Post-operative blood salvage with autologous retransfusion in primary total hip replacement

L. K. Smith,
D. H. Williams,
V. G. Langkamer

From Weston
General Hospital,
Weston-super-Mare,
England

Clinical, haematological or economic benefits of post-operative blood salvage with autologous blood re-transfusion have yet to be clearly demonstrated for primary total hip replacement. We performed a prospective randomised study to analyse differences in post-operative haemoglobin levels and homologous blood requirements in two groups of patients undergoing primary total hip replacement.

A series of 158 patients was studied. In one group two vacuum drains were used and in the other the ABTrans autologous retransfusion system. A total of 58 patients (76%) in the re-transfusion group received autologous blood. There was no significant difference in the mean post-operative haemoglobin levels in the two groups. There were, however, significantly fewer patients with post-operative haemoglobin values less than 9.0 g/dl and significantly fewer patients who required transfusion of homologous blood in the re-transfusion group. There was also a small overall cost saving in this group.

There were approximately 45 000 primary total hip replacements (THRs) undertaken in NHS Trusts in England and Wales in 2004.¹ The rate of homologous blood transfusion after primary THR can be as high as 30% to 40%,^{2,3} with the mean volume of transfused blood being 1.5 units per case.⁴ Pre-operative haemoglobin (Hb) levels below 13.0 g/dl,⁵ 12.0 g/dl,^{6,7} and 11.0 g/dl⁸ have been shown to increase the use of homologous blood transfusion. Other factors include age of over 75 years, body mass index (BMI) greater than 27 kg/m², male gender and hypertension, especially if more than two of these coexist.⁸

Homologous blood transfusion is not without risk.⁹ Although standards have improved, complications from administrative error, bacterial contamination, immunosuppression and possible viral contamination remain.^{3,10} The greatest risk of death is clerical error,¹¹ and estimates of mortality from bacterial contamination of platelet components range between one in 20 000 and one in 85 000.^{10,11} Risks of viral contamination per unit of blood transfused vary with the country concerned, with reports from the USA of one in 2 135 000 for human immunodeficiency virus, one in 1 935 000 for hepatitis C virus, one in 205 000 for hepatitis B virus and one in 2 993 000 for human T-lymphocyte viruses.^{10,12} Also, there are increasing reports of other transfusion-

related conditions, such as acute lung injury.^{10,13}

Various techniques have been developed to minimise the need for homologous blood transfusion, including pre-operative donation, intra-operative salvage and post-operative salvage. Pre-operative donation can present logistical problems, can be time-consuming, and is not always cost-effective. Wastage of donated blood can be as high as 45%.¹⁴ Some studies conclude that pre-operative donation is not indicated in non-anaemic patients, not cost-effective, and may increase the likelihood of autologous transfusion without lowering the risk of homologous blood transfusion.¹⁵ Intra-operative salvage has only been shown to be effective in patients where pre-donated blood is unavailable or when excessive blood loss is expected,¹⁶ and is not routinely recommended in simple primary THR.¹⁷ However, this technique is useful in complex revision cases or when major blood loss is anticipated.¹⁸

Although post-operative salvage is a safe technique with relatively few reported complications,^{19,20} its value in THR is controversial. Previous studies have included patients who had pre-donated blood and in whom autologous blood was salvaged either intra- or post-operatively. Some showed that patients receiving post-operative salvage have a lower incidence of homologous blood transfusion²¹ and

■ L. K. Smith, MCSP, MSc,
Research Associate
■ V. G. Langkamer, MBBS,
FRCS, MD, Consultant
Orthopaedic Surgeon
Department of Trauma and
Orthopaedic Surgery
Weston General Hospital,
Grange Road, Uphill, Weston-
super-Mare BS23 4TQ, UK.

■ D. H. Williams, MRCS, MSc,
Specialist Registrar
North Devon District Hospital,
Raleigh Park, Barnstaple,
Devon EX31 4JB, UK.

