Acta Orthop. Belg., 2007, **73**, 377-385

ORIGINAL STUDY

Comparison of autologous transfusion drains versus no drain in total knee arthroplasty

Alex P. JONES, Mark HARRISON, Anthony HUI

From James Cook University Hospital, Middlesbrough, Cleveland, England

Primary total knee arthroplasty is associated with blood loss both during surgery and in the immediate postoperative period, that may require allogenic blood transfusion. In view of the risks and financial implications of using allogenic blood, an accepted solution has been to utilise autotransfusion drains in the postoperative period thus allowing re-infusion of a patient's own blood. A number of studies have compared retransfusion techniques with standard drain use, but few report comparison with no drain use at all. We analysed data from patients undergoing primary total knee arthroplasty within our unit over an 18-month period. A total of 121 patients were included in the study : 53 received retransfusion drains whilst the remaining 68 received no drain at all. The mean postoperative haemoglobin drop was not significantly different between the two groups ($p > 0.05$). In the retransfusion group only one patient (2%) required allogenic blood transfusion postoperatively, whilst 4 of the 68 (6%) did so in the control group. This difference was not statistically significant either.

This study showed a low rate of allogenic blood use postoperatively (< 5%) where either a retransfusion drain or no drain was used at all. However because there was no measurable difference between the two, we conclude that using a retransfusion technique does not appear to be of significant financial or clinical benefit with regards to allogenic blood transfusions compared with using no drain.

Keywords : total knee arthroplasty ; autologous transfusion ; reinfusion drains ; haemoglobin ; blood transfusion.

INTRODUCTION

It is generally accepted that most patients undergoing a primary knee arthroplasty will experience some degree of blood loss in the postoperative period. Based on current literature, a reasonable estimate of this loss would be between 500 mls and 1000 mls (*9, 10, 19, 20, 23*). Most of this loss is believed to occur within the first 24 hours. In view of this, there is a consequent potential for patients to require post operative allogenic blood transfusion and estimated rates of transfusion are between 5 and 59% in uncomplicated primary knee arthroplasty (*5, 7, 15, 16, 18*). Transfusion criteria differ between published studies but a typical standard appears to be a post operative haemoglobin (Hb) level of 8 g/dl or less, or clinical signs of anaemia (*5, 7, 17*).

■ Alex P. Jones, MRCS, MBChB(Hons), BSc(Hons), SHO in Orthopaedics.

■ Mark Harrison, MBBS, SHO in Emergency Medicine.

■ Anthony Hui, FRCS, Consultant in Trauma and Orthopaedics.

James Cook University Hospital, Middlesbrough, Cleveland, England

Correspondence : Alex P. Jones, Division of Orthopaedic Surgery, James Cook University Hospital, Marton Road, Middlesbrough, Cleveland, England, TS4 3BW.

E-mail : AlexPJones@doctors.org.uk.

No benefits or funds were received in support of this study

Transfusion of allogenic blood comes with a number of associated risks such as transfusion reactions, transfusion associated lung injury and potential transmission of infection from blood borne viruses such as Hepatitis B and C (*21*). It is also expensive at a cost of approximately £ 120 per unit and there is only a finite supply available (*6, 21*). Consequently, one solution proposed has been to utilise a patient's own blood either by taking a preoperative blood donation or by using a retransfusion technique such that the patients may be reinfused with their own blood collected postoperatively (*4, 15*).

A number of studies have been published concerning this topic in order to assess the effectiveness of using the retransfusion technique in terms of maintaining adequate Hb levels post operatively and reducing the requirement for allogenic blood transfusions. At present results in published literature are varied. Some support the use of retransfusion systems (*5, 10, 14*) whilst others do not (*7, 22*).

With the lack of conclusive data, the current authors thought that it would be a useful exercise to perform a retrospective study within their own unit to ascertain whether reinfusion drains are effective in reducing allogenic blood use in uncomplicated primary total knee replacement assuming that an established transfusion policy is in place. More specifically however, we were aware that previous studies had compared the use of two different drain types, standard versus retransfusion whilst others had also identified that the drains themselves may be prolonging or increasing blood loss postoperatively. Consequently we wished to compare the results of retransfusion techniques with no drain use at all and the findings from this are presented here.

