

# Ten-year follow-up on Dutch orthopaedic blood management (DATA III survey)

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## Abstract

**Introduction** Hip and knee arthroplasties are frequently complicated by the need for allogeneic blood transfusions. This survey was conducted to assess the current use of perioperative blood-saving measures and to compare it with prior results.

**Materials and methods** All departments of orthopaedic surgery at Dutch hospitals were sent a follow-up survey on perioperative blood-saving measures, and data were compared to the results of two surveys conducted 5 and 10 years earlier.

**Results** The response rate was 94 out of 108 departments (87 %). Most departments used erythropoietin prior to hip and knee replacements at the expense of preoperative autologous blood donation. The use of intraoperative autologous retransfusion in revision hip (56 vs. 54 %) as well as revision knee arthroplasty (26 vs. 24 %), was virtually unchanged. Postoperative autologous retransfusion is still used by the majority of departments after both primary arthroplasty and revision of hip (58/53 %) and knee (65/61 %).

**Conclusions** Currently, just as in 2007, the majority of Dutch orthopaedic departments uses erythropoietin, normothermia and postoperative autologous retransfusion with hip and knee arthroplasty. Intraoperative retransfusion is used mainly with hip revision arthroplasty. Other effective

blood management modalities such as tranexamic acid have not been widely implemented.

**Keywords** Blood management · Orthopaedic · Prosthesis · Survey

## Introduction

Blood transfusions are frequently required after hip and knee arthroplasties. Adverse events can occur after allogeneic red blood cell transfusions. These include infections due to contaminated blood, (incompatibility) transfusion reactions [1–3], increased risk of postoperative infection due to effects on the immune system [3–6], delay of wound healing and prolonged hospital stay [3, 5]. It is therefore important to reduce the need for allogeneic blood transfusions. This can be achieved by increasing the patient's haemoglobin level preoperatively, by reducing blood loss and by autotransfusion. There is an increasing focus on perioperative blood management [7]. This survey was conducted to assess the current use of perioperative blood-saving measures and to compare it with the results of prior surveys and national guidelines.

## Materials and methods

A questionnaire on orthopaedic departmental protocols for perioperative blood management measures was sent to all 110 orthopaedic departments in Dutch hospitals. It was tailored to fit similar ones conducted in 2002 and 2007 [7]. Response rates in 2007 and 2002 were 79 % (87 out of 110 departments) and 84 % (81 out of 96 departments). The power analysis showed that, with a confidence interval of

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**Table 1** Preoperative blood-saving measurements used prior to arthroplasties of hip and knee in the studied orthopaedic departments *N* (%)

Arthroplasty	Preop. autologous blood donation			<i>P</i> <sup>a</sup>	Erythropoietin			<i>P</i> <sup>a</sup>	Iron
	2002	2007	2012		2002	2007	2012		
Total hip	11 (14)	10 (11)	4 (4)	0.10	26 (32)	57 (65)	55 (60)	0.50	27 (29)
Revision hip	6 (8)	9 (10)	4 (4)	0.17	25 (31)	58 (67)	52 (57)	0.21	27 (29)
Total knee	7 (9)	8 (9)	4 (4)	0.23	26 (32)	56 (64)	51 (55)	0.23	26 (28)
Revision knee	4 (5)	8 (9)	4 (4)	0.10	20 (25)	54 (62)	52 (57)	0.39	27 (29)
Hemi knee	2 (3)	6 (7)	2 (2)	0.26	11(13)	36 (41)	43 (47)	0.50	23 (25)

<sup>a</sup> Significance of difference between 2007 and 2012 data is calculated

**Table 2** Cessation of anticoagulants preoperatively, prior to arthroplasties of hip and knee in the studied orthopaedic departments *N* (%)

Anticoagulant	Discontinuation of medication		<i>P</i> <sup>b</sup>	Days prior to operation <sup>a</sup>		<i>P</i> <sup>b</sup>
	2007	2012		2007	2012	
NSAIDs	36 (41)	33 (36)	0.54	5.9 (2–10)	4.5 (1–10)	0.03*
Cox-2 selective NSAIDs	NA	37 (40)	–	NA	4.8 (1–14)	–
Acetylsalicylic acid	72 (83)	50 (54)	<0.01*	7.6 (3–42)	6.8 (5–10)	0.34
Clopidogrel	NA	77 (84)	–	NA	6.9 (1–10)	–
Dipyridamole	NA	64 (70)	–	NA	6.3 (1–10)	–
Acenocoumarol	87 (100)	90 (98)	0.18	5.0 (2–10)	4.6 (2–10)	0.27
Fenprocoumon	87 (100)	90 (98)	0.18	5.0 (2–10)	6.3 (2–10)	0.27