Correspondence should be sent
to Ms L. K. Smith; e-mail:
lindsay.smith@waht.swest.
nhs.uk

©2007 British Editorial Society
of Bone and Joint Surgery
doi:10.1302/0301-620X.89B8.
18736 \$2.00

J Bone Joint Surg [Br]
2007;89-B:1092-7.
Received 3 October 2006;
Accepted after revision 26 April
2007

higher post-operative Hb levels.²² Others question the clinical and economic benefit of post-operative salvage in primary THR.²³⁻²⁵ Another concluded that although the risk of homologous blood transfusion is reduced in revision arthroplasty and in patients who have not pre-donated blood, there is no benefit in those primary THR patients able to pre-donate their blood.²⁶ The introduction of minimal-incision techniques has been shown to reduce intra-operative loss of blood, but the rate of post-operative transfusion is not significantly reduced when compared to conventional surgery.²⁷ From these studies it is difficult to determine whether post-operative salvage is beneficial for primary THR patients. Indeed, it is suggested that drains are unnecessary in such cases, with one prospective randomised study quoting the rate of homologous blood transfusion as 33% in patients with drains and 26.4% in those without.²⁸

In our unit, pre-donation is not available and intra-operative salvage not implemented. We have used the ABTrans autologous retransfusion system (Surgical Innovations Ltd, Leeds, United Kingdom) for primary and revision hip and knee replacements since January 2000. A recent audit examined our use of this system in primary THR and showed a significant reduction in homologous blood transfusion as well as a reduced fall in the post-operative Hb value. The higher costs of the retransfusion system were offset by savings in homologous transfusion expense.

We undertook a randomised prospective study to determine whether post-operative salvage provides any clinical, haematological or economic benefit in primary THR. The aim was to determine whether post-operative salvage affects post-operative Hb values and reduces the need for homologous blood transfusion.

Patients and Methods

The study was approved by the local research ethics committee and was designed to compare two groups of patients undergoing primary THR with different types of drainage system. It was determined that 72 patients would be required in each group to detect a significant difference of 0.7 g/dl in post-operative Hb level (80% power, α value of 0.05) assuming a standard deviation (SD) of 1.5 g/dl obtained from the previous retrospective audit. A target of 190 participants was chosen to allow for patient loss during the study period.

Between December 2003 and December 2005, 190 consecutive patients undergoing elective primary THR for arthritis at Weston General Hospital were enrolled. Exclusion criteria included a history of coagulation disorder or unusual antibodies detected pre-operatively.

At pre-operative assessment, participants were instructed to discontinue aspirin and anti-inflammatory medication from ten days before surgery. Pre-operative Hb and haematocrit values were recorded. Six orthopaedic consultants and one orthopaedic specialist (including VGL) performed the operations. Some patients were given a pre-operative

dose of 3500 units of tinzaparin (low molecular weight heparin) according to anaesthetic instructions but most received it on the evening of surgery. A dose of 1.5 g of cefuroxime was given routinely at induction and a lateral approach used by all but one surgeon, who used a posterior approach. The cemented prostheses comprised a V40 Exeter stem (Stryker Howmedica UK, Newbury, United Kingdom) and a Cenator cup (Corin Medical, Cirencester, United Kingdom). The hybrid prostheses combined a cemented Exeter stem or CPS-PLUS stem (Plus Orthopedics, Swindon, United Kingdom) with an uncemented EP-FIT PLUS cup (Plus Orthopedics). The uncemented prostheses combined an EP-FIT PLUS cup with an SL-PLUS stem (Plus Orthopedics).

The patients were block randomised (computer generated) to one of two groups from sealed envelopes opened by a nurse after reduction of the prosthesis. Group A received two size 12 Medinorm vacuum drains (Van Straten, Quierried, Germany) and group B an ABTrans autologous retransfusion system. All drains have an external diameter of 4 mm and were inserted during closure of the wound deep to the tensor fascia lata. The autologous closed circuit system includes two drains with a Y connector and a 125 μ m filter through which the blood passes before entering the 1200 ml reservoir. The pressure in the collection reservoir was 20 kPa in the Medinorm drain and 13 kPa in the ABTrans system.

