Narayana Prasad · Vinod Padmanabhan ·
Arun Mullaji

Blood loss in total knee arthroplasty: an analysis of risk factors

Received: 23 December 2005 / Revised: 5 February 2006 / Accepted: 6 February 2006 / Published online: 28 March 2006
© Springer-Verlag 2006

Abstract The amount of blood loss in a primary cemented total knee arthroplasty (TKA) seems to vary in different reported studies. We carried out a prospective study to determine the factors affecting the peri-operative blood loss, hidden blood loss and blood transfusion requirements in a primary cemented total knee arthroplasty. The factors analysed were gender, diagnosis, tourniquet time and body mass index (BMI). We included a total of 66 consecutive patients who underwent primary TKA by a single surgeon (A.M). There was significantly more peri-operative blood loss in male patients than in females ($p=0.001$, Student's t test). The patients with rheumatoid arthritis did not show any statistical difference in peri-operative blood loss compared with that in patients with osteoarthritis. The tourniquet time and the surgical time showed a positive correlation with peri-operative blood loss. The BMI did not show any correlation with peri-operative blood loss. The incidence of blood transfusion was significantly higher in patients with rheumatoid knees as their pre-operative haemoglobin value was low. The amount of hidden blood loss in our series was 38%. We concluded that gender and tourniquet time plays a role in blood loss in TKA, but diagnosis (advanced osteoarthritis [OA] or rheumatoid arthritis (RA) does not. The blood transfusion depends on both pre-operative haemoglobin value and intra-operative blood loss. The post-operative transfusion trigger can be brought to 8.0 g% in a haemodynamically stable patient.

Résumé La quantité de perte de sang dans une prothèse totale du genou de première intention cimentée est variable suivant les différentes études. Nous avons réalisé une étude prospective pour déterminer quels étaient les facteurs de la perte sanguine péri-opératoire et quels étaient les facteurs qui entraînent dans la nécessité d'une transfusion, après une prothèse totale du genou de première intention. Les

facteurs analysés ont été le sexe, le diagnostic, l'utilisation d'un garrot, le BMI. Nous avons inclus dans cette étude, 66 patients consécutifs, opérés par le même chirurgien (A.M.). Il y a eu une de façon significative une augmentation des pertes sanguines péri-opératoires chez les patients de sexe masculin ($p=0.001$, Student's t test). Les patients présentant une arthrite rhumatoïde n'ont pas montré de différences significatives dans la perte de sang, comparés aux patients opérés pour gonarthrose. Le temps de garrot et le temps opératoire sont en corrélation avec les pertes de sang péri-opératoires, l'augmentation du BMI ne semble pas avoir de corrélation avec la perte sanguine. L'incidence des transfusions est de façon significative plus élevée chez les patients opérés pour arthrite rhumatoïde du genou et dont l'hémoglobine préopératoire était basse. Nous pouvons en conclure que le sexe et le temps de garrot ont une responsabilité dans la perte de sang dans la prothèse totale du genou mais, certainement pas l'étiologie. La nécessité de transfusion dépend du taux d'hémoglobine préopératoire et des pertes sanguines per-opératoires. Une transfusion peut être pratiquée pour 8.0 g% chez un patient haemodynamiquement stable.

Introduction

Total knee arthroplasty (TKA) is a major orthopaedic operation that involves significant blood loss because of extensive soft tissue release and bone cuts. It is estimated that in general 15 million transfusions are performed each year, with 20% having some adverse effect [28]. Risk of HIV transmission is a major concern, with 1–2% of transfusions developing this [28]. Allogenic transfusion is also associated with many immunological and other non-infectious transfusion complications [11]. The reported mortality rate for mismatched transfusions is variable, but can be expected to be approximately 10% due to shock, renal failure and bleeding [19]. Even autologous transfusion is not risk free, autologous donors as a group tend to be older and less healthy, which increases the chance of complications during donation, and of unrecognised bacteraemia at

N. Prasad (✉) · V. Padmanabhan · A. Mullaji
Trauma and Orthopaedics,
Bombay Hospital and Postgraduate Institute,
Mumbai, India
e-mail: nporth@ntlworld.com

Table 1 Patient demographics

Parameter	Statistic
Total patients	66
Males	21
Females	45
Median age (range)	67 years (49–81)
Mean height (SD)	156.3 cm (± 13.2)
Mean weight (SD)	69.2 kg (± 8.8)
Mean BMI (SD)	28.2 (kg/m ² ; ± 3.8)
Median (range) hospital stay	7 days (6–14)
Right side	38
Left side	27

the time of blood collection [18, 29]. Autologous transfusion may actually lead to decreased haemoglobin levels post-operatively, resulting in transfusion of autologous blood in people who, if they had not donated and thus lowered their haemoglobin level before surgery, would not have needed transfusion [7]. Autologous transfusion also causes unnecessary wastage of blood and unnecessary expenses [4, 7, 16].