MATERIALS AND METHODS

Data Collection

The study was performed retrospectively encompassing an eighteen-month period from January 2004 to July 2005. All primary total knee arthroplasties performed in the unit by two different surgeons were included. These formed two independent groups hereby termed Retransfusion group and Control group (where no drain was inserted at all). Exclusion criteria set out were revision surgery or unicompartmental replacements. All patients were operated on over the same time period, on the same day of the week, on the same wards with the same nursing and physiotherapy staff. Both surgeons employed the same selection criteria for their patients. Thromboprophylaxis was consistent between groups where all patients received oral aspirin 150 mg daily. Data was collected by review of case notes.

In all patients the following data was recorded :

- Age and sex of the patient
- Which knee was operated upon
- The full blood count (FBC) pre and post operation : Hb, white cell count (WCC) and platelets (PLT). The amount of allogenic blood transfusion required
- The incidence of deep vein thrombosis (DVT) that required active intervention, or pulmonary embolism (PE)
- Any other complications that occurred postoperatively

In the retransfusion group the following was additionally recorded :

- The correct use of drains in the retransfusion group was assessed. Correct use involved a successful collection of cells that were re-transfused within the six-hour period
- The mean collection volume from the retransfusion

In our unit all patients using the retransfusion technique were supposed to receive the re-infusion. Only patients with measured post operative Hb levels less than 8 g/dl or displaying clinical symptoms of anaemia with low Hb were prescribed allogenic blood regardless of group. All patients were not routinely screened for a DVT, only if there was a clinical indication for this. Any wound infection was determined by the prescription of antibiotics.

Statistical anaylsis

Statistical analysis of the recorded variables was performed using the 2-tailed Fischer exact test or paired t-test as appropriate (2). Thereafter numbers needed to treat (NNT) were calculated for relevant data (1).

RESULTS

The results of the study are summarised in tables I-IV.

Table I. — Mean pre and post operative Hb levels in each group

	Retransfusion group	Control group
Group mean Preoperative Haemoglobin Level (g/dl)	13.92 (95% CI 13.57 - 14.26)	13.36 (95% CI 13.01-13.71)
Group mean Postoperative Haemoglobin Level (g/dl)	11.18 (95% CI 10.80-11.56)	10.86 (95% CI 10.53-11.24)
Group mean drop in Haemoglobin (g/dl)	2.71 (95% CI 2.40 – 3.01)	2.51 (95% CI 2.29 – 2.73)
Range of Hb drop	(0.09 to 6.3)	(-0.3 to 5.4)
2 Tailed Paired t-test result	(p = 0.3145)	

Table II. — Mean pre and post operative WCC levels in each group

	Retransfusion group	Control group
Group mean Preoperative WCC	7.45 (95% CI 6.99 – 8.05)	7.57 (95% CI 7.03 – 8.12)
Group mean Post-operative WCC	10.19 (95% CI 9.49 – 10.89)	9.21 (95% CI 8.56 – 9.86)
Group mean increase in WCC	2.60 (95% CI 2.04 – 3.16)	1.63 (95% CI 1.08 – 2.18)
Range of WCC increase	(-2.8 to 6.8)	(-4.9 – 5.9)
2 Tailed Paired t-test result	(p = 0.0059)	

Patient demographics

A total of 121 patients were included with 44% in the retransfusion group and 56% in the control group. Forty six percent of procedures involved the left knee whilst 54% involved the right knee. In the retransfusion group the mean age was 70 years and 2 months, and the mean age in the control group was 70 years and 6 months. The male: female ratio was 51:49 in the retransfusion group, and 31:69 in the control (p = 0.0389). All procedures were undertaken for management of osteoarthritis of the knee joint.

Changes observed in Haemoglobin levels

The recorded Hb levels from each group are presented in table I. The mean decrease in Hb was 2.71 g/dl in the retransfusion group vs 2.51 g/dl in the control group. This difference is not statistically significant (p = 0.3145).

