TOTAL HIP REPLACEMENT, LOWER LIMB BLOOD FLOW AND VENOUS THROMBOGENESIS

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The effect of Charnley cemented total hip replacement on venous blood flow in the legs and its relationship to deep-vein thrombosis were investigated in 413 patients. Blood flow was measured using strain-gauge plethysmography before operation, after surgery, and after discharge from hospital. There was a significant reduction in both venous capacitance and venous outflow, affecting both legs but greater in the operated leg. Venous flow remained significantly below preoperative levels in the operated leg six weeks after surgery.

There was a highly significant correlation between the degree of reduction in blood flow and the development of postoperative deep-vein thrombosis. Venous stasis was shown to be a major factor in venous thrombogenesis.

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Deep-vein thrombosis (DVT) is a serious complication of hip surgery. Prophylaxis with low-molecular-weight heparin has not resolved the problem in orthopaedic surgery, and incidences of 25% to 33% have recently been reported after total hip replacement (Eriksson et al 1991; Lassen et al 1991; GHAT 1992), and 30% after hip fracture (Monreal et al 1989; Jørgensen et al 1992). Concern over potential bleeding complications and high cost have restricted the use of this heparin in the UK (Laverick, Croal and Mollan 1991). These factors and the introduction of the A-V Impulse System (Novamedix Ltd, Andover, UK) have generated a renewed interest in the role of venous stasis in the development of DVT.

It is difficult to demonstrate and quantify venous stasis postoperatively. Virchow (1859) identified reduced flow as one of three predisposing factors in the initiation of thrombosis, and Paterson and McLachlin (1954) correlated this 'stasis' with the origin of thrombi found at necropsy. McLachlin et al (1960) and Nicolaides et al (1972) demonstrated stasis venographically in the soleal sinuses and at the apices of venous valve pockets, and recently Kålebo et al (1990) have shown that thrombi occurring after total hip replacement are almost exclusively associated with a sinus or a valve pocket.

The effect of operation on the blood flow of the lower limb has been investigated in a number of ways. The clearance of $^{125}$I hippuran from the leg veins has been shown to be reduced after abdominal surgery (Kemble 1971). Browse (1962a) performed water plethysmography on 45 patients after a wide range of general surgical operations, and showed that arterial inflow was reduced in 75% after surgery. This was confirmed by Bird (1972) who also found increased peripheral resistance after surgery, injury or bed-rest. A functional assessment of the venous system was attempted by Triopolitis et al (1979) using a mercury strain-gauge plethysmograph. Venous capacitance ($V_c$) was shown to decrease in a small number of patients tested on the morning after surgery, but changes in venous outflow ($V_o$) were less definite.

Our study was designed to determine the effect of total hip arthroplasty on venous haemodynamics in both legs in the first few days after operation and at a review clinic, at six weeks. We also studied the association between venous flow and the development of DVT.

PATIENTS AND METHODS

The response of the venous system was assessed in 413 consecutive patients having a primary total hip arthroplasty with a cemented Charnley prosthesis, excluding only those with previous, venographically confirmed DVT. All the operations were performed through a posterior approach; spinal anaesthesia was used in 348 patients, and general anaesthesia in 65. Standard postoperative mobilisation consisted of sitting out of bed on the first postoperative day, standing non-weight-bearing on the first or second day, and walking with partial weight-bearing on the second or third day. All but 49 of the patients were able to achieve this programme, the others were slower to mobilise. The mean age of the patients was 67.5 years (25 to 94).

Two parameters of venous function were measured in both legs, by venous occlusion strain-gauge plethysmography before operation and on postoperative days
3, 5 and 7. The venous capacitance was assessed as the maximum percentage change in calf volume during a two-minute period of venous occlusion: this provides a measure of the ability of the venous volume to expand under simple stress such as exercise. Venous outflow was determined by the method of Cramer et al (1983), as the volume of blood flowing between 0.5 and 2.0 seconds after release of the occlusion, expressed as ml/100 ml of tissue/minute.

All measurements were made with the patients at rest in bed. Both feet were placed in a foot-rest and the maximum circumference of both calves was measured. A broad cuff was placed around each thigh and Indium-Gallium strain gauges (Medasonics, Mountainview, California) were applied to the measured circumferences of the calves. The point of measurement was marked at the first test with an indelible marker, and all subsequent tests were performed with the strain gauges at the same site. The thigh cuff was inflated to 55 mmHg for 120 seconds and the increase in calf volume recorded from the strain gauges. The cuff was then rapidly deflated and the outflow determined.

Venography was performed when symptoms or signs were present, or if non-invasive screening with the Belfast DVT Screener (Advanced Medical Technology Ltd, Coleraine, Northern Ireland) suggested the presence of a clot. A random group of 48 symptomless patients was also selected for venography on the day of discharge.

Statistical analysis used two-tailed, paired t-tests, with unpaired t-tests for comparing patient subgroups. Values of p < 0.05 were regarded as significant.

RESULTS

All 413 patients were examined preoperatively. After one early postoperative death 412 patients were assessed at day 3, 311 at day 5, and 186 at day 7. A total of 281 patients were assessed at a review clinic six weeks after operation.

There were no complications from the total of 3140
plethysmographic recordings. Venography was performed in 76 patients: DVT was confirmed in 15 operated and 5 non-operated legs, with 8 proximal and 12 distal thromboses.