Autologous retransfusion was given at four-hourly intervals from the opening of the drain, or when 400 ml had collected in the reservoir. The maximum time between collection and completion of each transfusion was six hours. The system was used for 24 hours or up to a total of 1600 ml. The protocol was derived from the manufacturer's recommendations which were constructed according to American Association of Blood Banks guidelines.²⁹ The Medinorm vacuum drains (Van Straten) were removed 48 hours after surgery.

The two groups were given identical routine post-operative care, which included two further doses of cefuroxime (750 mg) at eight-hour intervals and anti-embolism stockings. All were assisted to stand on the first post-operative day, and progressed to walking with a frame on the second day.

The individual orthopaedic team decided whether to give homologous blood transfusion. Local practice was to give two units if the post-operative Hb was less than 8.0 g/dl or if patients were symptomatic with Hb in the range of 8.0 g/dl to 10.0 g/dl. All were monitored for transfusion reactions, post-operative pyrexia, and wound or other complications. Post-operatively, the Hb and haematocrit values and the number of homologous units required were recorded. The effect of performance bias on the decision to transfuse (as a result of loss of blinding post-operatively) was analysed statistically.

The patients attended for follow-up at six to eight weeks; Hb and haematocrit values were recorded and the patients

Table I. Patient demographics, American Society of Anesthesiologists³³ (ASA) grade, anaesthetic type and type of prosthesis

	Group A (vacuum drain) (n = 82)	Group B (post-operative salvage) (n = 76)
Male:female	40:42	36:40
Age (years) mean (range)	75.5 (46 to 91)	73.5 (52 to 87)
Body mass index (kg/m ²), mean (range)	27 (17 to 36)	29 (17 to 51)
Diagnosis		
Osteoarthritis		
Rheumatoid arthritis	82	75
Orientation		1
Right:left	43:39	46:30
ASA grade (%)		
I	13 (16)	16 (21)
II	61 (74)	50 (66)
III	8 (10)	9 (12)
IV	0	1 (1)
Type of anaesthetic (%)		
General	9 (11)	5 (7)
Spinal	72 (88)	71 (93)
Other	1 (1)	
Prosthesis (%)		
Cemented	43 (52)	33 (43)
Hybrid	32 (39)	41 (54)
Uncemented	7 (9)	2 (3)

Table II. Pre-operative, post-operative and follow-up haemoglobin and haematocrit values (mean values and range)

	Group A (vacuum drain) (n = 82)	Group B (post-operative salvage) (n = 76)	Mann-Whitney U test (p-value)
Haemoglobin (g/dl)			
Pre-operative	13.59 (10.3 to 16.5)	13.61 (9.3 to 17.1)	0.859
Post-operative	10.61 (7.0 to 15.5)	10.77 (7.3 to 13.9)	0.324
Follow-up Hb	12.71 (9.9 to 15.6)	12.58 (9.9 to 16.4)	0.375
Haematocrit			
Pre-operative	0.400 (0.290 to 0.540)	0.401 (0.270 to 0.500)	0.712
Post-operative	0.311 (0.210 to 0.440)	0.314 (0.210 to 0.400)	0.434
Follow-up Hct	0.378 (0.300 to 0.470)	0.374 (0.300 to 0.480)	0.430

completed a questionnaire on satisfaction with the outcome,³⁰ which was qualified by a questionnaire rating vigour.³¹

The costs of the drains and blood-giving sets were obtained from the hospital supplies department, and the hospital liaison nurse from the National Blood Service supplied the cost of a unit of packed red blood cells.³²

Statistical analysis was performed using the Statistical Package for Social Sciences version 11 (SPSS Inc., Chicago, Illinois). The Mann-Whitney U test (non-parametric data) was used for the comparison of univariate means and the chi-squared test for comparison of categorical variables.

