 45 (67.1%) were used and 22 were discarded (32.9%) (Figure 2).

Redon recovery

1) Historic cohort: Postoperative drainage with Redon blood recovery was used in 79 patients (40.1%) and was not used in 118 (59.9%); of these 13 required allogenic transfusion (24.5%).

2) Current cohort: Postoperative drainage with Redon blood recovery was used in 100 out of 107 patients (93.5%).

The average amount of blood recovered through the drainages was 608 cc, with a range of 150 to 1,575 cc.

If we break down the amount of blood recovered per group it is possible to see: Group A: 714 cc, group B: 589 cc and group C: 687 cc (average: 663 cc).

If we compare both cohorts, it is possible to see that the percentage of use of Redon drainage went from 40.1% in the historic cohort to 93.5% in the current cohort, and this difference is statistically significant ($X^2 = 84.3$, df = 1, $p < 0.05$). The average amount of blood recovered increased from 383 to 608 cc.

Transfusion threshold

In the historic cohort 113 patients received allogenic blood transfusion and in the current cohort 8 required allogenic transfusion.

Clinical evolution and complication rates

In the historic cohort the only information available was on prostheses infections, so that is the only data compared.

In the historic cohort there were 3 patients (1.5%) who suffered prostheses infections and in the current cohort 1 patient (0.09%).

One patient had deep vein thrombosis in the non-operated leg. She was in group B and did not receive a transfusion of predonated blood.

Two nosocomial infections were seen: there was a respiratory infection in a patient with a history of heart disease and hypertension, this patient was in group C and did not require transfusion; and there was a urinary infection in a patient with a history of heart disease and hypertension, this patient was in group B but did not enter the predonation protocol because of their disease history and received a transfusion of 2 units of allogenic blood.

Oral iron

None of the patients in the historic cohort received oral iron based on a protocol. Oral iron was administered preoperatively to all patients in group A who received EPO (30 patients) and to those in the predonation protocol in group B (34 patients).

DISCUSSION

The probability of complications related to the transfusion of a unit of red blood cells is 1.71/1,000 and there may be serious complications that cause significant patient morbidity and even death (0.74% of all hospital admissions due to transfusion reaction [TR]).

In our country blood donation is completely altruistic, however, there is a cost related to blood transfusion as has been shown in the systematic review carried out by Amin et al[13]. These investigators also carried out a study in Canada on the costs generated during the years 2002-2003[14] and they calculated that the mean cost of a blood bag in this country was 264.81$.

The preoperative phase is the moment when, based on assessment of Hb levels, we can carry out actions to improve them. Currently this is mainly through use of EPO, now available. However, we can also use blood-saving techniques such as autotransfusion, as a predonation or by acute normovolemic hemodilution and intravenous iron.

Indications for the administration of EPO are a level of Hb of 10-13 g/dl, since the probability of transfusion is greatest in this group. EPO can be administered once (primary surgery) or as a coadjuvant in autotransfusion programs[15]. However, EPO administration has a series of contraindications: non-controlled hypertension, recent acute myocardial infarction, unstable angina, severe peripheral vascular disease and recent stroke. Other disadvantages are: the need for intra-hospital coordination of the different services involved, monitoring of Hb levels so as not to exceed 15 g/dl, a fixed predetermined operation date and the high cost of these.

When we mention autotransfusion we are referring to 3 different techniques:

1) Predonation-autotransfusion.
2) Acute normovolemic hemodilution.
3) Blood recovery (intra or postoperative). We will analyze this technique later, since here we wish to refer to measures during the preoperative phase.

The first published reference to this technique was that of Milles et al in 1962. Predonation-autotransfusion may be considered the 'gold standard' within blood-saving techniques, although it may have some disadvantages in some cases: patients are anemic when they reach surgery, a high percentage of extracted blood bags are not used, the number of transfusions increases, with their respective risks and costs[16], there can be the same number of administrative errors (confusion with blood bags) as with allogenic transfusion, the cost/effectiveness ratio is low in primary surgery[7] and it implies an increase of organizational work and some discomfort for the patient.

However, there are arguments in favor of this procedure: there is a significant decrease in allogenic transfusion[17,18], there are lower rates of postoperative infection than with allogenic transfusion, it saves «blood that others cannot donate to themselves», patient anemia and the low percentage of use of the predonated bags is due to incorrect calculations of patients' needs[17,18], there is a decrease of risk of thromboembolic events in knee and hip replacement surgery[19]. Undoubtedly in our country predonation is at a lower level of use in relation to the total number of donations[20].

Major surgery causes a systemic inflammatory response, in which the tumor mediators involved (tumor necrosis factor [TNF], interleukin [IL]-1, interferon [INF]) inhibit erythropoeisis by suppression of the erythroid line, and, therefore, indirectly inhibit the production of endogenous EPO. Furthermore, these cytokines induce functional iron deficiency, even though iron deposits are normal[21]. We currently have iron sucrose available to act on the inflammatory response. However, the use of iron sucrose in our country was approved in the year 2000, and there is little

published literature referring to its use in our specialty, and what there is is basically related to the management of anemia in cases of hip fracture[22].

We must attempt to reduce blood losses during surgery and use appropriate hemosthasis. In the cases of hip and spine surgery, intraoperative blood recovery is of great use, although this is not the case in knee surgery. To improve hemosthasis we can use systemic hemosthatic agents, fibrin sealers, an appropriate surgical technique, and avoid hypothermia in surgical patients.

