

# Autologous blood transfusion in total hip arthroplasty

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## ABSTRACT

**Purpose.** To determine the possibility of avoiding homologous blood transfusion during total hip arthroplasty, and to clarify the problems associated with autologous blood transfusion.

**Methods.** A total of 253 patients received autologous blood transfusion during total hip arthroplasty between April 1990 and December 2000. Patients were assessed for the volume of haemorrhage during surgery, possibility of avoidance of homologous blood transfusion, and the disposal of autologous blood.

**Results.** There were no significant differences in the mean volume of haemorrhage among different underlying diseases. The mean total volume of haemorrhage was 2039 (standard deviation, 992) ml in revision surgery and 1673 (717.3) ml in primary surgery ( $p < 0.05$ ). The rate of avoidance of homologous blood transfusion was 75% among patients who underwent primary surgery, and 61% among those

who underwent revision surgery. The rate was 95% in cases in which a combination of preoperative blood pooling and intra-operative recovery was used, 49% in cases where the preoperative blood pooling system alone was used, and 42% in those in which the intra-operative recovery system alone was employed. The autologous blood had to be disposed of in 3 (1%) cases, all of which were revision procedures with replacement of the polyethylene liner alone.

**Conclusion.** Combined use of the preoperative blood pooling and intra-operative recovery systems is effective for avoiding homologous blood transfusion.

**Key words:** arthroplasty, replacement, hip; blood transfusion, autologous

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## INTRODUCTION

Owing to advancements in blood transfusion, surgery has evolved considerably in recent years. However,

problems associated with homologous blood transfusion, such as transmission of infections and immunological side-effects, have attracted attention. Because blood transfusion is a type of transplantation, autologous blood transfusion has been recommended to prevent such problems. This technique of using preoperatively pooled blood for autologous blood transfusion has been widely practised, particularly for elective surgery.

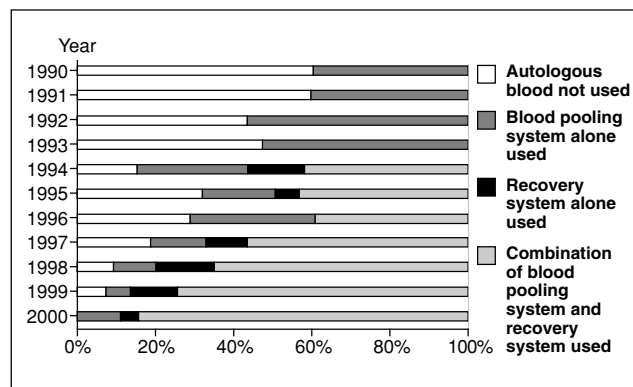
For total hip arthroplasty (THA), homologous blood transfusion has increasingly been avoided, while autologous blood transfusion has gained popularity. According to reports from various institutions,<sup>1-5</sup> the avoidance rate for homologous blood transfusion for THA has been 90% or higher in the past several years.

At the Department of Orthopedic Surgery, Tokyo Medical University, we have been using autologous rather than homologous blood transfusion for THA since April 1990. However, we have not completely avoided homologous blood transfusion. In this report, we discuss our experience of blood transfusion during THA and identify ways of increasing the avoidance rate of homologous blood transfusion, as well as problems associated with autologous blood transfusion.

## METHODS

Between April 1990 and December 2000, a total of 253 patients underwent THA with autologous blood transfusion at the Department of Orthopedic Surgery, Tokyo Medical University. The patients consisted of 56 men and 197 women, whose mean age at surgery was 60.3 (standard deviation [SD], 11.5; range, 32–81 years). Of the 253 patients, 202 had osteoarthritis (OA), 13 had rheumatoid arthritis (RA), and 38 had avascular necrosis of the femoral head (ANF). In all, 204 patients and 49 patients underwent primary and revision THA, respectively. Cement was used in 79 cases of primary THA, and bone grafting was used for 91 cases. Of the 49 patients undergoing revision THA, 35 underwent total replacement, 8 underwent replacement of the cup side alone, 3 underwent replacement of the stem side alone, and 3 underwent replacement of the polyethylene (PE) liner alone. A posterolateral approach was used in surgery; general anaesthesia was administered to all patients, and no anticoagulants were used postoperatively.