The amount of blood loss and incidence of blood transfusion in a primary cemented TKA appear to be highly variable in the published literature [2, 3, 8, 23, 26]. We carried out a prospective study to analyse various factors affecting the blood loss in a primary uncomplicated cemented total knee arthroplasty and to compare the blood loss and blood transfusion incidence in our series with some of the published series. The independent factors analysed were gender, diagnosis, body mass index and tourniquet time. We also decided to measure the hidden blood loss associated with TKA.

Patients and methods

A prospective study was conducted for a 6-month period starting in January 2002 involving all patients who underwent primary TKA performed by a single surgeon (A.M) in our institution. A total of 66 patients were considered for the study after excluding four patients who underwent bilateral TKA within a period of 1 week. Patients who had had previous knee surgery were also not considered for the study. None of the patients had any haematological disorders. Informed consent was obtained from all participants.

Table 2 Summary of results. *TQ* tourniquet

Parameter	Statistic
Mean TQ time (SD) in min	71.7 (± 17.68)
Mean surgical time (SD) in min	117.9 (± 19.62)
Mean intra-operative blood loss (SD) in ml	220 (± 115.6)
Mean drainage (SD) in ml	443 (± 160.9)
Apparent blood loss (SD) in ml	663 (± 209.7)
Estimated blood loss (SD) in ml	1,073 (± 436.8)

Table 3 Comparison of blood loss in male female patients. *Hb* haemoglobin

	Intra-operative loss (ml)	Post-operative drainage (ml)	Hb drop (g%)	Average transfusion unit	Tourniquet time (min)
Male	265 $\pm$ 144	554 $\pm$ 142	2.53 $\pm$ 0.86	0.43 $\pm$ 0.67	75.3 $\pm$ 10.2
Female	203.8 $\pm$ 100	402 $\pm$ 148.5	2.35 $\pm$ 0.68	0.28 $\pm$ 0.57	70.04 $\pm$ 14
<i>P</i> value	0.139	0.001	0.62	0.37	0.14

The patients' age, height (ht), weight (wt) and body mass index (BMI) were recorded. All patients received pre-operative iron supplementation for 4 weeks and NSAIDS were stopped 1 week prior to the operation. Advanced osteoarthritis (OA) was the reason for performing TKA in 50 patients whereas advanced rheumatoid arthritis (RA) was the indication in 16 patients.

A standard technique was used in all the cases. The procedure was performed under spinal/epidural anaesthesia and a tourniquet was inflated 100 mmHg above the systolic blood pressure in all of the patients. An anterior midline skin incision and a medial parapatellar arthrotomy were performed. To reduce the intra-operative blood loss from the femoral hole an intramedullary plug with bone grafts was used [23]. The implant used was a cemented press fit condylar (PFC) prosthesis. The tourniquet was deflated before closure to achieve haemostasis and a meticulous closure was performed after inserting a Redivac suction drain inside the joint. The drain was removed after 48 h. We did not use a re-infusion drain or intra-operative cell savers during our study period.

In all the cases intra-operative blood loss was assessed by weighing the sponges used during the procedure and also by measuring the amount of blood in the suction bottle. The amount of post-operative blood loss was calculated by measuring the amount of blood in the drainage bottle after 48 h. All patients had their haemoglobin (Hb) and packed cell volume (PCV) checked, on the pre-operative day and on post-operative days 1, 2, 7 and 15. The drop in Hb was calculated between the lowest post-operative value and the pre-operative value. Continuous passive motion and full

Table 4 Comparison of blood loss in osteoarthritis (OA) and rheumatoid arthritis (RA) patients

	Intra-operative loss (ml)	Drainage (ml)	Hb drop (g%)	Average transfusion	Tourniquet time (minutes)
OA	216 $\pm$ 104	440 $\pm$ 173	2.39 $\pm$ 0.76	0.24 $\pm$ 0.53	70 $\pm$ 13.4
RA	235 $\pm$ 126	455 $\pm$ 168	2.24 $\pm$ 0.64	0.66 $\pm$ 0.72	77.8 $\pm$ 20
<i>P</i> value	0.78	0.90	0.68	0.04	0.22

Fig. 1 Relationship between tourniquet time and intra-operative blood loss

weight-bearing mobilisation were started on the second day after drain removal. Any patient who had a post-operative Hb value of less than 8.0 g% received a blood transfusion. A physician and an anaesthetist assessed all patients post-operatively.