Currently, and specifically in knee and hip replacement surgery, MIS techniques are beginning to be used, amongst other theoretical benefits they would cause less blood loss[23]. For the moment this has not been demonstrated in total knee replacement, since bleeding is similar, in part due to the fact that passive mobilization is begun 6 hours after surgery and this contributes to greater bleeding[24].

During the postoperative phase we only have 2 options available: recovery of postoperative blood and the use of an appropriate transfusion threshold. This first option has many detractors since there is no scientific evidence to justify the use of a Redon drainage during the postoperative period[25]; this has been confirmed in a meta-analysis carried out in 2004 by Parker et al[26]; the need for transfusion is greater if postoperative Redon drainage is used. The blood transfused is not of good quality. But there are many who defend this procedure since Redon blood recovery decreases the need for allogenic transfusion. In a meta-analysis performed by ISPOT (*International Study of Perioperative Transfusion*) in 1999 it was seen that Redon recovery decreased the relative risk of allogenic transfusion by 39%. Subsequently, in 2004, the Cochrane[27] library, also concluded that the use of recovery decreased the risk of allogenic transfusion by 42%. It is an autotransfusion method that does not entail the disadvantages of pre-storage. The quality of the blood recovered is guaranteed. For this to be true, it is indispensable to recover blood during the first 4 hours postoperatively and to transfuse it before 6 hours of the postoperative period[9] have gone by. Furthermore, it is not convenient to transfuse more than 1,000 cc to prevent hypervolemic complications. Currently it has been proven that filtered unwashed blood is equivalent in safety to washed blood[8,28].

When the expression «transfusion threshold» is used, it refers to the clinical circumstances of the patient at the time of deciding whether or not to give a blood transfusion. Currently, isolated Hb values are not enough to decide whether to give a blood transfusion. It is necessary to assess other clinical parameters. In 1942, Adams and Lundy recommended the 10/30 rule as advisable values for carrying out a blood transfusion thus avoiding possible risks to the patient. This rule was adhered to practically uniformly until the end of the eighties. However, with the appearance of HIV and its transmission by blood transfusion, this rule came to be queried. In the USA in 1988 a consensus conference took place and it was recommended that transfusion be carried out when Hb levels were between 7 and 10 g/dl[20].

In a prospective randomized study carried out by Herbert et al in Canada it was seen that in patients in the Intensive Care Unit under 55 years of age and with an APACHE (*Acute Physiology and Chronic Health Evaluation*) score < 20, that maintained a level of Hb between 7 and 9 g/dl, the results obtained without transfusion were the same or even better than in patients with HB levels above 10 g/dl, always provided the patients were normovolemic. However, in patients with active ischemic coronary syndrome, if Hb levels were not maintained above 10 g/dl, morbid-mortality increased. In another study, Bak et al carried out preoperative acute normovolemic hemodilution in 8 healthy patients (between 13 and 61 years of age). Subsequently, these patients underwent scoliosis correction surgery and during the whole process were monitored by transesophageal ultrasound and it was seen that a Hb level of 8 g/dl was tolerated by these patients without any problem.

Jehovah's Witnesses are the population in which acute post-surgical anemia has been best studied. In a retrospective cohort study on 2,083 patients, Carson et al saw that in 300 patients with Hb levels between 7 and 8 g/dl there was 0% mortality and 9.5% morbidity. However, if Hb levels descended to 5 g/dl, 30 day mortality was 34%.

However, currently no study has been performed to define the level of Hb at which it is necessary to administrate blood transfusion. As we commented at the beginning, the decision to administer blood transfusions must be based on the general clinical status of the patient[11,29].

When we speak of blood substitutes, we mean red cell substitutes, since these provide the body with O2, whereas volume, as has been mentioned previously, can be replaced by crystalloid and/or colloid solutions. Currently the red cell substitutes available are Hb solutions and perfluorocarbonates.

At the moment only a few studies with few patients have been performed using these substances; their use does not seem to be widespread, save in military operations or civilian catastrophes as resuscitating agents until the patient reaches the nearest hospital.

In view of our results we can formulate the following conclusions:

1) The most important predictive value to establish the probability of the need for transfusions is preoperative Hb. According to the results obtained, it seems reasonable to use the new blood-saving protocol we have proposed.

2) EPO is a safe and effective drug. It should be used in patients with greater probability of need for allogenic transfusion and although it has a high cost, is the only thing currently available for this group of patients. On the other

hand, it is not always necessary to use 4 doses to avoid administering allogenic transfusions.

3) Predonation-autotransfusion is very effective. In this series, none of the patients that received a transfusion of their own predonated blood required allogenic transfusions. However, its efficacy is low since we did not use 32.9% of the predonated blood bags.

4) For Redon recovery in this study we used a Consta VacTM CBC II Stryker®, which has been seen to be very safe. This confirms that in this type of surgery and using this system it is not necessary to wash filtered blood. The efficacy of this procedure is high, and we have seen that the average recovery of blood is equivalent to at least a bag of red blood cell concentrate and the cost is similar.

5) It is important to keep in mind that the organization of a blood-saving system requires a large organizational effort, which necessarily involves the Services of Hematology, Anesthesia and Surgery.

6) However, we must not forget that allogenic blood transfusion continues to be an essential procedure in everyday medical practice.

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Conflict of interests

The authors have declared that they have no conflict of interests.