Changes observed in white blood cell count (WCC)

The recorded WCC levels from each group are presented in table II. WCC increased postoperatively in both groups. The mean increase was $2.60 \times 10^9/1$ in the retransfusion group vs $1.62 \times 10^9/1$ in the control group. This difference is statistically significant ($p < 0.01$).

Changes observed in Platelet count (PLT)

The recorded PLT levels from each group are presented in table III. There was a mean drop in PLT of $33.18 \times 10^9/1$ in the retransfusion group vs $42.78 \times 10^9/1$ in the control group. This difference is not statistically significant (p = 0.1191).

Requirement for allogenic blood transfusion

In the retransfusion group only 1 out of 53 patients (2%) received an allogenic transfusion, and was given a total of 2 units. In the control group 4 patients of the 68 (6%) received allogenic transfusions postoperatively. A total of 15 units were given. Statistical analysis of this observational difference using a 2-tailed Fischer exact test did not show a significant difference at the 5% level (p = 0.3943). The 95% confidence intervals spanned zero (-2.68 to 10.68) and so we cannot be sure that use of a retransfusion drain is actually helpful in reducing allogenic blood requirements. However if this is assumed then the NNT would be 26 patients for a single patient reduction in allogenic blood requirement.

Table III. — Mean pre and post operative PLT levels in each group

	Retransfusion group	Control group
Group mean Preoperative PLT	257.06 (95% CI 236.89 – 277.23)	263.27 (95% CI 246.87 – 279.67)
Group mean Post-operative PLT	225.84 (95% CI 204.60 – 247.09)	220.69 (95% CI 206.63 –234.76)
Group mean decrease in PLT	33.18 (95% CI 20.50 - 45.86)	42.78 (95% CI 33.96 – 51.59)
Range of PLT decrease	(-120 to 78)	(-172 to 37)
2 Tailed Paired t-test result	(P = 0.1191)	

Table IV. — Difference in costs between the retransfusion and control groups

	Retransfusion group (£)	Control Group (£)
Drain cost	65	0
Allogenic Blood	4.54	25.52
Tx dose of fragmin	0	0.97
Tx dose of warfarin	0	0.26
Tx dose of antibiotics	0.32	0.10
TOTALS	69.86	26.85

Incidence of Deep Vein Thrombosis requiring treatment

In the retransfusion group none of the patients were diagnosed as having a clinically significant DVT. In the control group 2 patients of the 68 (3%) were shown to have a clinically significant DVT that required treatment with low molecular weight heparin (LMWH) followed by Warfarin for 3 months. Analysis of this observational difference using a 2-tailed Fischer exact test did not show a significant difference at the 5% level (p = 0.5036).

We found that the 95% confidence intervals spanned zero (-1.07 to 6.95). Therefore we cannot be sure that use of a drain is actually helpful in reducing clinically significant DVTs. However if this is assumed then the NNT would be 34 patients for a single patient reduction in DVT incidence.

Incidence of Post-Operative Infection

In the retransfusion group, 5 of the 53 patients (9%) were diagnosed as having a clinically significant infection requiring antibibiotic treatment. Antibiotics were prescribed for any superficial wound infection, or for any systemic infection such as chest or urine. In the control group, 2 patients of the 68 (3%) were shown to have a clinically significant infection that required treatment with antibiotics. Analysis of this observational difference using a 2-tailed Fischer exact test did not show a significant difference at the 5% level (p = 0.2379).

We found that the 95% confidence intervals spanned zero (-3.92 to 18.87). Therefore we cannot be sure that use of a drain actually increases the incidence of post-operative wound infection. However if this is assumed then the NNT would be 16 patients for a single patient increase in wound infection incidence.

Correct usage of retransfusion drains

Seventy-five percent of patients in the retransfusion group successfully received autologous transfusion. The mean transfusion volume was 389 ml (range 50 ml-1000 ml). Eight percent did not receive their transfusion because of nursing error, and in the remaining 17% there was no documentation to confirm the retransfusion. Consequently we were concerned how this may affect results and discussed the findings with our statistician. We then repeated the analysis excluding these patients

and found that the overall results were not significantly affected in terms of the NNT and statistical significance.