Results

From the 190 patients who agreed to participate, 158 sets of complete data were obtained. There were 22 incomplete Hb values, and ten patients did not fulfil the inclusion criteria.

There were 82 patients in group A and 76 in group B. Their demographics, the American Society of Anesthesiologists (ASA) grades,³³ types of anaesthetic and prostheses

are shown in Table I. The mean duration of the operation was the same for both groups at 1.6 hours (0.75 to 3.0). Pre-operative chemical prophylaxis for deep-vein thrombosis (DVT) was given to 17 patients (21%) in group A and 14 (18%) in group B. There was no association between pre-operative administration of tinzaparin and post-operative Hb value or requirement for homologous transfusion. Post-operative pyrexia was recorded in 29 patients (35%) in group A and 25 patients (33%) in group B. There was no statistically significant difference between the groups for length of stay. The mean for group A was 6.98 days (4 to 17) and the mean for group B was 6.40 days (4 to 11). The mean time to follow-up assessment was seven weeks (4 to 12).

Wound complications were recorded in five patients (6%) in group A and in 3 (4%) from group B (not significant). They included two possible superficial wound infections in each group, two haematomas in group A, one in group B, and one washout for possible infection three weeks post-operatively in group A, with no long-term sequelae to date.

Table III. Volume of blood collected and autologous re-transfusion, units of homologous blood transfusion and number of patients transfused

	Group A (vacuum drain) (n = 82)	Group B (post-operative salvage) (n = 76)
Volume in drains: mean (range) (ml)	535 (100 to 1900) (10% records incomplete)	316 (0 to 1000)
Volume retransfused: mean (range) (ml)	-	252 (0 to 800)
Number of patients retransfused (%)	-	58 (76)
Units of homologous blood transfused		
Total units	44	14
Range of units	0 to 5	0 to 5
Units per person	0.54	0.18
Number of patients in group receiving homologous blood transfusion (%)	17 (21)	6 (8)

Fig. 1

Bar chart showing the number of patients, in group A and B, receiving homologous blood transfusion (HBT) in relation to post-operative haemoglobin (Hb) value.

The Hb and haematocrit values are shown in Table II. There were no significant differences between the groups in the mean values of pre-operative, immediate post-operative and follow-up Hb and haematocrit levels. However, 16 patients (20%) in group A had a post-operative Hb level below 9.0 g/dl, compared to six patients (8%) in group B (chi-squared test, $p = 0.035$).

The volume of fluid collected post-operatively, the volume of blood re-transfused and number of units of homologous blood required are shown in Table III. Statistical analysis of the proportion of patients in each group who received homologous blood showed that group A was more strongly associated with the use of homologous blood than group B (chi-squared test, $p = 0.022$).

Figure 1 shows the number of patients in each group receiving homologous blood transfusion in relation to post-operative Hb value. These results were statistically analysed for performance bias, which could have arisen when

the decision to transfuse was made, but no such evidence was found.

There were ten patients (6.3%) older than 75 years (six group A, four group B) with pre-operative Hb less than 13.0 g/dl. This subgroup was not associated with a greater use of homologous blood (chi-squared test, $p = 0.899$). There was no association of increased need for homologous blood with type of prosthesis or BMI (chi-squared test, $p = 0.182$ for prosthesis type; $p = 0.077$ for BMI).

Patient satisfaction was recorded on a Likert scale³⁴ of 1 to 5, least to most satisfied. The median (5, 1 to 5) was the same for both groups. Similarly, patient vigour was recorded on a Likert scale of 1 to 5, least to most tired, and both groups had a median of 2 (1 to 5).

The final analysis was to compare the cost to the hospital per patient. As there was no difference in the length of stay between the groups and all other parameters were comparable, the only factors to be considered were the costs of the drains and red cells transfused. These results are shown in Table IV.

