VENOUS HAEMODYNAMICS IN BOTH LEGS AFTER TOTAL KNEE REPLACEMENT

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We studied the effect of total knee replacement on venous flow in 110 patients. Resting venous blood flow was measured using strain-gauge plethysmography before operation, after surgery and after discharge from hospital. There was a significant reduction in mean venous capacitance ($p < 0.001$) and mean venous outflow ($p < 0.004$) affecting only the operated leg. Both improved significantly after mobilisation in the early postoperative period, returning to preoperative levels by six days after surgery and before discharge from hospital.

Our findings showed that venous stasis may contribute to deep-vein thrombosis only in the first few days after total knee replacement. This would be the most important period for the use of flow-enhancing prophylactic devices.

Comparison with changes in blood flow after total hip replacement identified different patterns of altered haemodynamics suggesting that there are different mechanisms of venous stasis and thrombogenesis in hip and knee arthritis and during surgery for these conditions.

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Deep-vein thrombosis (DVT) is a serious complication of major surgery, and is well recognised in joint replacement. Initially, its incidence in total knee replacement (TKR) was thought to be low, but more recently it has been reported to be between 25% and 80%. Proximal venous thrombi are uncommon after TKR whereas in total hip replacement many of the thrombi are in the thigh and there is a higher incidence of symptomatic pulmonary embolism. The serious nature of these complications, however, probably warrants prophylaxis in TKR. A recent study of the use of prophylactic agents has shown that DVT after TKR is less preventable by standard anticoagulant agents than that after total hip replacement. This may reflect a different mechanism of thrombogenesis after these two procedures.

The role of altered blood flow in the initiation and propagation of DVT has been studied in general surgical procedures, and recently we showed that reduced venous flow in the legs was a major factor in deep venous thrombogenesis after total hip replacement.

There have been no reported studies on blood flow after TKR, but the use of external pneumatic compression has shown that flow enhancement does prevent DVT. This suggests that venous stasis may be an important factor in thrombosis after TKR.

Our aim was to determine the effect of TKR on the venous haemodynamics in both legs in the first few weeks after operation. The measurement technique was similar to that used in our previous study on total hip replacement, and allows a comparison between these two procedures.

PATIENTS AND METHODS
We studied 110 consecutive patients who had had unilateral TKR in which a cemented Insall-Burstein II prosthesis (Zimmer Inc, Warsaw, Indiana) had been implanted through a midline approach. There were 36 men and 74 women with a mean age of 69 years (37 to 84). Spinal anaesthesia was used in 77 patients, general anaesthesia in 14 and both general and spinal in 19. DVT prophylaxis was provided with intravenous Dextran 70 (Pharmacia, Milton Keynes, UK) during the operation and for two days after surgery. Postoperative mobilisation included sitting out of bed on the second postoperative day, standing non-weight-bearing on the third or fourth day and walking with partial weight-bearing on the fourth or fifth day.

Two parameters of venous function were measured in...
both legs by venous occlusion strain-gauge plethysmography before operation, on postoperative days 4, 6 and 8 and at a review clinic 6 to 7 weeks after discharge. The venous capacitance (Vc) gave a measure of the ability of the venous volume to expand during proximal occlusion and was assessed as the maximum percentage change in calf volume during a two-minute period of venous occlusion; this provided an indication of arterial filling and the presence of venoconstriction or dilatation. The venous outflow (Vo) was determined by the method of Cramer et al as the volume of blood flowing between 0.5 and 2.0 seconds after release of the occlusion, expressed in ml/100 ml of tissue/minute. Plethysmography was performed as previously described. All bandages were removed from the leg before measurement of blood flow since these have been shown to affect venous blood flow. A simple adhesive dressing (Meepore) was left covering the wound. This was well above the maximum circumference of the calf where the strain gauge was applied.

Statistical analysis used the two-tailed paired t-test. Values of p < 0.05 were regarded as significant.

RESULTS

All 110 patients were assessed during their hospital stay. There were no complications in the 528 bilateral recordings and no deaths in the study period. Unilateral swelling of the leg and calf pain were common in the first postoperative days, and necessitated ascending venography in five patients. All venograms were reported as normal and no patient was investigated for or had pulmonary embolism. Of the 110 patients, 98 (89%) were able to attend the review clinic at a mean of 48 days (42 to 52).

Preoperatively, there was no difference in either Vc or Vo between the two legs (Vc p > 0.75; Vo p > 0.55). After TKR, there was a fall in both legs which was maximal at the fourth postoperative day, but was statistically significant only in the operated leg (operated leg: Vc p < 0.001, Vo p < 0.004; non-operated leg: Vc p > 0.45, Vo p > 0.15) (Figs 1 and 2). There was no significant difference between the legs after surgery other than at day 4 (Vc p > 0.05; Vo < 0.035). After day 4 Vc and Vo increased in both legs until the completion of the study period. By day 6 there was no statistical difference from the preoperative levels in either leg (operated leg: Vc p > 0.65, Vo p > 0.59; non-operated leg: Vc p > 0.42, Vo p > 0.18).