\* Significant difference

<sup>a</sup> Significance of difference between 2007 and 2012 data is calculated

<sup>b</sup> Mean and range

95 %, the response of at least 86 of 110 departments was required for our analysis. The questionnaire was expanded to include newly introduced blood-saving measures. The current choice of perioperative blood management measures with total hip, hemi hip and revision hip arthroplasty as well as total knee, hemi knee and revision knee arthroplasty were assessed. In 2012 a package with the questionnaire, a cover letter, and a stamped return envelope were sent to all these orthopaedic departments. Non-respondents were sent a reminder after 4 months, and were contacted by telephone if necessary. Categorical data and dichotomous variables were summarised as percentages of the responding departments by means of SPSS 21 (New York).

## Results

The questionnaire was ultimately answered properly by 94 out of 110 departments. Two clinics were excluded because they reported performing spine surgery exclusively. The adjusted response rate was therefore 87 %. Eleven (12 %) departments stated that they had no specific departmental protocol on blood-saving measures in 2012.

### Preoperative blood-saving measures

The use of preoperative autologous blood donation has been steadily decreasing over the years and is currently

used in only 4 % of departments (Table 1). Compared to 2002, in 2007 there was a considerable increase in the use of erythropoietin for hip as well as knee arthroplasty. Currently, the majority (50–60 %) of orthopaedic departments continues to use erythropoietin after primary and revision hip and knee arthroplasty, although a slight decrease can be observed. Iron supplementation is being used by 27 % of departments.

Table 2 shows the discontinuation of different anticoagulants and the associated time before operation. Most departments discontinue the various anticoagulants, except for non-steroid anti-inflammatory drugs (NSAIDs) and Cox-2 selective NSAIDs, which are stopped preoperatively by a minority (40 %). Also noteworthy is the significant decrease in the number of departments that discontinues aspirin before the operation ( $P < 0.01$ ).

### Intraoperative blood-saving measures

Intraoperative retransfusion is predominantly used during revision hip arthroplasty (56 % of departments) (Table 3). A further decrease in use of cell saving is observed in primary hip and knee arthroplasty, compared to 2007 and 2002. Normothermia and tourniquets are used by most departments. Tranexamic acid is used by 8–15 %. The use of other techniques, such as epinephrine injections, acute normovolemic hemodilution and controlled hypotension, are listed in Table 3.

**Table 3** Intraoperative blood-saving measurements during arthroplasties of hip and knee in the studied orthopaedic departments *N* (%)

Arthroplasty	Intraoperative retransfusion		<i>P</i> <sup>a</sup>	TA	NT	T	FG	PG	Epi	ANH	CH
	2002	2007									
Total hip	12 (15)	17 (19)	0.06	13 (14)	68 (74)	NA	0	0	3 (3)	11 (12)	10 (11)
Revision hip	32 (40)	47 (54)	0.73	14 (15)	67 (73)	NA	0	0	2 (2)	14 (15)	13 (14)
Hemi hip	5 (6)	10 (12)	0.07	7 (8)	67 (73)	NA	0	0	2 (2)	10 (11)	11 (12)
Total knee	8 (10)	12 (14)	0.06	11 (12)	66 (72)	83 (90)	1 (1)	1 (1)	5 (5)	11 (12)	11 (12)
Revision knee	13 (16)	21 (24)	0.85	12 (13)	65 (71)	80 (87)	1 (1)	1 (1)	2 (2)	12 (13)	12 (13)
Hemi knee	5 (6)	10 (11)	0.17	8 (9)	67 (73)	78 (85)	1 (1)	1 (1)	3 (3)	10 (11)	10 (11)

TA tranexamic acid, NT normothermia, T tourniquet, FG fibrin gel, PG platelet gel, Epi epinephrine injections or lavage, ANH normovolemic hemodilution, CH controlled hypotension

<sup>a</sup> Significance of difference between 2007 and 2012 data is calculated

## Postoperative blood-saving measures

The marked increase in the use of postoperative autologous retransfusion observed in 2007 was maintained, and the majority of departments still uses retransfusion drains in 2012 (Table 4). A slight increase is observed with hemi hip and hemi knee arthroplasty. Blood transfusion was done according to the 4-5-6-transfusion trigger rule [8] in all departments, except for three. Thirty-three percent of departments used Cox-2 selective NSAIDS postoperatively, instead of non-selective NSAIDS.