Discussion

In this study, the groups were comparable and there were no significant differences between them in pre-operative status, operative details, clinical outcomes, patient satisfaction or length of hospital stay. Post-operative salvage was not associated with an increased risk of early complications. The association between homologous blood transfusion and infection is controversial. Some studies report an increased infection risk following homologous transfusion,¹⁴ and this is reduced if autologous transfusion is used.³ Long-term follow-up of our cases will continue to determine whether this is the case.

In the post-operative salvage group, 58 patients (76%) were re-transfused a mean blood volume of 252 ml (0 to 800); blood was discarded in 18 (24%) of this group because of insufficient volume. This is comparable with other studies which reported mean re-transfusion volumes of 264 ml and positive re-transfusion rates of 75.6%.²¹

There were no differences in Hb or haematocrit levels between the two groups throughout the study period. Other studies, which included patients for whom pre-operative donation and intra-operative salvage were

Table IV. Cost comparison between drain types

	Medinorm vacuum drains	Autologous re-transfusion system
Cost of drains (£)	17.24	58.16
Number of homologous blood transfusion units per person	0.54	0.18
Cost of one unit of blood (RBC*) (£)	131.80	131.80
RBC per patient cost (£)	71.17	23.72
Total cost per patient (drain plus RBC) (£)	88.41	81.88

* RBC, red blood cells

available, concluded that post-operative salvage had no haematological benefit.^{35,36} However, we found a significantly higher percentage of patients in the vacuum drain group whose post-operative Hb fell to 0.9 g/dl or less (20% compared to 8%). The significance or clinical relevance of this difference is unknown, as no obvious pre-operative or operative predisposing factors were identified. Statistical analysis did not demonstrate any association of homologous transfusion with advanced age (> 75 years) or pre-operative Hb below 13.0 g/dl, factors that have been shown to increase the likelihood of homologous transfusion.⁵⁻⁸ This may be a result of the relatively small number of patients in this group (10 of 158, 6.3%).

The most important finding in our study was a significant reduction in the number of patients requiring homologous transfusion in the post-operative salvage group. A total of 17 patients (21%) with vacuum drains required homologous transfusion, compared to six (8%) in those where post-operative salvage was available. Comparison with other studies is difficult because some included primary and revision cases as well as patients for whom pre-operative donation or intra-operative salvage was available. A reduction in homologous transfusion has been reported in primary arthroplasty when post-operative salvage is used.²⁰ Nevertheless, other studies have indicated that post-operative salvage does not result in significant haematological, transfusion or clinical benefit in uncomplicated primary THR.^{35,36} The inclusion of a group in which no drain was used may have provided additional information, although figures from one study showed a higher rate of homologous transfusion for patients with no drains (26.4%) than our rates of homologous transfusion (21% in those with a vacuum drain and 8% in those with an autologous system).²⁸

The analysis of cost concluded that the use of vacuum drains alone was associated with a cost increase of 8% compared to post-operative salvage. This is calculated on the basis of cost per unit of packed red blood cells during surgery. Although the current price of a unit of blood is not anticipated to change, future costing may have to include additional screening tests. In our hospital, there has been a requirement to reduce the use of blood by 10%. Both these considerations favour the continued use of autologous retransfusion systems on economic grounds.

There are weaknesses in our study, which ideally should have included a group where no drainage was used, but we felt that such a group would be difficult to 'blind'. No attempt was made to calculate the intra-operative loss of blood. Although we are aware of techniques to calculate this, it was felt that consistent and accurate intra-operative data could not be guaranteed. The size of the study sample was determined principally to test the hypothesis that post-operative salvage reduces the necessity for homologous blood transfusion in THR. As a result, the groups were too small to subdivide for the purpose of analysing smaller variables with statistical accuracy.

This study confirms that post-operative salvage significantly reduces the necessity for homologous blood transfusion in primary THR in a small, busy district general hospital. We found the ABTrans autologous re-transfusion system easy to use, safe and cost-effective. The only obvious clinical or haematological benefit was that the post-operative Hb was less likely to drop below 9.0 g/dl. As a result, our unit uses autologous re-transfusion for all primary THRs.