Financial Implications

The financial costs for each group are outlined in table IV. This shows the costs for the retransfusion drains and the cost of both allogenic blood, DVT treatment and antibiotics as a calculated amount per patient per group.

DISCUSSION

Studies that support the use of retransfusion techniques in primary knee arthroplasty

Previous studies have typically compared autologous drains with standard vacuum drains (*3, 5, 10, 14*). Each of these studies identified a decreased need for allogenic transfusion when using a reinfusion drain. Two of them however did have a very high rate of transfusion in the control groups, which would significantly affect the implied result (*5, 10*). For example, Dramis and Plewes (*5*) transfused 59% of their control group compared with 9% of the reinfusion group, whilst Hendrych (*10*) gave all control patients allogenic blood. One study reported higher post-operative Hb levels with reinfusion of drained blood (*14*).

Whether a patient is anaemic preoperatively may impact the need for post-operative blood transfusion. Consequently Handel *et al* (*9*) classified the patients in their study as normal (Hb > 12 g/dl) and anaemic (Hb < 12 g/dl) prior to surgery. They found that 21% of the anaemic group required allogenic transfusion whilst less than 1% in the normal group did so ($p < 0.001$). In the anaemic group 42% received a mean re-infusion of 284 ml, whilst only 23% in the normal group received a retransfusion. They concluded that the use of retransfusion could help avoid the use of additional allogenic blood transfusion. However although the authors claim the study supports the use of transfusion drains, the result is much less clear in patients who are not anaemic preoperatively.

Rees, Jeavons and Dixon (*18*) compared different drain types and claimed that there was little difference in costs between the standard drains and retransfusion drains. But they did report a decreased need for postoperative allogenic blood transfusion from 28% to 4% when retransfusion drains were used.

Studies that do not support retransfusion techniques in primary knee arthroplasty

Not all studies appear to support the beneficial effects of retransfusion techniques. For example, Tellisi *et al* (*22*) report that 16% of patients using a retransfusion system still needed allogenic transfusion. They also found that 34% of all patients in their study were unable to receive autologous blood anyway because there was either insufficient volume collected or the accepted 6-hour time interval had elapsed. Furthermore, there was no significant difference in post operative Hb levels with or without autologous transfusion having taken place.

Another group had initially performed an audit where they found 11% of patients needed post operative allogenic blood. Consequently they altered their clinical practice to utilise retransfusion drains. A repeat audit following the changes failed to show any significant decrease in allogenic blood use (*7*).

Jain and Jain (*11*) showed patients using retransfusion techniques had higher haemoglobin levels on the first postoperative day, and yet the receipt of salvaged blood did not significantly reduce the incidence of allogenic blood transfusion. The authors proposed this could be due to the increased blood loss of the retransfusion technique itself.

Allogenic blood use and Hb changes

The results of the current study showed that requirement for allogenic blood was low in both groups compared with previous published literature. This may not be unexpected given that less than 5% of patients were anaemic preoperatively and no excessive blood losses were recorded. From an observational perspective, patients in the retransfusion group appeared to require fewer

allogenic blood transfusions and yet had a slightly greater drop in Hb postoperatively. However as neither of these differences were statistically significant we cannot accept these observations to be true. A mean volume of 389 ml was obtained from the retransfusion drains for reinfusion. Therefore one explanation for the lack of difference between the two groups would be that using a drain serves only to allow a reinfusion of an additional blood loss when compared with using no drain at all. Indeed Roy *et al* (*19*) undertook a randomised control trial to assess the effect of delayed drain clamp opening on post-operative bleeding by delaying release of the clamp on a suction drain. In patients where drain clamps were closed for the first hour postoperatively there was a statistically significant reduction in postoperative bleeding ($p = < 0.001$) from 1050 ml (95% CI 728 - 1172 ml) to 732 ml (95% CI 620-845 ml). The mean decrease in Hb and post-operative transfusion requirement were also less in the delayed clamp release group.