## Conclusions

### Principle findings

The use of perioperative blood-saving measures is varied but standard in the Netherlands. The most-used modalities are erythropoietin, normothermia, tourniquets in knee surgery, retransfusion drains, and the 4-5-6-transfusion trigger. NSAIDS and aspirin are less frequently discontinued preoperatively than before, and effective blood-saving measures such as tranexamic acid are not implemented by the majority of departments.

### Strengths and weaknesses

We believe the results of our survey are valid, because the high survey response (84, 79 and 84 %) limits non-responder bias. Furthermore, we included a very complete list of possible blood-saving measures. Potential weaknesses are those common to postal surveys: lack of control over who completes the questionnaire and potential inaccuracy in the information provided. This represents an audit of practice, without additional information on the reasons for the responses given. In addition, we did not quantify the frequency with which different blood-saving measures were used in individual departments in this and previous surveys.

### Meaning of findings

Only two comparable surveys could be identified. A 2006 Scottish questionnaire on hip revision arthroplasty showed that 10 out of 62 (16 %) orthopaedic surgeons routinely used intraoperative cell salvage, 11 % used postoperative cell salvage, 3 % routinely used tranexamic acid and 73 % used a transfusion protocol [9]. By contrast, our survey shows that 56 % of departments uses intraoperative cell salvage and 53 % postoperative cell salvage. Thirty-two percent of Scottish surgeons stated that cell salvage was not available.

**Table 4** Postoperative blood-saving measurements after arthroplasties of hip and knee in the studied orthopaedic departments *N* (%)

Arthroplasty	Postop. autologous retransfusion			<i>P</i> <sup>a</sup>	No drain 2012	Compression bandage 2012	Cryo-therapy 2012	Leg elevation 2012	Fixed flexion knee 2012
	2002	2007	2012						
Total hip	11 (14)	50 (58)	53 (58)	0.97	26 (28)	28 (30)	4 (4)	NA	NA
Revision hip	10 (13)	47 (54)	49 (53)	0.91	19 (21)	28 (30)	5 (5)	NA	NA
Hemi hip	6 (8)	36 (41)	43 (47)	0.41	26 (28)	24 (26)	3 (3)	NA	NA
Total knee	19 (23)	61 (70)	60 (65)	0.41	23 (25)	58 (63)	15 (16)	16 (17)	1 (1)
Revision knee	12 (15)	51 (59)	56 (61)	0.85	17 (19)	57 (62)	11 (12)	13 (14)	1 (1)
Hemi knee	6 (8)	42 (48)	49 (53)	0.54	27 (29)	55 (60)	14 (15)	16 (17)	1 (1)

<sup>a</sup> Significance of difference between 2007 and 2012 data is calculated

The other survey was conducted amongst 81 Dutch orthopaedic departments in January 2012 [10]. Postoperative drainage and retransfusion and erythropoietin were used most frequently, in concordance with our analysis. The frequency of the use of blood-saving measures after total hip or total knee arthroplasty was described as frequent (regularly, almost always or always) or non-frequent (never and almost never). No distinction was made between hip and knee surgery, or between primary or revision surgery. The use of blood-saving measures after hemi hip arthroplasty and hemi knee arthroplasty were not investigated.

Because blood loss varies between different types of surgery, e.g., hemi knee arthroplasty or revision hip arthroplasty, blood-saving measures also vary: they are tailored to the type of surgery. Therefore, in our study more detail regarding type of surgery and a wider range of blood-saving measures were described. Moreover, we were able to compare data from October 2012 to data from our two previous surveys with exactly the same design.