At our institution, predeposit autologous blood transfusion has been adopted since April 1990, and intra-operative autologous blood transfusion using a cell saver (Cell Saver 4; Haemonetics Co., Braintree



**Figure 1** Development of an autologous blood transfusion protocol at the Department of Orthopedic Surgery, Tokyo Medical University.

[MA], US) has been used since February 1994 (Fig. 1). For both primary and revision THA, the minimum target of blood collection is 800 ml. Whenever possible, 1200 ml of blood is pooled, and the whole-blood liquefaction preservation method using citrate-phosphate-dextrose preservative solution is adopted for all cases. The preoperative blood pooling system alone was used in 81 (32%) patients, the intra-operative recovery system alone in 24 (9%) patients, and combination of both systems in 148 (59%) patients. Blood collection for autologous blood transfusion was based on the standards of the Japanese Society of Blood Transfusion.

The current range of indications for blood collection is wide: blood is collected, if possible, even from patients with a haemoglobin (Hb) level of 100 g/l. A total of 400 ml of blood is collected once a week. Erythropoietin at 12 000 U per dose is administered at each blood collection, and iron and iron salts are administered to all patients. Erythropoietin is administered before blood pooling for patients who have a serum Hb level of 130 g/l or lower. When the Hb level increases to 140 g/l or above, or when the haematocrit increases to at least 42% after the start of blood pooling, administration of erythropoietin is discontinued or delayed until the next blood collection date.

Postoperative homologous blood transfusion is initiated when the serum Hb becomes 80 g/l or lower in patients older than 70 years, or when the serum Hb becomes 70 g/l in younger patients. In younger patients, the Hb level is monitored, and the blood pressure, pulse, and preoperative Hb level are also monitored before homologous blood transfusion starts. For patients with RA, the preoperative Hb level is monitored before homologous blood transfusion starts,

because these patients show a disease-specific tendency towards developing anaemia.

In this study, patients' total bleeding volume, rate of avoidance of homologous blood transfusion, and frequency of disposal of autologous blood were correlated to their underlying disease, surgical procedure performed, and the method of autologous blood collection. The Mann-Whitney *U* test, Kruskal-Wallis test, and Spearman's rank correlation were used for statistical analysis. Differences were considered significant at  $p < 0.05$ .

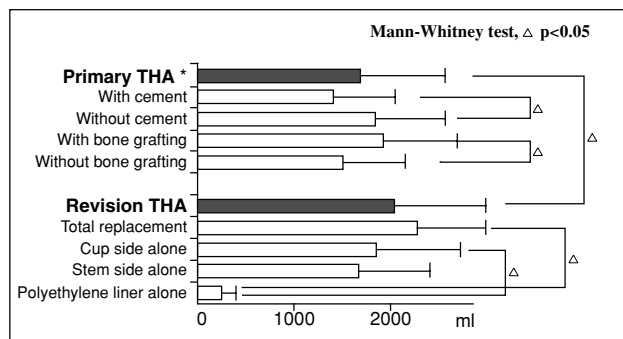
## RESULTS

### Bleeding volume

The mean operative time was 75 (SD, 24) minutes and 187 (SD, 36) minutes for primary THA and revision THA, respectively. There were no complications associated with autologous blood transfusion. The mean total bleeding volume (intra-operatively and postoperatively) was 1715 (SD, 760) ml among patients with OA, 1650 (SD, 801) ml among patients with RA, and 1356 (SD, 561) ml among patients with ANF. The mean volume, by patient age, was 1566 (SD, 823) ml among patients younger than 40 years, 1681 (SD, 602) ml among 40- to 70-year-olds, and 1584 (SD, 724) ml among patients older than 70 years. Thus, the mean total bleeding volume did not significantly vary in terms of disease type or patient age (Mann-Whitney *U* test).

When patients were stratified according to the surgical procedure they received, the mean bleeding volume was significantly larger among those undergoing revision THA than among those undergoing primary THA: 1866 (SD, 787) ml versus 1615 (SD, 602) ml, respectively ( $p = 0.02$ ). Furthermore, the mean bleeding volume during primary THA was larger without cement use than with: 1749 (SD, 652) ml versus 1395 (SD, 494) ml ( $p < 0.001$ ), and larger with bone grafting than without: 1821 (SD, 586) ml versus 1458 (SD, 561) ml ( $p < 0.001$ ). The total bleeding volume for patients undergoing revision THA was relatively low in those undergoing replacement of the PE liner alone, averaging 242 (SD, 126) ml (Fig. 2).