Intra-operative and post-operative blood loss, drop in Hb and incidence of blood transfusion were compared in male and female patients and also separately in patients with a diagnosis of osteoarthritis and rheumatoid arthritis. A statistical analysis was carried out using multivariate regression analysis and the Student's *t* test. All values were calculated as mean $\pm$ standard deviation. *P* value less than 0.05 was considered significant. Attempts were made to find out whether factors such as tourniquet (TQ) time, BMI, gender and diagnosis have any relation with total blood loss. The Pearson correlation coefficient was also used to find out the relationships between BMI and blood loss and tourniquet time and blood loss. SPSS 11 software was used for all statistical calculations.

Estimated blood loss was measured by using the formula described by Gross, which uses the maximum post-operative decrease in the level of haemoglobin adjusted for the weight and height of the patient [12]. Hidden blood loss was calculated by subtracting the apparent total blood loss from the estimated blood loss.

Results

Among the total of 66 patients studied 45 were females and 21 were males. The median age was 67 years (49–81). The mean BMI was 28.16 (± 3.8). The mean surgical time was 117.9 min (± 19.6) and the mean TQ time was 71.7 min

Fig. 2 Relationship between tourniquet and post-operative blood loss

Table 5 Charting of haemoglobin level. *PCV* packed cell volume

	Pre-operative	Day 1	Day 2	Day 7	Day 14
Hb (g%)	11.90 $\pm$ 1.50	10.02 $\pm$ 1.32	9.51 $\pm$ 1.23	9.66 $\pm$ 1.13	9.75 $\pm$ 0.54
PCV	35.9 $\pm$ 4.68	29.95 $\pm$ 4.12	28.70 $\pm$ 3.9	29.29 $\pm$ 3.34	29.63 $\pm$ 3.49

(± 17.7 ; Table 1). The mean intra-operative blood loss was 220 ml (± 115.6) and the average post-operative drainage was 443 ml (± 160.9). The total measured blood loss thus amounted to 663 ml (± 209.7) in a primary uncomplicated TKR. The mean drop in Hb was 2.39 g% (Table 2).

Gender

The gender of the patient played a role in post-operative blood loss ($p < 0.05$), but not in intra-operative blood loss (Table 3). The total apparent peri-operative blood loss (intra-operative + post-operative) was significantly more in male patients, with a *p* value of 0.001. The drop in Hb in male patients was more than that in female patients, but there was no statistical significance and there was no statistically significant difference in the tourniquet time in either of the groups (Table 3). The mean pre-operative Hb in female patients were 11.62 $\pm$ 0.94 g%, which was lower than the value of 12.67 $\pm$ 2.31 g% in male patients, but there was no statistical significance ($p = 0.9$). There was no significant difference in the average number of units of

Table 6 Comparison of various studies on total blood loss (ml). *TA* tranexamic acid

Reference	Statistics
[8]	805
[2]	686 (490–990) RA 583 (315–925) OA
[23]	1,215 (400–2,050)
[3]	1,410 $\pm$ 480 (placebo) 730 $\pm$ 280 (prophylactic TA)
[26]	785 (670–880; control group) 776 (393–1,159; pre-operative TA) 896 (495–1,310; intra-operative TA) 528 (252–925; pre-operative + intra-operative TA)
[14]	881 $\pm$ 292 ^a (intra-operative tourniquet release) 745 $\pm$ 262 ^a (tourniquet release after closure)
[27]	528.5 (90–2,100) ^a (tourniquet used) 661.6 (160–1,820) ^a (tourniquet not used) 1,234.9 (143–2,355; tourniquet used) 1,557.4 (323–2,896; tourniquet not used)
Current series	664 $\pm$ 209 657 (230–1,050) OA 690 (320–1,270) RA

^aThese values are only the post-operative drainage

Table 7 Comparison of incidence of blood transfusion in primary TKA

Reference	Drained	RA (%)	OA (%)	Total (%)
[24]	Yes	58	35	39
	No	50	11	16
[8]	Yes	69	32	
[6]				84
Current series	Yes	41.66	14.8	22.2

blood transfused in male and female patients either ($p>0.05$; Table 3).