#### Preoperative blood-saving measures

Our study shows that only 4 % of Dutch orthopaedic departments still uses preoperative autologous blood donation, compared to 10 % in 2007. Preoperative blood donation reduces the relative risk of receiving allogeneic blood transfusion. The risk on any transfusion (allogeneic of autologous), however, is augmented [11]. The infrequent use is in concordance with the Dutch guideline on blood transfusion [12], which advises using this technique with reticence due to complex logistics and relatively high costs.

The efficacy of erythropoietin in orthopaedic surgery has been demonstrated in several randomised controlled trials [13–15]. For patients with preoperative Hb >10 to ≤13 g/dl, epoetin alfa therapy dramatically increases perioperative Hb levels and reduces patient exposure to allogeneic blood transfusion [13, 15]. Its costs, although reduced, remain an issue. Most departments currently use erythropoietin.

According to one report, 23 % of patients with preoperative anaemia have an iron deficiency [16]. Iron, orally or intravenously supplied, decreases preoperative anaemia and is less expensive than erythropoietin. However, iron is not widely used in the Netherlands, even though the Dutch guidelines [12] advise correcting preoperative iron deficiency at least 4 weeks prior to major elective surgery.

#### Intraoperative blood-saving measures

Intraoperative retransfusion is predominantly used during revision hip arthroplasty (56 % of departments), when substantial blood loss is to be expected. Intraoperative retransfusion is an effective method to significantly decrease the use of donor blood [12, 17–19].

Hypothermia reduces the function of thrombocytes and coagulation factors, resulting in increased risk of bleeding [20, 21]. Maintaining normothermia therefore aids in the reduction of blood loss. Currently, more than 70 % of departments aim to maintain normothermia. When the expected blood loss is at least 40 % of circulating blood volume, acute normovolemic hemodilution (ANH) is a safe and cheap technique to reduce the amount of allogeneic blood transfusions [22, 23]. A reduction of 30 % transfusions is observed, but results vary [24, 25]. ANH is reportedly the most cost-effective method to reduce the amount of allogeneic blood transfusions [12, 26], but is not used often because of its extensive procedure.

Use of fibrin sealant can reduce the number of allogeneic blood transfusions. A Cochrane review and meta-analysis reported that fibrin sealant treatment reduced the rate of allogeneic red cell transfusions by 54 % on average [27, 28]. Other reviews emphasise its very promising use, especially in TKA [29, 30], but more high-quality evidence is necessary. Not enough evidence is available to recommend the use of platelet-leucocyte-enriched gel as a local method for haemostasis [12]. Low rates of use in our survey may reflect clinical uncertainty.

Another very potent and cost-effective agent to reduce intraoperative blood loss is tranexamic acid. Even though the Dutch guideline advises using tranexamic acid, it is not widely used. Tranexamic acid significantly reduces blood loss, the number of blood transfusions and the number of patients that need a blood transfusion [31] without increasing the risk on thromboembolic events.

#### Postoperative blood-saving measures

Compared to 2002, in 2007 a dramatic increase in the use of postoperative autologous retransfusion was observed. In 2012, the majority of departments used postoperative autologous retransfusion, as in 2007. This is in accordance with the Dutch guideline, which advises using perioperative autotransfusion in all cases of major surgery in which a great amount of blood loss is to be expected. A slight increase is observed with hemi hip and hemi knee arthroplasty. Reductions in the number of allogeneic blood transfusions of 55 % are observed in orthopaedic surgery [19].

No drainage compared with closed-suction drainage without autotransfusion reduces the transfusion rates from 40 to 31 % in THA, and from 50 to 31 % in TKA [32]; 19–29 % of the departments in our survey did not use a drain. The trigger for postoperative allogeneic blood transfusion was according to the 4-5-6 rule [8] in all departments, except for three. Restrictive transfusion strategies reduced the risk of receiving a RBC transfusion by 39 %.

The combined use of multiple blood-saving methods is much more effective than a single technique [4, 33, 34]. With a blood management algorithm, allogeneic red blood cell transfusions can be reduced up to 80 % [4, 33, 34].

In summary, our survey reveals that there is a positive attitude among orthopaedic surgeons towards blood-saving measures. The use of perioperative blood-saving measures is varied but standard in the Netherlands in 2012, just as in 2007. The most-used modalities are erythropoietin, normothermia, tourniquets in knee surgery, retransfusion drains and the 4-5-6-transfusion trigger. NSAIDs and aspirin are discontinued preoperatively less frequently than before, and effective blood-saving measures such as tranexamic acid are not widely implemented.