Overall, the mean total bleeding volume was substantial, particularly for patients who underwent surgery at relatively early stage of the study—for some patients, between 2000 and 3000 ml. However, in the last few years of the study period, the mean total bleeding volume remained at approximately 1500 ml. The mean postoperative bleeding volume collected by a continuous aspirator was 818 ml, which



\* THA total hip arthroplasty

Figure 2 Total volume of intra-operative and postoperative bleeding depending on the type of surgical procedure conducted.

accounted for a large proportion of the mean total bleeding volume.

### Avoidance of homologous blood transfusion

The overall rate of avoidance of homologous blood transfusion was 72%. The avoidance rate was about 63% among patients with RA, which was lower than that among patients with OA (71%) as well as patients with ANF (84%). The avoidance rate was 53% in patients older than 71 years, which was lower than that in patients aged 70 years or younger (77% among 40- to 70-year-olds and 74% among those younger than 40 years). In terms of surgical procedure, the avoidance rate was 61% and 75% among patients undergoing revision and primary THA, respectively. The avoidance rate was higher among patients undergoing primary THA who used cement, than among those who did not (80% versus 67%,  $p < 0.001$ ); it was also higher among patients undergoing primary THA without bone grafting than among those who received a bone graft (80% versus 70%,  $p < 0.05$ ). For patients undergoing replacement of the PE liner alone during revision THA, the mean total bleeding volume was lowest and the avoidance rate was 100% (Table 1).

When patients were stratified by their method of blood transfusion, the avoidance rate was 49% for those using the blood pooling system alone, 42% for those using the intra-operative recovery system alone, and 95% for those using a combination of both methods. The differences of these rates were significant (Kruskal-Wallis test,  $p < 0.001$ ) [Fig. 3].

There was a significant correlation between avoidance rate and operative time (Spearman's rank correlation,  $p < 0.001$ ). The avoidance rate was low when the operative time was long, probably

**Table 1**  
Rate of avoidance of homologous blood transfusion

| Surgical procedure                          | Rate of avoidance (%) |
|---|-----------------------|
| <b>Overall</b>                              | 72                    |
| <b>Primary total hip arthroplasty</b>       | 75                    |
| With cement                                 | 80                    |
| Without cement                              | 67                    |
| With bone grafting                          | 70                    |
| Without bone grafting                       | 80                    |
| <b>Revision total hip arthroplasty</b>      | 61                    |
| Total replacement                           | 60                    |
| Replacement of the cup side alone           | 75                    |
| Replacement of the stem side alone          | 67                    |
| Replacement of the polyethylene liner alone | 100                   |

**Table 2**

Avoidance rate of homologous blood transfusion in primary total hip arthroplasty\* by volume of pooled blood and age

| Pooled blood (ml) | Age (years) [mean, SD] | Avoidance rate (%) |
|-------------------|------------------------|--------------------|
| 200–400           | 62.3 (11.0)            | 65                 |
| 401–800           | 59.3 (9.9)             | 95                 |
| 801–1200          | 61.2 (9.8)             | 100                |

\* With combined use of blood pooling and intra-operative recovery systems

**Table 3**

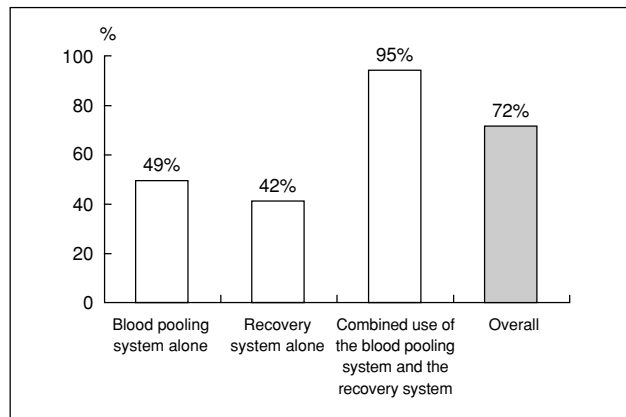
Avoidance rate of homologous blood transfusion in primary total hip arthroplasty\* by haemoglobin level before blood pooling

| Haemoglobin level before blood pooling (g/l) | Avoidance rate (%) |
|--|--------------------|
| 100–109                                      | 100                |
| 110–119                                      | 85                 |
| 120–129                                      | 89                 |
| ≥130   | 100                |

\* With combined use of blood pooling and intra-operative recovery systems

because of the relationship between total bleeding volume and operative time (Kruskal-Wallis test,  $p < 0.001$ ). Conversely, the avoidance rate was high when the operative time was short—for example, 97% avoidance rate for an operative time of shorter than 2 hours.

