We have assessed the effect of the donation of autologous blood and the preoperative level of haemoglobin on the prevalence of postoperative thromboembolism in 2043 patients who had a total hip arthroplasty. The level of haemoglobin was determined seven to ten days before surgery and all patients had venography of the operated leg on the fifth postoperative day. The number of patients who had donated autologous blood (1037) was similar to that who had not (1006).

A significant decrease in the incidence of deep-vein thrombosis (DVT) was noted in those who had donated blood preoperatively (9.0%) compared with those who had not (13.5%) (p = 0.003). For all patients, the lower the preoperative level of haemoglobin the less likely it was that a postoperative DVT would develop.

Of those who had donated blood, 0.3% developed a postoperative pulmonary embolism compared with 0.7% in those who had not, but this difference was not statistically significant. No significant difference was found in the requirements for transfusion between the two groups.

Numerous studies have reported the incidence of thromboembolism after total hip arthroplasty (THA).\(^1\)\(^-\)\(^10\) It is a common and potentially fatal complication of the operation and since THA is an elective procedure, effective prophylaxis is essential. Many strategies have been studied, including anticoagulation, the use of mechanical pneumatic compression devices, hypotensive epidural anaesthesia, and early mobilisation.\(^4\)\(^-\)\(^9\),\(^11\)\(^-\)\(^18\) in attempts to decrease the incidence of deep-vein thrombosis (DVT) and potentially fatal pulmonary embolism (PE).

Recently, Anders et al.\(^1\) described a decreased incidence of DVT in patients who had donated autologous blood before total knee arthroplasty compared with those who had not. They were unable, however, to show such a correlation in THA because of the small sample size of only 166 patients.

In this study, using postoperative venography, we have evaluated the effect of autologous blood donation on the incidence of DVT and PE in 2043 patients who had undergone THA.

**Patients and Methods**

Between January 1990 and December 1993 we reviewed 2043 patients after THA. There were 1112 women and 931 men. Of these, 1037 had participated in preoperative autologous blood donation and the remaining 1006 had not. Patients did not donate blood for medical or religious reasons and because of logistics, since the blood donation centre was located in an urban area which was not always accessible to patients living outside the city. Donations of blood were given at seven- to ten-day intervals with the last being a week before surgery. All procedures were performed under hypotensive epidural anaesthesia. We excluded patients with a past history of DVT, rheumatoid disease, psoriasis, septic arthritis, and those having bilateral procedures.

Approximately 95% of patients donated two units of autologous blood and the remaining 5% one or three units. Iron-replacement therapy, consisting of 325 mg of ferrous sulphate administered orally twice daily, was introduced before the first donation. All patients received postoperative prophylaxis against DVT with compression stockings, early mobilisation and aspirin (325 mg twice daily for six weeks), and all had ascending venography on the fifth postoperative day.

The age, gender, preoperative level of haemoglobin, preoperative blood donation, postoperative blood transfusion, and the results of venography were obtained from the medical records.
The preoperative level of haemoglobin was obtained seven to ten days before surgery. The clinical diagnosis of pulmonary embolism was confirmed using ventilation perfusion scanning.

An epidemiologist performed the statistical analysis using IBM SPSS/PC software (SPSS, Chicago, Illinois). Chi-squared tests were used to test the significance of blood donation on the incidence of DVT between the two groups, and logistic regression and multivariate analysis to correlate the level of haemoglobin and age with the incidence of DVT. The Mantel-Haenszel Inference test was carried out to determine the significance of the preoperative level of haemoglobin on the incidence of DVT for each group.

**Results**

DVT was found in 93 of the 1037 patients (9.0%) who had donated blood compared with 136 of the 1006 (13.5%) who had not. This difference was significant (chi-squared test, \( p = 0.003 \); 95% confidence interval (CI) -0.18 to -0.05). The unadjusted odds ratio associated with autologous blood donation was 0.63 (95% CI 0.48 to 0.83). In the group who donated blood there were 572 women and 465 men while the non-donation group consisted of 540 women and 466 men. There was therefore no statistically significant difference in gender (\( p = 0.2 \)). The mean preoperative level of haemoglobin in the patients was similar in both groups, 12.7 mg/dl in those who donated blood compared with 12.9 mg/dl in those who did not (\( p = 0.03 \)). The mean age of patients who donated blood (63.2 years) was slightly less than that of those who did not (66.4 years) (\( p < 0.001 \)). The differences in the mean level of haemoglobin and mean age did not correlate significantly with the difference in incidence of DVT between the groups by logistic regression analysis. Within the blood donation group, the common odds ratio among the three levels of haemoglobin was 0.70 (95% CI 0.53 to 0.92). Using the Mantel-Haenszel Inference test, a significant correlation was observed for the two groups between the increasing level of haemoglobin and increasing incidence of DVT (Table I).