The authors gratefully acknowledge the participation of local orthopaedic surgeons in this study and the support of the Research and Effectiveness Department at United Bristol Healthcare NHS Trust.

Although none of the authors has received or will receive benefits for personal or professional use from a commercial party related directly or indirectly to the subject of this article, benefits have been or will be received but will be directed solely to a research fund, foundation, educational institution, or other nonprofit organisation with which one or more of the authors are associated.

References

1. **NJR.** Summary Report to the 2nd annual report. National Joint Registry for England and Wales, September 2005. <http://www.njrcentre.org.uk> (date last accessed 26 September 2006).
2. **Sehat KR, Evans RL, Newman JH.** Hidden blood loss following hip and knee arthroplasty: correct management of blood loss should take hidden loss into account. *J Bone Joint Surg [Br]* 2004;86-B:561-5.
3. **Rosencher N, Kerkkamp HEM, Macheras G, et al.** Orthopedic surgery transfusion haemoglobin European overview (OSTHEO) study: blood management in elective knee and hip arthroplasty in Europe. *Transfusion* 2003;43:459-69.
4. **Helm AT, Karski MT, Parsons SJ, Sampath JS, Bale RS.** A strategy for reducing blood-transfusion requirements in elective orthopaedic surgery: audit of an algorithm for arthroplasty of the lower limb. *J Bone Joint Surg [Br]* 2003;85-B:484-9.
5. **Salido JA, Marin LA, Gomez LA, Zorrilla P, Martinez C.** Preoperative haemoglobin levels and the need for transfusion after prosthetic hip and knee surgery. *J Bone Joint Surg [Am]* 2002;84-A:216-20.
6. **Marx RG, Wotherspoon S, Stephens D, Davey JR.** Patient factors affecting autologous and allogeneic blood transfusion rates in total hip arthroplasty. *Am J Orthopedics* 2001;30:867-71.
7. **Aderinto J, Brenkel IJ.** Pre-operative predictors of the requirement for blood transfusion following total hip replacement. *J Bone Joint Surg [Br]* 2004;86-B:970-3.
8. **Pola E, Papaleo P, Santoliquido A, et al.** Clinical factors associated with an increased risk of perioperative blood transfusion in nonanaemic patients undergoing total hip arthroplasty. *J Bone Joint Surg [Am]* 2004;86-A:57-61.