The avoidance rate was also significantly correlated to the total bleeding volume (Spearman's rank correlation coefficient,  $p < 0.001$ ): when the total bleeding volume was high, the avoidance rate was



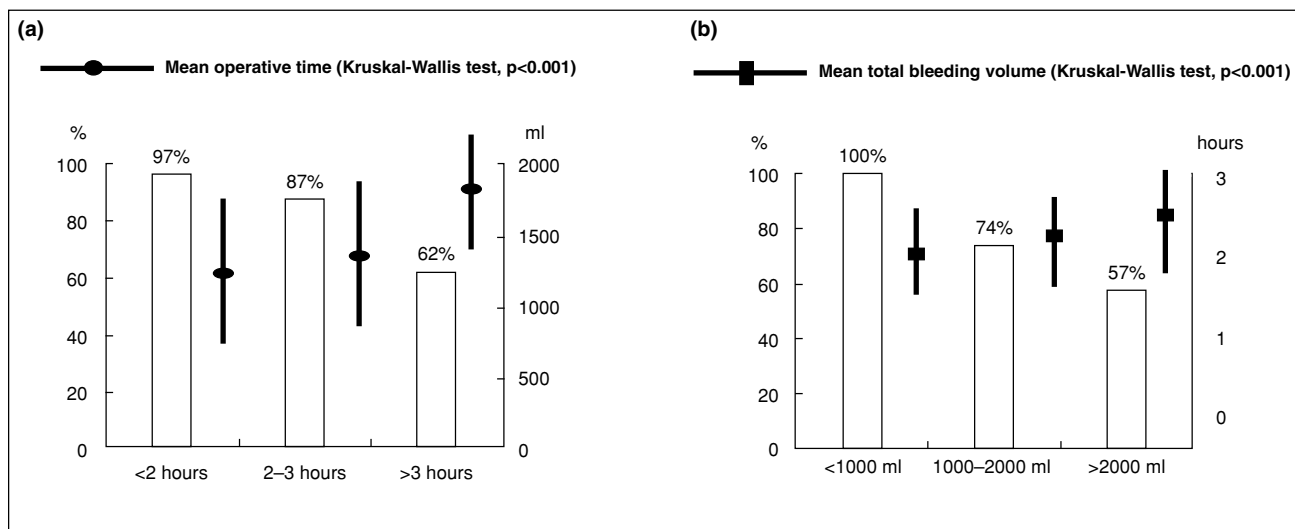
**Figure 3** There was a significant difference in the rate of avoidance of homologous blood transfusion depending on the blood transfusion method used (Kruskal-Wallis test,  $p < 0.001$ ).

low. Homologous blood transfusion was avoided in all patients whose total bleeding volume was less than 1000 ml (Fig. 4).

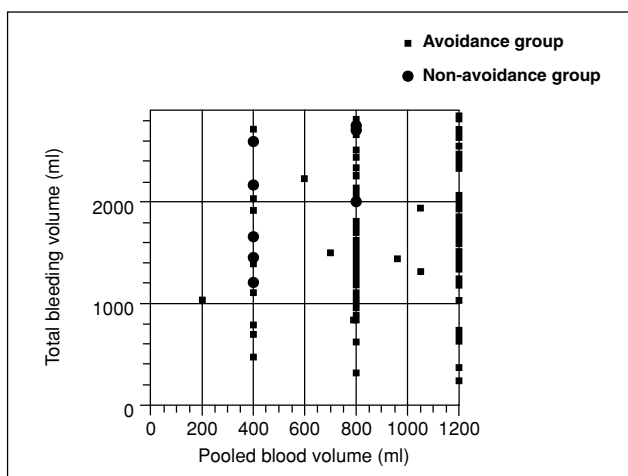
The avoidance rate was also assessed according to the year in which the surgery was performed. It was 31% for years 1990 to 1993, 73% for years 1994 to 1997, and 92% for years 1998 to 2000. The avoidance rate showed an annual increase and reached 85% in year 2000, which was associated with an increase in the proportion of patients using a combination of preoperative blood pooling and intra-operative recovery system. The increase in the proportion was attributable not only to the introduction of the intra-operative recovery system, but also to the expanded range of indications for the blood pooling system. In addition, our institution reconsidered the timing of initiation of homologous blood transfusion during the study period.