Diagnosis

The diagnosis (OA/RA) did not produce any significant difference in intra-operative and post-operative blood loss ($p>0.05$) and there was no significant difference in the tourniquet time in either of the groups (Table 4). There was no significant drop in Hb in patients with RA (Table 4). The mean pre-operative Hb in patients with OA was 12.16 ± 1.5 g% and it was higher than patients in the RA group with a mean pre-operative Hb of 10.9 ± 1.01 g%. This was statistically significant ($p=0.009$). The average number of units of blood transfused in patients with a diagnosis of rheumatoid arthritis was significantly more than that in patients with osteoarthritis ($p=0.04$; Table 4).

Tourniquet time and BMI

Total blood loss was charted against tourniquet time and BMI in a graph using a scatter diagram. The statistical significance was analysed using the Pearson correlation co-efficient. There was a significant positive correlation between intra-operative blood loss and tourniquet time ($p=0.0001$; Fig. 1) and also with total surgical time ($p=0.003$). There was a positive correlation between post-operative blood loss and tourniquet time, but on statistical analysis it was not very significant ($p=0.07$; Fig. 2). The same was true in the case of total surgical time and post-operative blood loss ($p=0.08$). The apparent total blood loss (intra-operative + post-operative) showed a positive correlation with tourniquet time ($p=0.001$) and total surgical time ($p=0.006$). There was no correlation between peri-operative blood loss and BMI.

Of the patients who received blood transfusion 66.6% had a pre-operative Hb level of less than 10.5 g%. In patients with post-operative Hb of less than 8.0 g% only 50% had symptoms such as fatigue and dizziness. Two patients were transfused because of symptoms of anaemia in spite of having a post-operative Hb level above 9 g%. On charting the Hb and PCV values (pre-operative and post-operative; Table 5) it was found that by the seventh day Hb showed a marginal increase in most cases, which went on increasing, as evidenced by the day 14 value.

The calculated mean estimated blood loss according to the formula of Gross was 1,073 ml (Table 2) and hence the mean hidden blood loss was calculated as 410 ml. This amounts to about 38% of the total estimated blood loss.

We did not have any complications other than one case of delayed wound healing. There were no cases of infection.

Discussion

Pattison et al. examined blood loss in 44 rheumatoid patients and concluded that it was a haemolytic or redistribution process that resulted in the post-operative drop in Hb [22]. Erskine et al. in 1981 summated blood loss from a variety of sources and concluded that the major source of blood loss occurred intra-operatively, but this was a small study with five patients [9].

In 1991, Cushner and Friedman, in their study involving 112 primary TKA, reported that the gender of the patient played a role in blood loss, with males having greater loss. In their study transfusion rates were higher in females probably because of low pre-operative Hb levels. They concluded that age, diagnosis, operative time and TQ time were not related to blood loss following TKA, but that the transfusion rate was high in RA patients [8]. Our series shows that there is greater intra-operative and post-operative blood loss in male patients than in female patients. The haemoglobin drop and average number of units of blood transfusion received per patient were higher in male patients, although not statistically significant. These results from our series support the conclusion in the study by Cushner and Friedman that gender does play a role in blood loss and that male patients experience greater loss. In our series the blood transfusion rate was higher in male patients compared with female patients, although this was not statistically significant (Table 3). This result is contrary to the findings of Cushner and Friedman [8].

In our series there was no statistically significant difference between the OA and RA groups with regard to intra-operative and post-operative blood loss, although the transfusion rate was significantly higher in RA patients. The main indication for blood transfusion after TKA has been a low pre-operative Hb level in several reported studies [5, 8, 10]. The results from our study comparing patients with OA and RA suggest that the significantly low pre-operative haemoglobin value in patients with RA is the main reason for increased transfusion rates in the RA group. The blood transfusion rate in male patients in our study was on the higher side compared with the female patients, despite having a higher pre-operative haemoglobin value. This finding, although not statistically significant, suggests that intra-operative blood loss has a definite influence on the blood transfusion rate. This justifies our search to determine the factors affecting blood loss in TKA.