**Conflict of interest** None.

#### References

- Goodnough LT (2003) Risks of blood transfusion. *Crit Care Med* 31:S678–S686
- Shander A, Javidrooz M, Ozawa S, Hare GM (2011) What is really dangerous: anaemia or transfusion? *Br J Anaesth* 107 Suppl 1:i41–i59
- Bierbaum BE, Callaghan JJ, Galante JO, Rubash HE, Tooms RE, Welch RB (1999) An analysis of blood management in patients having a total hip or knee arthroplasty. *J Bone Jt Surg Am* 81:2–10
- Slappendel R, Dirksen R, Weber EW, van der Schaaf DB (2003) An algorithm to reduce allogeneic red blood cell transfusions for major orthopaedic surgery. *Acta Orthop Scand* 74:569–575
- Blumberg N (1997) Allogeneic transfusion and infection: economic and clinical implications. *Semin Hematol* 34:34–40
- Innerhofer P, Klingler A, Klimmer C, Fries D, Nussbaumer W (2005) Risk for postoperative infection after transfusion of white blood cell-filtered allogeneic or autologous blood components in orthopaedic patients undergoing primary arthroplasty. *Transfusion* 45:103–110
- Horstmann WG, Eetema HB, Verheyen CCPM (2010) Dutch orthopaedic blood-management surveys 2002 and 2007: an increasing use of blood saving measures. *Arch Orthop Trauma Surg* 130(1):55–59
- Carson JL, Carless PA, Hebert PC (2012) Transfusion thresholds and other strategies for guiding allogeneic red blood cell transfusion. *Cochrane Database Syst Rev* 4:CD002042
- Harkness M, Palmer JB, Watson D, Walsh TS (2008) A questionnaire-based survey of perioperative blood conservation practice for revision hip arthroplasty in Scotland. *Transfus Med* 18(5):296–301
- Voorn VMA, Marang-van de Mheen PJ, Wentink MM, So-Osman C, Vliet Vlieland TPM, Koopman-Van Gemert AWMM, Nelissen RGHH, Van Bodegom-Vos L, the LISBOA study group (2013) Frequent use of blood-saving measures in elective orthopaedic surgery: a 2012 Dutch blood management survey. *BMC Musculoskelet Disord* 14:230
- Henry DA, Carless PA, Moxey AJ, O'Connell D, Forgie MA, Wells PS, Fergusson D (2002) Pre-operative autologous donation for minimising perioperative allogeneic blood transfusion. *Cochrane Database Syst Rev* (2):CD003602
- Centraal Begeleidings Orgaan (2011) Guideline Blood Transfusion
- Earnshaw P (2001) Blood conservation in orthopaedic surgery: the role of epoetin alfa. *Int Orthop* 25:273–278
- Moonen AF, Thomassen BJ, Knoors NT, van Os JJ, Verburg AD, Pilot P (2008) Pre-operative injections of epoetin-alpha versus post-operative retransfusion of autologous shed blood in total hip and knee replacement: a prospective randomised clinical trial. *J Bone Jt Surg Br* 90(8):1079–1083
- Weber EW, Hémon Y, Mähler S, Dalén T, Rouwet E, van Os J, Vosmaer A, van der Ark P (2005) Effects of epoetin alfa on blood transfusions and postoperative recovery in orthopaedic surgery: the European Epoetin Alfa Surgery Trial (EEST). *Eur J Anaesthesiol* 22(4):249–257
- Saleh E, McClelland DB, Hay A, Semple D, Walsh TS (2007) Prevalence of anaemia before major joint arthroplasty and the potential impact of preoperative investigation and correction on perioperative blood transfusions. *Br J Anaesth* 99:801–808
- Horstmann WG, Swierstra MJ, Ohanis D, Castelein RM, Kollen BJ, Verheyen CC (2013) Reduction of blood loss with the use of a new combined intra-operative and post-operative autologous blood transfusion system compared with no drainage in primary total hip replacement. *Bone Jt J* 95-B(5):616–622
- Huët C, Salmi LR, Fergusson D, Koopman-van Gemert AW, Rubens F, Laupacis A (1999) A meta-analysis of the effectiveness of cell salvage to minimize perioperative allogeneic blood transfusion in cardiac and orthopaedic surgery. International study of perioperative transfusion (ISPOT) investigators. *Anesth Analg* 89(4):861–869
- Carless PA, Henry DA, Moxey AJ, O'Connell D, Brown T, Fergusson DA (2010) Cell salvage for minimising perioperative