For patients undergoing primary THA who used a combination of blood pooling and preoperative recovery systems, the avoidance rate was 65% for those with 200 to 400 ml of pooled blood. Thus, when the pooled blood volume was insufficient, the avoidance rate was low. However, the avoidance rate increased when the pooled blood volume increased. The avoidance rate reached 100% when the pooled blood volume was between 801 and 1200 ml (Fig. 5 and Table 2).

Homologous blood transfusion could be avoided in all patients in whom the Hb level before blood pooling was at least 125 g/l, although there were variations in the avoidance rate among patients (Fig. 6 and Table 3). In patients who used a combination of blood pooling and recovery systems, there were significant differences in the time to recovery of the serum Hb level, depending on the volume of the



**Figure 4** Rate of avoidance of homologous blood transfusion. **(a)** By operative time: there were significant differences in the rate of avoidance of homologous blood transfusion (Spearman's rank correlation coefficient test,  $p < 0.001$ ). **(b)** By total bleeding volume: there were significant differences in the rate of avoidance of homologous blood transfusion (Spearman's rank correlation coefficient test,  $p < 0.001$ ).



**Figure 5** Relationships of the pooled blood volume and total bleeding volume with the avoidance of homologous blood transfusion among patients who underwent primary total hip arthroplasty using both blood pooling and intra-operative recovery systems.

pooled blood (Kruskal-Wallis test), suggesting an effect of autotransfusion (Fig. 7 and Table 2).

**Suspension cases**

Autologous blood was disposed of in 3 (1%) cases, all of which were replacements of the PE liner alone. The mean total bleeding volume was 242 ml for these 3 patients, and their mean Hb level was 129 g/l before

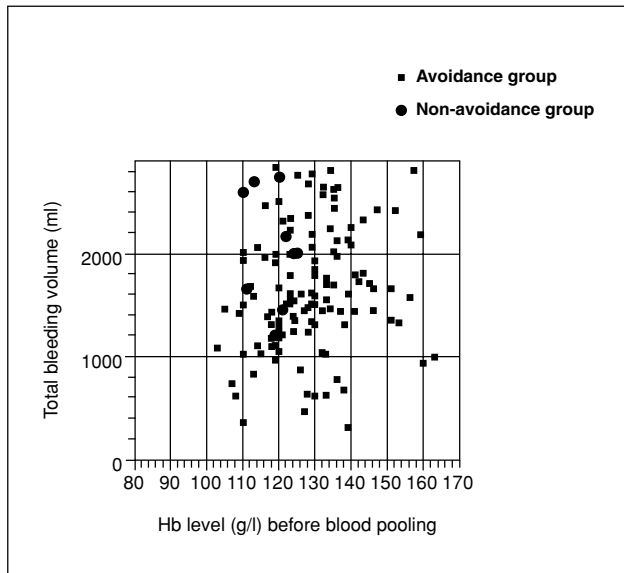
blood collection, 104 g/l immediately before the surgery, and 103 g/l at minimum postoperatively. Autologous blood transfusion with preoperatively pooled blood was suspended during blood collection in 51 (20%) patients. Criteria for suspension included an Hb level of less than 100 g/l, development of the vasovagal reflex, and request of the patients. Suspension was most commonly occurred because of the development of anaemia after blood collection; blood collection was tentatively suspended for 30 (59%) of these patients, whose mean Hb level before the blood collection was 121 (SD, 6.1) g/l. Autologous blood transfusion was suspended because of insufficient volume of collected blood in 13 (25%) cases. And it was suspended because of development of vasovagal reflex in 8 (13%) patients.

Attention should be given to cases in which the vasovagal reflex could become severe. In our study, signs such as declining blood pressure, emotional discomfort, and cold perspiration were observed, but none of the patients showed disturbed consciousness. All patients showed symptomatic improvement with fluid replacement.