The percentage reduction in mean blood flow after surgery was calculated from the preoperative levels and the measured flow at day 4. In the operated legs, the mean Vc fell by 26% (3.23 to 2.56) and the mean Vo by 19.4% (48.8 to 40.87 ml/100 ml/min). In the non-operated legs, the percentage reduction in flow was small; the mean Vc fell by 8.2% (3.31 to 3.06) and the mean Vo by 10.8% (51.46 to 45.89 ml/100 ml/min). By day six, only seven patients had a Vc or Vo more than 10% below the preoperative value (maximum 13%).

At review of 98 patients six to seven weeks after operation, the mean values of Vc and Vo in both legs had returned to preoperative levels (operated leg: Vc p > 0.7, Vo p > 0.78; non-operated leg: Vc p > 0.61, Vo p > 0.37). In the operated legs the values were in fact slightly greater than the preoperative levels. The mean changes in venous haemodynamics with 95% confidence intervals are given in Table I.

DISCUSSION

Venous stasis as a causative factor in DVT has been proposed by many workers. We studied venous haemodynamics in total hip replacement and reported a significant reduction in both Vc and Vo in both legs, which was much greater in the operated leg. Venous flow remained significantly below preoperative levels in the operated leg six weeks after surgery. Furthermore, there
was a highly significant correlation between the degree of reduction in blood flow and the development of post-operative DVT confirmed by venography.\(^9\)

In this study the fall in Vc and Vo after TKR was significant only in the operated leg. The non-operated leg had a small and short-lived disturbance of venous flow after surgery. These findings may be due to a general effect of immobility, surgery or anaesthesia affecting both legs and compounded by the surgical trauma in the operated leg. As soon as the patient started actively to mobilise, there was a rapid improvement in the Vc and Vo in both legs. By day 6, the values for both had returned to preoperative levels. This contrasts with the significant disturbances of both Vc and Vo several weeks after total hip replacement (Figs 3 and 4). Maynard, Sculco and Ghello\(^28\) have shown that in patients with TKR who developed DVT, it occurred within 24 hours of surgery in 86%; this supports the concept of the initiation of thrombosis early after surgery in the operated leg.\(^28\)

We found no difference in the venous haemodynamics between the operated and non-operated legs before TKR. Before total hip replacement the arthritic limb was found to be significantly different, suggesting that arthritic disease or limb dysfunction caused by hip arthritis alters venous physiology. In arthritis of the knee, it may be that the diseased joint affects the function of both legs equally or may have little effect on venous blood flow before surgery.

Stoodley and Sikorski\(^29\) have studied the effects of hip and knee arthritis on gait and mobility. They concluded that hip disease significantly affected walking speed, endurance, step length and the metabolic cost of walking, but that knee arthritis, although it altered the normal pattern compared with a control group, had much less effect. This may indicate that knee arthritis does not have such a profound affect on normal muscle pump function and hence venous blood flow. Further study is necessary to identify the optimal methods of mobilisation of patients after hip and knee replacement.

Several studies\(^11,20,21,23,30-33\) have advocated the prevention of venous thromboembolism by flow enhancement. The use of intermittent pneumatic compression devices is established and in prospective, randomised trials they have been shown to be effective in the prevention of DVT after TKR. The A-V Impulse System has also been evaluated in small studies and has been shown to reduce the incidence of thrombi after total hip replacement.\(^32,34\) Like intermittent pneumatic compression, however, it was less beneficial after knee surgery in which there is less effect on incidence and a more qualitative benefit in terms of the extent of the thrombosis.\(^8,30\) Our findings suggest that the contribution of venous stasis to DVT in TKR is limited to the first few days

\[\text{Table I. Mean changes in venous capacitance (Vc;\%)}\text{ and venous outflow (Vo; ml/100 ml tissue/minute) in both legs of 98 patients}\]

<table>
<thead>
<tr>
<th>Days</th>
<th>Vc Change in Vc</th>
<th>95% CI</th>
<th>Vo Change in Vo</th>
<th>95% CI</th>
<th>Vc Change in Vc</th>
<th>95% CI</th>
<th>Vo Change in Vo</th>
<th>95% CI</th>
</tr>
</thead>
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<tr>
<td>0</td>
<td>3.23</td>
<td>-</td>
<td>48.79</td>
<td>-</td>
<td>3.31</td>
<td>-</td>
<td>51.46</td>
<td>-</td>
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<td>2.56</td>
<td>-0.67*</td>
<td>40.87</td>
<td>-7.85†</td>
<td>3.06</td>
<td>-0.26</td>
<td>45.89</td>
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<td>+0.13</td>
<td>47.22</td>
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<td>+0.32</td>
<td>45.58</td>
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</tr>
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<td>3.15</td>
<td>-0.19</td>
<td>47.81</td>
<td>-4.88</td>
</tr>
</tbody>
</table>

\(^* p < 0.001\)
\(^† p < 0.004\)
after surgery. This would be the most important time to use flow-enhancing pumps and compression devices.

There is a much shorter period of altered venous hemodynamics after TKR than after total hip replacement. The pattern of thrombosis is also very different between the two types of arthroplasty. Proximal thrombi and profound venous stasis are associated with hip surgery while isolated calf thrombi are the usual sequelae of knee surgery. This may indicate a different mechanism of thrombogenesis, minor thrombi forming in small-calibre calf veins during transient stasis immediately after surgery, and proximal thrombi in larger thigh veins only with stasis of a greater degree or longer duration.

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REFERENCES