- allogeneic blood transfusion. *Cochrane Database Syst Rev* (3):CD001888
20. Corazza ML, Hranchook AM (2000) Massive blood transfusion therapy. *AANA J* 68(4):311–314
  21. Eastridge BJ, Malone D, Holcomb JB (2006) Early predictors of transfusion and mortality after injury: a review of the data-based literature. *J Trauma* 60(6 Suppl):S20–S25
  22. Society of Thoracic Surgeons Blood Conservation Guideline Task Force, Ferraris VA, Ferraris SP, Saha SP, Hessel EA 2nd, Haan CK, Royston BD, Bridges CR, Higgins RS, Despotis G, Brown JR, Society of cardiovascular anesthesiologists special task force on blood transfusion, Spiess BD, Shore-Lesserson L, Stafford-Smith M, Mazer CD, Bennett-Guerrero E, Hill SE, Body S (2007) Perioperative blood transfusion and blood conservation in cardiac surgery: the Society of Thoracic Surgeons and The Society of Cardiovascular Anesthesiologists clinical practice guideline. *Ann Thorac Surg* 83(5 Suppl):S27–S86
  23. Bryson GL, Laupacis A, Wells GA (1998) Does acute normovolemic hemodilution reduce perioperative allogeneic transfusion? A meta-analysis. The international study of perioperative transfusion. *Anesth Analg* 86(1):9–15
  24. Höhn L, Schweizer A, Licker M, Morel DR (2002) Absence of beneficial effect of acute normovolemic hemodilution combined with aprotinin on allogeneic blood transfusion requirements in cardiac surgery. *Anesthesiology* 96(2):276–282
  25. Ramnath AN, Naber HR, de Boer A, Leusink JA (2003) No benefit of intraoperative whole blood sequestration and auto transfusion during coronary artery bypass grafting: results of a randomized clinical trial. *J Thorac Cardiovasc Surg* 125(6):1432–1437
  26. Davies L, Brown TJ, Haynes S, Payne K, Elliott RA, McCol-lum C (2006) Cost-effectiveness of cell salvage and alternative methods of minimising perioperative allogeneic blood transfusion: a systematic review and economic model. *Health Technol Assess* 10(44):iii–iv ix–x, 1–210
  27. Carless PA, Henry DA, Anthony DM (2003) Fibrin sealant use for minimising peri-operative allogeneic blood transfusion. *Cochrane Database Syst Rev* (2):CD004171
  28. Carless PA, Anthony DM, Henry DA (2002) Systematic review of the use of fibrin sealant to minimize perioperative allogeneic blood transfusion. *Br J Surg* 89:695–703
  29. Patel S, Rodriguez-Merchan EC, Haddad FS (2010) The use of fibrin glue in surgery of the knee. *J Bone Jt Surg Br* 92:1325–1331
  30. Thoms RJ, Marwin SE (2009) The role of fibrin sealants in orthopaedic surgery. *J Am Acad Orthop Surg* 17:727–736
  31. Henry DA, Carless PA, Moxey AJ, O’Connell D, Stokes BJ, Fergusson DA, Ker K (2011) Anti-fibrinolytic use for minimising perioperative allogeneic blood transfusion. *Cochrane Database Syst Rev* (3):CD001886
  32. Parker MJ, Livingstone V, Clifton R, McKee A (2007) Closed suction surgical wound drainage after orthopaedic surgery. *Cochrane Database Syst Rev* (3):CD001825
  33. Wong CJ, Vandervoort MK, Vandervoort SL, Donner A, Zou G, MacDonald JK, Freedman J, Karkouti K, MacDonald SJ, Feagan BG (2007) A cluster-randomized controlled trial of a blood conservation algorithm in patients undergoing total hip joint arthroplasty. *Transfusion* 47(5):832–841
  34. Pierson JL, Hannon TJ, Earles DR (2004) A blood-conservation algorithm to reduce blood transfusions after total hip and knee arthroplasty. *J Bone Joint Surg Am* 86-A(7):1512–1518