A difference in the incidence of PE was observed between the groups. In those who donated blood, only three patients (0.3%) had a PE compared with seven (0.7%) in those who did not. This difference was not significant as the odds ratio of 0.41 (95% CI 0.07 to 1.8) confirms.

The postoperative requirements for transfusion were also assessed for each group. There was no significant correlation between transfusion requirements and the incidence of DVT (\( p = 0.08 \); Table II). The common odds ratio between the two groups of patients and the three levels of transfusion required was 0.63 (95% CI 0.48 to 0.83).

**Discussion**

Total joint arthroplasty is a potent stimulator of thromboembolic disease and much research has been devoted to lowering the risk of the potentially fatal complications of DVT and PE, using methods such as mechanical compression and anticoagulation.\(^{19,20}\) Most studies concerning the aetiology of DVT validate Virchow’s original hypothesis that a triad of factors is responsible for thrombosis: hypercoagulability of blood, interference in its flow, and changes in the vessel wall.\(^{21}\) Surgical trauma activates clotting and tissue factors, occlusion of the femoral vein may occur during dislocation and intraoperative manipulation may damage the vessel wall.

We have identified two elements which significantly lower the incidence of DVT. Preoperative blood donation reduced the incidence of postoperative DVT from 13.5% to 9.0% and a lower preoperative level of haemoglobin was associated with a lower incidence of DVT. To our knowledge, this is the first study to demonstrate this. Anders et al.\(^1\) showed a significant correlation between autologous blood donation and the incidence of DVT in patients undergoing total knee arthroplasty, but were unable to suggest the same for THA. Their study consisted of 166

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### Table I. The incidence of DVT (%; number) in the patients who donated blood and those who did not compared with the level of haemoglobin (mg/dl)

<table>
<thead>
<tr>
<th>Haemoglobin level</th>
<th>Donated blood</th>
<th>Did not donate blood</th>
<th>Odds ratio (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;12.0</td>
<td>8.0 (28/350)</td>
<td>9.2 (28/303)</td>
<td>0.85 (0.49 to 1.5)</td>
</tr>
<tr>
<td>12.0 to 14.0</td>
<td>9.0 (41/458)</td>
<td>13.9 (62/446)</td>
<td>0.61 (0.40 to 0.93)</td>
</tr>
<tr>
<td>&gt;14.0</td>
<td>10.5 (24/229)</td>
<td>17.9 (46/257)</td>
<td>0.54 (0.32 to 0.91)</td>
</tr>
</tbody>
</table>

### Table II. The incidence of DVT (number; %) in those who donated blood and those who did not compared with the transfusion requirements

<table>
<thead>
<tr>
<th>Transfusion requirements (units)</th>
<th>Donated blood</th>
<th>Did not donate blood</th>
<th>Odds ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>DVT rate</td>
<td>Mean preop Hb level (mg/dl)</td>
</tr>
<tr>
<td>0</td>
<td>318</td>
<td>26 (8.2)</td>
<td>13.4 ± 1.4</td>
</tr>
<tr>
<td>1</td>
<td>444</td>
<td>42 (9.5)</td>
<td>12.6 ± 1.4</td>
</tr>
<tr>
<td>2 or more</td>
<td>267</td>
<td>25 (9.4)</td>
<td>12.0 ± 1.4</td>
</tr>
</tbody>
</table>
patients who had had THA and who were all male veterans. Although a greater number of risk factors was analysed, the size of the sample was too small and varied for a statistical conclusion to be reached. The veteran population is not representative of the general public and is not a good group for comparison.

We believe that our study is generally more applicable. By investigating a large group of patients, consisting of both men and women, we attempted to equalise the potential risk factors between our two groups. Many variables, including the presence of varicose veins, cardiac disease, hypertension, obesity, previous cerebrovascular disease, and a history of smoking were not analysed. Anders et al found no correlation between these secondary risk factors and the incidence of DVT.