9. **No authors listed.** SHOT. Summary of annual report 2004. Serious Hazards of Transfusion Office, Manchester Blood Centre. <http://www.shotuk.org> (date last accessed 26 September 2006).
10. **Sandler SG, Yu H, Rassai N.** Risks of blood transfusion and their prevention. *Clin Adv Hematol Oncol* 2003;1:307-13.
11. **Hillyer CD, Josephson CD, Blajchman MA, et al.** Bacterial contamination of blood components: risks, strategies, and regulation: joint ASH and AABB educational session in transfusion medicine. *Hematology Am Soc Hematol Edu Program* 2003;575-89.
12. **Pillonel J, Le Marrec N, Girault A, David D, Laperche S.** Epidemiological surveillance of blood donors and residual risk of blood-borne infections in France, 2001 to 2003. *Transfus Clin Biol* 2005;12:239-46 (in French).
13. **Goodnough LT.** Risks of blood transfusion. *Anesthesiol Clin North America* 2005;23:241-52.
14. **Bierbaum BE, Callaghan JJ, Galante JO, et al.** An analysis of blood management in patients having a total hip or knee arthroplasty. *J Bone Joint Surg [Am]* 1999;81-A:2-10.
15. **Billote DB, Glisson SN, Green D, Wixson RL.** A prospective, randomized study of preoperative autologous donation for hip replacement surgery. *J Bone Joint Surg [Am]* 2002;84-A:1299-304.
16. **Guerra JJ, Cuckler JM.** Cost effectiveness of intraoperative autotransfusion in total hip arthroplasty surgery. *Clin Orthop* 1995;315:212-22.
17. **Turner RH, Capozzi JD, Kim A, Anas PP, Hardman E.** Blood conservation in major orthopaedic surgery. *Clin Orthop* 1990;256:299-305.
18. **Wilson WJ.** Intraoperative autologous transfusion in revision total hip arthroplasty. *J Bone Joint Surg [Am]* 1989;71-A:8-14.
19. **Faris PM, Ritter MA, Keating EM, Valeri CR.** Unwashed filtered shed blood collected after knee and hip arthroplasties: a source of autologous red blood cells. *J Bone Joint Surg [Am]* 1991;73-A:1169-78.
20. **Han CD, Shin DE.** Postoperative blood salvage and reinfusion after total joint arthroplasty. *J Arthroplasty* 1997;12:511-16.
21. **Grosvenor D, Goyal V, Goodman S.** Efficacy of postoperative blood salvage following total hip arthroplasty in patients with and without deposited autologous units. *J Bone Joint Surg [Am]* 2000;82-A:951-4.
22. **Gannon DM, Lombardi AV, Mallory TH, et al.** An evaluation of the efficacy of postoperative blood salvage after total joint arthroplasty. *J Arthroplasty* 1991;6:109-14.
23. **Rizzi L, Bertacchi P, Ghezzi LM, Bellavita P, Scudeller G.** Postoperative blood salvage in hip and knee arthroplasty. *Acta Orthop Scand* 1998;69:31-4.
24. **Slagis SV, Benjamin JB, Volz RG, Giordano GF.** Postoperative blood salvage in total hip and knee arthroplasty. *J Bone Joint Surg [Br]* 1991;73-B:591-4.
25. **Gardner A, Datta A, Bell K.** Use of re-transfusion versus vacuum drains in primary total hip replacement. *Hip International* 2005;15:223-5.
26. **Ayers DC, Murray DG, Duerr DM.** Blood salvage after total hip arthroplasty. *J Bone Joint Surg [Am]* 1995;77-A:1347-51.
27. **Ogonda L, Wilson R, Archbold P, et al.** A minimal-incision technique in total hip arthroplasty does not improve early postoperative outcomes: a prospective, randomized, controlled trial. *J Bone Joint Surg [Am]* 2005;87-A:701-10.
28. **Walsley PJ, Kelly MB, Hill RMF, Brenkel I.** A prospective, randomised, controlled trial of the use of drains in total hip arthroplasty. *J Bone Joint Surg [Br]* 2005;87-B:1397-401.
29. **No authors listed.** Standards for perioperative autologous blood collection and administration. First ed. Bethesda: American Association of Blood Banks, 2007.
30. **Brokelman RBG, van Loom CJM, Rijnberg WJ.** Patient versus surgeon satisfaction after total hip arthroplasty. *J Bone Joint Surg [Br]* 2003;85-B:495-8.
31. **Keating MR, Ranawat CS, Cats-Baril W.** Assessment of postoperative vigor in patients undergoing elective total joint arthroplasty: a concise patient- and caregiver-based instrument. *Orthopedics* 1999;22:119-28.
32. **No authors listed.** National Blood Service. <http://www.blood.co.uk> (date last accessed 20 July 2007).
33. **No authors listed.** ASA Physical Status Classification System. American Society of Anesthesiologists. <http://www.asahq.org/clinical/physicalstatus.htm> (date last accessed 20 July 2007).
34. **Bowling A.** *Research methods in health*. Second ed. Maidenhead: Open University Press 2002:289-94.
35. **Rollo VJ, Hozack WJ, Rothman RH, Chao W, Eng KO.** Prospective randomized evaluation of blood salvage techniques for primary total hip arthroplasty. *J Arthroplasty* 1995;10:532-9.
36. **Mauerhan DR, Nussman D, Mokris JG, Beaver WB.** Effect of postoperative reinfusion systems on haemoglobin levels in primary total hip and total knee arthroplasties. *J Arthroplasty* 1993;8:523-7.