Shen *et al* (*20*) also reported similar findings when early drain clamping was performed. The mean blood loss was halved when the drain was clamped after injection of adrenaline compared to the retransfusion technique. These studies suggest that clamping off a drain or indeed not using one at all may reduce blood loss by a tamponade effect. Consequently using a retransfusion may be futile as although it allows the patient to have their blood returned to them, it is associated with an increased blood loss in the first instance. Again this provides evidence that ties in with the current study findings in that the control group without drains did not need significantly more allogenic transfusion.

A further study supporting this theory is that by Tsumara *et al* (*23*). This group compared reinfusion drains against drain clamping in 212 knee replacements. They found that the mean volume of blood drained was reduced from 662 mls to 352 mls when early clamping was performed. Consequently they reported that allogenic blood was needed in more patients in the reinfusion group than the early drain clamping group. They concluded that drain clamping is more effective than post operative autologous blood transfusion in reducing blood loss after this procedure.

Less than 5% of the patients in this study were anaemic preoperatively (< 12 g/dl Hb). Hence our findings would also be in keeping with some other studies where it was shown that retransfusion techniques only provided significant benefit in patients who were initially anaemic. The mean Hb preoperatively was 13.3 g/dl (CI 13.0-13.7) and 13.9 g/dl (CI 13.5-14.2) in the control and retransfusion groups respectively. A patient with a preoperative Hb of 13.5 g/dl is unlikely to need postoperative transfusion according to our transfusion criteria, considering the mean drop was around 2.5 g/dl in each group.

A further factor that should not be forgotten however is that whilst the groups appeared well matched in most ways, there were still some demographic differences observed. The most noteworthy was the difference in the male to female ratios. The control group consisted of considerably more females than did the retransfusion group. The relevance of this in terms of blood requirements and drop in Hb are that results from a study by Prasad *et al* (*17*) suggests males tend to bleed more than females in total knee arthroplasty and this difference is significant ($p < 0.001$). Hence the gender difference between groups here may distort the apparent findings regarding blood loss, as more males were present in the retransfusion group.

Effects of retransfusion techniques on PLT and WCC

There were statistically significant differences in the postoperative WCC when comparing retransfusion with control groups. The mean WCC increased more in the retransfusion group. However no statistically significant increase in infection rate or other complication rate was observed and hence we would conclude that there was no obvious measurable effect with this difference.

There was an observational difference in the postoperative platelet count between the two groups in that there appeared to be a greater loss in the control group. However, once again this difference was not statistically significant. No patients required PLT infusion and no patients were reported as having any coagulopathy pre or post

operatively. Hence we would conclude that any difference had no obvious measurable effect.

Incidence of Deep Vein Thrombosis or post operative infections requiring treatment

Again there were only observational differences with these parameters. In spite of the fact that no patients in the retransfusion group required DVT treatment, there was no statistically significant difference observed. Hence our conclusion would be that using a retransfusion drain does not affect either infection or thrombosis formation positively or negatively.

Financial implications

One of the key reasons for using the retransfusion technique has been to reduce the financial burden that allogenic blood transfusion represents. Hence consideration of the different costs is important. A previous study that considered the financial implications of reinfusion drains suggested that a saving of 111 Euro was achieved in terms of the cost saving on allogenic blood (*5*). The results of this study however show that it was actually more expensive per patient to utilise the retransfusion drains as the cost of these exceeded any saving made in terms of allogenic blood.

We previously stated that previous authors have shown there is little difference in the cost of drains whether standard or retransfusion versions are used (*18*). If this was the case and one was determined to use a drain, it would seem pertinent to use a retransfusion example with the potential for reinfusion. However, we costed normal drains ourselves and found them to be considerably cheaper at £ 7 compared to £ 65 in our unit. Overall therefore we cannot find provide justification for using cell reinfusion drains on either a clinical or financial basis.