Since this is a retrospective study, randomisation of the patients for the donation of autologous blood did not occur and there may have been some selection bias. In theory, patients who were unable to donate autologous blood may have been at greater risk of developing thromboembolic disease. There were, however, other reasons besides health which prevented the donation. Those with a history of thromboembolism were excluded and each patient underwent surgery with hypotensive epidural anaesthesia. Westrich et al examined hypotensive epidural anaesthesia in relation to the incidence of DVT after THA and found that this lowered the incidence of thrombosis.

The correlation between decreased levels of haemoglobin and a lower incidence of DVT supports Virchow’s belief that blood viscosity, and therefore blood flow, was primarily dependent on the level of haemoglobin. Patients with a low level of haemoglobin have a decreased blood viscosity which may correlate with a lower incidence of DVT. Several other studies have a also supported the use of haemodilution as a means of prophylaxis against DVT.

Pearson demonstrated that in patients with polycythaemia vera a high packed red cell volume reduced the plasmatic zone at the vessel wall in which platelets were dispersed, and increased the platelet-platelet contact as well as interaction between the platelets and the vessel wall. These factors increase the likelihood of the formation of thrombi. Gudmandsson and Bjelle studied the viscosity of the blood in patients with rheumatoid arthritis and found an increase in plasma viscosity when compared with a normal control group. The concept that removal of plasma and proteins may decrease the incidence of thrombosis was, however, refuted by Mansouri et al. In normal donors who had undergone plasmapheresis, there was improvement in the viscosity but it was only beneficial if carried out within 24 hours of surgery.

In rabbits rendered thrombocytopenic, Blajchman et al demonstrated an increased bleeding time as the hematocrit decreased and Anand and Feffer noted the same in anaemic patients, independent of their platelet count. They theorised that an increase in circulating red blood cell mass increased the radial movement of platelets and their interaction with endothelium. By contrast, Cadroy and Hanson demonstrated in primates that changes in haematocrit did not affect the formation of thrombi, since a low flow was associated with a high rate of thrombosis. Haemodilution and a reduced haematocrit are well known to inhibit haemostasis. While the donation of 500 ml of whole blood decreases the circulating haemoglobin mass, the intravascular volume is replaced within 24 hours or less. For seven to ten days after donation there will be less oxygen-carrying capacity, since approximately 10% of the total red blood cells have been removed. The heart rate will rise as will the rate of flow. An additional mechanism which reduces blood viscosity is a reduction in body temperature, noted by Valeri et al to prolong the bleeding time.

In our study the mechanism by which blood donation protects patients from postoperative DVT is unclear. The slight difference in the preoperative level of haemoglobin (0.2 mg/dl) between the two groups cannot explain the marked difference in the incidence of DVT. The protective effect may not be due to the depletion of red cells and haemodilution, but to the decrease in blood proteins responsible for thrombogenesis, although Anders et al found no effect of blood donation on the preoperative prothrombin time or platelet count. The answer may be found in proteins such as fibrinogen degradation products, antithrombin III, and tissue plasminogen activators, all of which play an important role in both thrombogenesis and thrombolysis. No study has analysed these potent proteins in relation to blood donation.

In our study the number of units of autologous blood given postoperatively did not correlate with the prevalence of DVT. A lower preoperative haemoglobin was associated with a lower incidence of DVT. This also applied to those who did not donate autologous blood.

We have shown that there is an additional mechanism which counters DVT in patients undergoing THA. Not only does autologous blood donation decrease the need for homologous blood transfusion, it also lowers the preoperative level of haemoglobin which correlates with a lower incidence of DVT. The odds ratio in Table I suggests that as the preoperative level of haemoglobin increases the preoperative donation of blood succeeds in reducing DVT. Patients who did not donate blood preoperatively, and had a preoperative level of haemoglobin greater than 14 mg/dl, had the highest incidence of DVT at 17.9% (46/257) (Table I). Patients who fit this profile may need more attention to prophylaxis.

There is a correlation between DVT and the likelihood of subsequent PE. Proximal thrombosis (femoral or popliteal) may pose the greatest risk of embolisation. The frequency of symptomatic PE after total joint arthroplasty with prophylaxis ranges from 1.7 to 3.4%. Our study shows a strong association between a lower incidence of DVT and a lower incidence of symptomatic PE in those donating autologous blood. Unfortunately, the sample size was small.
and did not reach statistical significance, but it appears that preoperative donation of blood may help to avoid a potentially fatal PE.

Preoperative autologous blood donation is a simple and safe approach to prophylaxis for DVT. The cost-effectiveness has yet to be assessed.

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References