**DISCUSSION**

**Problems associated with autologous blood transfusion**

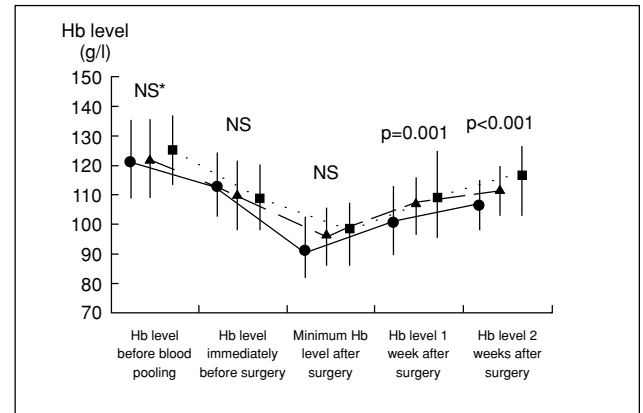
Problems with autologous blood transfusion include restrictions on the indications for the blood pooling system, the pooled blood volume, and preoperative



**Figure 6** Relationships of the haemoglobin (Hb) level before blood pooling and the total bleeding volume with the avoidance of homologous blood transfusion among patients who underwent primary total hip arthroplasty using both blood pooling and intra-operative recovery systems.

anaemia.<sup>6</sup> Preoperative planning and scheduling also become necessary. The vasovagal reflex that is associated with blood collection is frequently due to patient anxiety towards issues such as blood collection, tension, empty stomach, and strain. These causative factors must always be borne in mind by physicians and patients.

As for the recovery system, detection of bacteria from the ambient air (atmospheric bacteria) in the recovered blood has been reported.<sup>7,8</sup> Thus, the possibility of infection cannot be excluded when the recovery system is used. At our institution, no case of sepsis has been recorded following prosthetic surgery. As for the detection of atmospheric bacteria, we believe that the perioperative administration of antibiotics needs not be a cause for great concern because such bacterial contamination involves mainly attenuated indigenous bacteria, and reports have shown that these atmospheric bacteria can be countered by usual antibiotics.<sup>1</sup> The non-wash type of recovery system could be easily used, and thus no expensive concentration wash-type system is required. The plasma component is not lost with the use of the non-wash type, unlike when the wash-type is used, but components other than red blood cells, such as floating fats and free Hb, also stay on during the use of the non-wash recovery type. In THA, materials such as bone fragments, cement, and metal pieces become



\* NS not significant

**Figure 7** Change in haemoglobin (Hb) level in patients who used a combination of blood pooling and intra-operative recovery systems (Kruskal-Wallis test).

mixed into the blood in the operative field. A filter for blood transfusion is used for the non-wash recovery type as well, but wash-type recovery is preferred from the aspect of safety. Mixing of foreign objects into the blood can be efficiently avoided with the use of the wash-type recovery.<sup>1</sup> At our institution, intra-operative autologous blood transfusion is, as a rule, not used for patients undergoing revision THA who have metallosis. In our early experience of using this autologous blood transfusion technique, metal pieces were sometimes observed in the return blood in patients.

### Starting homologous blood transfusion

Initiation of blood transfusion when the serum Hb level is 100 g/l and haematocrit level is 30%—the so-called 10–30 theory, which had been adopted without any evidence—is no longer valid. Rather, the timing for starting blood transfusion is reassessed with the avoidance of homologous blood transfusion keeping in mind. At our institution, the criteria for determining the start time of homologous blood transfusion during surgery in cases of OA include a serum Hb level of less than 80 g/l in patients older than 70 years, and a level of less than 70 g/l in younger patients. Blood pressure, pulse, and preoperative Hb level are also assessed for reference. Wakimoto et al.<sup>5</sup> have concluded that blood transfusion is unnecessary, even in elderly patients with an Hb level of 80 g/l or more, and in younger or adult patients with an Hb level of 70 g/l or more. Adequate assessment and delay of the start time of homologous blood transfusion can lead to the avoidance of complications.

### Expanding the range of indications for blood pooling

The threshold Hb level for preoperative blood pooling at our institution is 100 g/l, but using a cut-off Hb level of 90 g/l has also been debated. It is impossible to avoid the development of anaemia immediately before the surgery because of blood pooling; however, as described by Fuji and Sakurai,<sup>6</sup> the Hb level should, as a rule, be 100 g/l or more.