The body mass index did not show any relationship with either the intra-operative or the post-operative blood loss. The use of tourniquet is a matter of debate in total knee arthroplasty. One of the randomised controlled trials on the

use of tourniquets in total knee arthroplasty showed no difference in the amount of blood loss whether a tourniquet was used or not [27]. The time of tourniquet release is also a matter of debate. Hersekli et al. showed that intra-operative release of the tourniquet causes more blood loss compared with keeping the tourniquet inflated until the application of a compressive bandage at the end of surgery [14]. The amount of blood loss in our study, despite the use of a tourniquet and releasing it intra-operatively, is lower than both the above-mentioned studies (Table 6). However, our study showed increased peri-operative blood loss associated with increasing tourniquet time. The probable reason for this is increased fibrinolysis associated with tourniquet use [1]. This suggests that in surgical procedures where a longer operating time is expected, the prolonged use of a tourniquet may actually increase peri-operative blood loss.

There are few studies aimed at reducing intra- and post-operative blood loss. In 1993, Raut et al. in their study observed that post-operative blood loss is lower in TKA after using a cemented press fit condylar prosthesis and a femoral intramedullary plug [23]. Page et al. studied the effect of TQ release and blood loss, and concluded that blood loss was lower with intra-operative TQ release and haemostasis with diathermy [21]. Some authors recommend the use of tranexamic acid, a fibrinolytic inhibitor, during the knee arthroplasty to reduce intra- and post-operative blood loss [13, 15]. The total peri-operative blood loss in our series was on the lower side compared with the other reported studies (Table 6) [2, 3, 8, 23, 26].

Keating et al. in 1998 showed a drop in Hb in unilateral TKA to be 3.85 g%, their average pre-operative Hb was 13.98 g% [15]. In our study the average pre-operative Hb was only 11.9 g%, and the drop in Hb was also less (2.53 g% in male patients, 2.35 g% in female patients). The drop in Hb does not always correspond to the visible amount of blood loss because there is a definite amount of hidden blood loss and this was reported as being 50% of total blood loss in one of the studies [25]. The hidden blood loss in our series was 38% of the estimated blood loss. The technique of deflating the tourniquet to achieve haemostasis before closure may be a reason for a decrease in the percentage of hidden blood loss compared with the previous study [25].

The use of blood transfusion in our study has been low compared with many reported studies (Table 7) [8, 15, 24, 28], mainly because our patients were found to tolerate low post-operative Hb up to 8.0 g% and the amount of peri-operative blood loss was on the lower side, which may be related to the use of a cemented prosthesis [20] and an intramedullary femoral plug [23], although we did not analyse these factors by randomisation in our study. The need for transfusion was assessed by our physician and anaesthetist, who were initially reluctant to bring down the transfusion trigger to 8.0 g%. Many recent studies have addressed the prevalence of clinically inappropriate over-transfusion, and show a widening acceptance of lower haematocrit and haemoglobin levels in patients who are otherwise stable [13, 17]. The patients in our series were able

to tolerate low post-operative Hb (even less than 8 g%), mainly because they were accustomed to a low pre-operative Hb. This series also highlights the low pre-operative haemoglobin value in this group from an Asian population compared with white patients [3, 15]. The patients with rheumatoid arthritis, in concurrence with other studies, needed more transfusion, mainly because of low pre-operative Hb values [5, 8, 10].

We conclude that gender and tourniquet time play a role in peri-operative blood loss and the incidence of transfusion depends not only on pre-operative haemoglobin levels, but also on peri-operative blood loss. The transfusion trigger can be brought down to as low as 8.0 g% in an otherwise medically stable patient undergoing TKA. Hidden blood loss should also be taken into account when considering the various blood re-infusion strategies.