Correct usage of the retransfusion drains

This study has shown that in 75% of patients the retransfusion drains were correctly used and blood was successfully reinfused. Although this rate was good compared with some other studies in the literature, having potentially up to one quarter of patients unable to receive adequate transfusion may cast doubt on the effectiveness of the technique itself. As discussed in the results section, we did repeat the analysis after exclusion of these patients to ensure that the findings were not significantly altered.

Drawbacks of using unwashed drained blood

There are a number of potential risks associated with reinfusing unwashed drained blood. These are well documented and include increased levels of free Hb and effects on the immune system. It is thought that the passage of blood through various tubing and filters can risk haemolysis and consequent Hb release. A high level of free Hb can be toxic to glomerular cells leading to renal impairment. In this study we did not focus on post operative renal function, but no specific problems were highlighted in the reinfusion group. There is conflicting evidence regarding the effects on the immune system, with some suggestions that retransfusion is associated with release of potentially harmful proinflammatory substances such as histamine and prostaglandins. Conversely, there are reports that retransfusion may upregulate the immune system and confer some kind of clinical benefit (*8*). In this study the presence of a significantly greater rise in WCC in the retransfusion group may indicate that retransfusion does have some effect on the immune system response.

Weaknesses of the study

There were a number of confounding factors and weaknesses in this study and the authors fully accept these limitations. Firstly we have assumed that the groups are comparable, but there were inherent differences between them including the difference in lead surgeons and surgical teams. Furthermore different prostheses were used. In the control Scorpio (Stryker, USA) was used and in the retransfusion group PFC Sigma (DePuy, USA) was used.

As we have already stated, there were significantly more females in the control group and this

may have had a bearing on many factors including blood loss and rehabilitation time. Furthermore as stated above, we do not have detailed information on the other comorbidities of the patients involved. Suffice to say that we accept they must have all been medically fit to undergo elective knee surgery in the first instance.

We also accept that due to the size of the patient groups, there is a risk of type 2 error regarding results, in particular regarding the use of allogenic blood transfusion. However we feel we can adequately address this issue because even if a type 2 error had occurred and we assume there is a statistically significant difference in allogenic blood requirement between groups, the clinical significance of using a retransfusion drain would remain unchanged due to the large NNT. That is to say that it would not be justified on clinical grounds to use reinfusion drains in 26 patients in order to save a single autologous transfusion. To further address such issues a meta-analysis of similar small studies could be performed. The fact that only 75% were successfully reinfused would actually lend more weight to the suggestion that reinfusion is not beneficial over no drain use.

We also accept that there was no defined randomisation process involved other than the natural selection to surgeons that occurred. However this was a retrospective study and analysis of the two patient groups as described, showed they were well matched in most characteristics. As far as we are aware no similar studies have been performed using randomisation.

CONCLUSION

The results from this study have shown similarly low rates of allogenic blood use in both groups of patients with similar decreases in Hb postoperatively. Consequently the findings suggest that using a retransfusion drain vs. no drain at all in uncomplicated primary knee arthroplasty does not convey any measurable benefit in terms of blood loss. Furthermore reinfusion drains also appear to convey a greater financial cost than no drain use.