Some reports have shown the efficacy of erythropoietin, administration of which in cases with preoperative anaemia has been shown to decrease the incidence of anaemia after blood collection and increase the Hb level after blood pooling.<sup>4,9</sup> Steroids have also been reported to be effective in reducing anaemia and increasing the Hb level in patients with RA.<sup>10</sup> Such innovative strategies should be vigorously pursued in treating anaemia in patients undergoing THA.

The use of erythropoietin is recommended when autologous blood is pooled; the pooled blood volume should be at least 800 ml, and the interval between blood pooling should be scheduled at least one week apart. Subcutaneous infusion of erythropoietin (24 000 U per dose), which has been approved before blood pooling, is administered at our institution. Because the effects of erythropoietin become more prominent in the presence of iron, iron salts is administered together with erythropoietin. The serum levels of iron and ferritin are regularly monitored to avoid the Hb level exceeding 140 g/l. Following erythropoietin administration, platelet aggregation and blood viscosity may increase.<sup>11</sup> These changes—in addition to excessive elevation of the Hb level—may result in thrombo-embolic complications.<sup>3</sup> However, in a study of ascending venography of the affected extremities in 104 surgically treated joints within a month of the surgery, the post-THA incidence of deep vein thrombosis was not increased with the use of erythropoietin.<sup>1</sup> The influence of erythropoietin on the coagulation-fibrinolytic systems and on haemangio-endothelial cells has also been ruled out by multi-institutional joint studies.<sup>2</sup>

### Disposal of autologous blood

In Japan, autologous blood that is not used should be disposed of according to the guidelines established by Japanese Ministry of Public Health and Welfare. At our institution, autologous blood is disposed of to prevent thrombo-embolic complications owing to elevated blood viscosity in the following cases: an Hb

level of 150 g/l or higher,<sup>5</sup> or an Hb level exceeding the preoperative value.

In recent years, problems associated with the disposal of autologous blood have come to light, and the procedure's cost-effectiveness has been questioned.<sup>5,6,12-18</sup> Popovsky,<sup>16</sup> in particular, highlighted that about 40% to 99% of pooled blood is currently discarded. Renner et al.<sup>19</sup> surveyed 612 facilities and found that 38% of autologous blood was discarded. Etchason et al.<sup>13</sup> indicated that the ratio of cost-benefit to safety of autologous blood pooling is not necessarily favourable, even when the current risks associated with homologous blood transfusion are considered—for example, the rate of transmission of human immunodeficiency virus (1 in 225 000) and hepatitis C virus (1 in 3000). Hence, the indications for blood pooling and the pooled blood volume should be reconsidered, and the standards for autotransfusion should be reassessed.

The main reason for the disposal of pooled blood is that the intra-operative bleeding volume is lower than predicted. To resolve the problem, it is important for each facility to establish a maximum surgical blood order schedule and to obey the restrictions it imposes. In this regard, Axelrod et al.<sup>20</sup> advocated that a "schedule of optimal preoperative collection of autologous blood" should be established for autologous blood pooling at each facility, and that autologous blood should be pooled only according to this schedule.

At our institution, all cases of blood disposal were due to the low volume of haemorrhage in patients undergoing replacement of the PE liner alone. The bleeding volume is significantly lower in cases of PE liner replacement than in cases of total hip replacement. Regardless of whichever procedures, 800 ml to 1200 ml of autologous blood is usually pooled and prepared preoperatively in case of the potential necessity of total replacement. Under such circumstances, the disposal of autologous blood is relatively high. To minimise the incidence of autologous blood disposal, the preoperative diagnostic imaging findings and indications for surgical procedures should be precisely assessed and considered before the volume of blood pooling is determined.

### CONCLUSION

Of the 253 patients underwent THA with autologous blood transfusion, the rate of avoidance of homologous blood transfusion was 95%. Autologous blood transfusion by using both of blood pooling and intra-operative recovery systems can avoid homologous

blood transfusion in most cases. In addition, to avoid transmission of infections and immunological side-effects associated with homologous blood transfusion, we recommend that the range of indications for blood pooling be expanded; anaemic condition of patients before blood collection be improved; the starting time of homologous blood transfusion be delayed, and the volume of transfusion be reduced. Attention should also be paid to problems concerned with the disposal of autologous blood, and the appropriate

volume of blood to be pooled should be carefully assessed as well.

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