References

1. Aglietti P, Baldini A, Vena LM, Abbate R, Fedi S, Falciani M (2000) Effect of tourniquet use on activation of coagulation in total knee replacement. *Clin Orthop Relat Res* 371:169–177
2. Albert GM, Matthew PF, Daniel EM, Parsons JR (1990) Perioperative blood loss associated with total knee arthroplasty. *J Bone Joint Surg Am* 72:1010–1012
3. Benoni G, Fredin H (1996) Fibrinolytic inhibition with tranexamic acid reduces blood loss and blood transfusion after knee arthroplasty. *J Bone Joint Surg Br* 78:434–440
4. Bernstein LH, Coles M, Granata A (1997) The Bridgeport Hospital experience with autologous transfusion in orthopedic surgery. *Orthopedics* 20:677–680
5. Bierbaum BE, Callaghan JJ, Galante JO, Rubash HE, Tooms RE, Welch RE (1999) An analysis of blood management in patients having a total hip or knee arthroplasty. *J Bone Joint Surg Am* 81:2–10
6. Capraro L (1998) *Transfusion practices in primary total joint replacement in Finland*. *Vox Sang* 75:1–6
7. Cohen JA, Brecher ME (1995) Preoperative autologous blood donation: benefit or detriment; a mathematical analysis. *Transfusion* 35:640–644
8. Cushner FD, Friedman RJ (1991) Blood loss in total knee arthroplasty. *Clin Orthop Relat Res* 269:98–101
9. Erskine JG, Fraser C, Simpson R, Protheroe K, Walker ID (1981) Blood loss with knee joint replacement. *J R Coll Edinb* 26:245
10. Faris PM, Spence RK, Larholt KM, Sampson AR, Frei D (1999) The predictive power of baseline hemoglobin for transfusion risk in surgery patients. *Orthopedics* 22 [1 Suppl]: S135–S140
11. Fiebig E (1998) Safety of the blood supply. *Clin Orthop Relat Res* 357:6–18
12. Gross JB (1983) Estimating allowable blood loss: corrected for dilution. *Anesthesiology* 58:277–280
13. Han CD, Shin DE (1997) Post operative blood salvage and reinfusion after total joint arthroplasty. *J Arthroplasty* 12:511–516
14. Hersekli MA, Akpinar S, Okoc G, Ozalay M et al (2004) The timing of tourniquet release and its influence on blood loss after total knee arthroplasty. *Int Orthop* 28:138–141
15. Keating EM, Meding JB, Faris PM, Ritter MA (1998) Predictors of transfusion risk in elective knee surgery. *Clin Orthop Relat Res* 357:50–59
16. Macfarlane BJ, Mar XL, Anquist K (1988) Analysis of a protocol for an autologous blood transfusion program for total joint replacement surgery. *Can J Surg* 31:126–179
17. Manner PA, Rubash HE, Herndon JH (1998) Future trends in transfusion. *Clin Orthop Relat Res* 357:101–115

18. Mcvay PA, Toy PT (1996) Very severe outcomes associated with autologous blood donation [letter]. *Transfusion* 36:761
19. Mollison PL, Engelfriet CP, Contreras M (1993) *Blood transfusion in clinical medicine*, 9th edn. Blackwell, Oxford
20. Mylod AG, France MP, Muser DE, Parsons JR (1990) Perioperative blood loss associated with total knee arthroplasty. *J Bone Joint Surg Am* 72:1010–1012
21. Page MH, Shepherd BD, Harrison JM (1984) Reduction of blood loss in knee arthroplasty. *Aust N Z J Surg* 54:141
22. Pattison E, Protheroe K, Pringle RM, Kennedy AC, Dick WC (1973) Reduction in hemoglobin after knee joint surgery. *Ann Rheum Dis* 32:582–584
23. Raut VV, Stone MH, Wroblewski BM (1993) Reduction of postoperative blood loss after press-fit condylar knee arthroplasty with use of a femoral intramedullary plug. *J Bone Joint Surg Am* 75:1356–1357
24. Reilly TJ, Ivan AG, William P, Maureen R (1986) The use of postoperative suction drainage in total knee arthroplasty. *Clin Orthop Relat Res* 208:238–252 July
25. Sehat KR, Evans R, Newman JH (2000) How much blood is really lost in total knee arthroplasty? Correct blood loss management should take hidden loss into account. *Knee* 7:151–155
26. Tanaka N, Sakahashi H, Sato E, Hirose K, Ishima T, Ishii S (2001) Timing of the administration of tranexamic acid for maximum reduction in blood loss in arthroplasty of the knee. *J Bone Joint Surg Br* 83:702–705
27. Vandenbussche E, Duranthon LD, Couturier M, Pidhorz L, Augereau B (2002) The effect of tourniquet use in total knee arthroplasty. *Int Orthop* 26:306–309
28. Walker RH (1987) Transfusion risks. *Am J Clin Pathol* 88:374
29. Yomtovian R (1996) Autologous transfusion complications. In: Popovsky MA (ed) *Transfusion reactions*. American Association of Blood Banks Press, Bethesda, pp 237–280