REFERENCES

1. **Altman DG.** Confidence intervals for the number needed to treat. *BMJ* 1998 ; 317 : 1309-1312.
2. **Armitage P, Berry G.** In : *Statistical Methods in Medical Research*. Oxford : Blackwell Scientific Publications, 1994 : 1234.
3. **Cheng SC, Hung TS, Tse PY.** Investigation of the use of drained blood reinfusion after total knee arthroplasty : a prospective randomised controlled study. *J Orthop Surg* (*Hong Kong*) 2005 ; 13 : 120-124.
4. **Clark CR, Spratt KF, Blondin M, Craig S, Fink L.** Perioperative autotransfusion in total hip and knee arthroplasty. *J Arthroplasty* 2006 ; 21 : 23-35.
5. **Dramis A, Plewes, J.** Autologous blood transfusion after primary unilateral total knee replacement surgery. *Acta Orthop Belg* 2006 ; 72 : 15-17.
6. **Forbes JM, Anderson MD, Anderson GF, Bleecker GC, Rossi EC, Moss GS.** Costs of blood transfusion. *Transfusion* 1991 ; 31 : 318-323.
7. **Glynn A, McCarthy T, McCarroll M, Murray P.** A prospective audit of blood usage post primary total knee arthroplasty. *Acta Orthop Belg* 2006 ; 72 : 24-28.
8. **Hamer A.** Postoperative cell salvage. In : Thomas D, Thompson J, Ridler B (eds). *A Manual for Blood Conservation*. TFM Publishing Ltd, UK. pp 123-132.
9. **Handel M, Boluki D, Loibl O *et al.*** Postoperative autologous retransfusion of collected shed blood after total knee arthroplasty with the cell saver. *Orthop Ihre Grenzgeb*. 2006 ; 144 : 97-101.
10. **Hendrych J.** Use of post-operative drainage and autotransfusion sets in total knee arthroplasty. *Acta Chir Orthop Traumatol Cech* 2006 ; 73 : 34-38.
11. **Jain R, Jain SJ.** Blood salvage in total hip and knee arthroplasty in a community hospital : a retrospective study. *Orthop Surg* (*Hong Kong*) 2005 ; 13 : 19-26.
12. **Jones HW, Savage L, White C *et al.*** Postoperative autologous blood salvage drains-are they useful in primary uncemented hip and knee arthroplasty ? A prospective study of 186 cases. *Acta Orthop Belg* 2004 ; 70 : 466-473.
13. **Kalairajah Y, Simpson D, Cossey AJ, Verrall GM, Spriggins AJ.** Blood loss after total knee replacement : effects of computer-assisted surgery. *J Bone Joint Surg* 2005 ; 87-B : 1480-1482.
14. **Kirkos JM, Krystallis CT, Konstantinidis PA, Papavasiliou KA, Kyrkos MJ, Ikonomidis LG.** Postoperative re-perfusion of drained blood in patients undergoing total knee arthroplasty : is it effective and cost-efficient ? *Acta Orthop Belg* 2006 ; 72 : 18-23.
15. **Lee GC, Hawes T, Cushner FD, Scott WN.** Current trends in blood conservation in total knee arthroplasty. *Clin Orthop* 2005 ; 440 : 170-4.
16. **Munoz M, Ariza D, Garceran MJ, Gomez A, Campos A.** Benefits of postoperative shed blood reinfusion in patients undergoing unilateral total knee

replacement. *Arch Orthop Trauma Surg* 2005 ; 125 : 385-389.

17. **Prasad N, Padmanabhan V, Mullaji A.** Blood loss in total knee arthroplasty : an analysis of risk factors. *Int Orthop* 2007 ; 31 : 39-44
18. **Rees JE, Jeavons R, Dixon JH.** An economic justification for autologous blood re-infusion in primary total knee replacement surgery. *Ann R Coll Surg Engl* 2005 ; 87 : 102-105.
19. **Roy N, Smith M, Anwar M, Elsworth C.** Delayed release of drain in total knee replacement reduces blood loss. A prospective randomised study. *Acta Orthop Belg* 2006 ; 72 : 34-38.
20. **Shen PC, Jou IM, Lin YT, Lai KA, Yang CY, Chern TC.** Comparison between 4-hour clamping drainage and nonclamping drainage after total knee arthroplasty. *J Arthroplasty* 2005 ; 20 : 909-913.
21. **Stainsby D, Cohen H, Jones H *et al.*** Serious Hazards of Transfusion Annual Report 2005, ISBN 0953278980, 30th November. 2006.
22. **Tellisi N, Kakwani R, Hulse N, Abusitta G, Ashammakhi N, Wahab KA.** Autologous blood transfusion following total knee arthroplasty : Is it always necessary ? *Int Orthop* 2006 ; 30 : 412-414.
23. **Tsumara N, Yoshiya S, Chin T, Shiba R, Kohso K, Doita M.** A prospective comparison of clamping the drain or post-operative salvage of blood in reducing blood loss after total knee arthroplasty. *J Bone Joint Surg* 2006 ; 88-B : 49-53.