Total hip replacement produced a reduction of mean venous capacitance (Vc) and venous outflow (Vo) (Figs 1 and 2). Both Vc and Vo were significantly lower in the operated than in the non-operated leg, even before operation (p < 0.04 for Vc; p < 0.0002 for Vo). There was a highly significant fall in both parameters in both legs after surgery (operated leg, Vc and Vo p < 0.0002; non-operated leg, Vc and Vo p < 0.0002). This fall was maximal at day 3 for Vo, but for Vc, it continued in the operated leg to a minimum at day 5. The values then increased over the study period.

At review at six weeks, the mean values for Vc and Vo in the operated leg were still significantly below preoperative levels (p < 0.02 and p < 0.05 respectively). In the non-operated leg the mean values for Vc and Vo also remained below preoperative values, but the difference was not significant (p < 0.3 and p < 0.06 respectively). At review, venous function in the operated leg was still significantly different from that of the non-operated leg (Vc, p < 0.002; Vo, p < 0.0002).

The correlation between DVT and venous flow was established by comparing the response in legs with or without thrombosis on venography with that in the whole group. Figures 3 and 4 show that the pattern of reduced flow was seen in all three groups. The patients who developed DVT after surgery had different venous parameters even before operation, with a significantly lower Vc and Vo than operated legs without DVT (Vc, p < 0.009; Vo, p < 0.04). In operated legs without DVT the mean reduction after surgery was by 15.7% for Vc (2.95% to 2.49%) and by 9.0% for Vo (49.43 to 44.95 ml/100 ml/min). In legs which subsequently developed clot, the mean fall in Vc was by 24.8% (2.19% to 1.65%) and in Vo, 35.3% (39.07 to 25.29 ml/100 ml/min). Those with DVT did not recover preoperative levels of Vo by six weeks (p < 0.03).
Not all patients had a fall in Vc or Vo in the first five days after surgery. In a small number (15.3%) there was no change or a moderate rise in both parameters by day five. No patient in this group had evidence of DVT either clinically or venographically.

The effect of either spinal or general anaesthesia was studied but the small number of patients who had general anaesthesia made it impossible to show any significant difference between the groups. Both groups had a similar pattern and similar degree of reduction in venous flow after surgery.

DISCUSSION

Venous stasis has been reported to have a central role in the initiation and propagation of DVT (Nicolaides et al 1972; Thomas 1985). Our study provides the first confirmation of a gross disturbance in lower-limb venous haemodynamics after total hip replacement, although previous smaller studies have established that venous and arterial flow is reduced in the few days after abdominal and vascular surgery (Browse 1962a; Bird 1972; Tripolitis et al 1979). We have also shown that venous flow remains below preoperative levels for several weeks after the operation.

The marked difference in Vc and Vo between operated and non-operated legs before operation was unexpected, but can perhaps be explained by consideration of the activity of the patient before admission. Blood flow to the calf is determined by the metabolic requirements of the muscles and other tissues: Browse (1962b) showed that resting calf blood flow is very constant and that variation is primarily associated with exercise. Venous distensibility and hence a large Vc are necessary only if the blood flow to the limb is regularly increased in response to exercise. Immobility or reduced calf muscle activity due to arthritic pain and stiffness results in a poor venous response to increased blood flow. The lower Vc in operated limbs may reflect the poor function of the calf muscles in a leg with an arthritic hip.

The fall in Vc and Vo after operation was significant in both legs. There would appear to be two mechanisms. First, there is a general, perhaps humoral, response which affects both limbs. Secondly, there is a local response, mainly affecting Vc in the operated limb. The general response causes a reduction in capacitance and outflow up to the third postoperative day. After this the recovery in the non-operated leg suggests that the general effect is less marked. In the operated leg, however, the local effect continues to cause a fall in capacitance until the fifth postoperative day. These changes in venous flow were seen despite a programme of active mobilisation which began on the day after surgery with partial weight-bearing. We found no difference in the pattern of the venous response between those who mobilised normally and the 49 patients who mobilised more slowly.

We showed an association between reduced flow and subsequent thrombosis. The fall in Vc and Vo was much larger in those legs which developed DVT. They had shown significantly lower Vc and Vo values preoperatively, suggesting that they were in a high-risk state before surgery. In these patients, further disturbance of venous haemodynamics after operation may have provided the conditions for thrombogenesis. Correlation between disturbed preoperative and postoperative coagulation and fibrinolytic markers and DVT has been difficult to establish (Aberg, Nilsson and Hedner 1973; Gunn 1979; Reilly, Burden and Fossard 1980; Layer and Burnand 1985; Paramo, Alfarro and Rocha 1985). Our study provides a correlation between low Vc and Vo and postoperative thrombosis. Of the 15.3% of patients who had no postoperative fall in Vc or Vo none developed a thrombosis during the study period.

The persistence of low venous flow after discharge from hospital was much greater than expected: operated limbs had not regained preoperative levels after six weeks, even though these preoperative levels were lower than those for the non-operated side. It seems that initially the effects of arthritis and then those of total hip replacement cause a profound alteration in venous physiology which lasts for many weeks or months. We are now assessing this series of patients at three months after surgery, to determine when the operated leg recovers and achieves values similar to those of the non-operated leg.

Our findings suggest that the ‘at-risk’ period for the development of thrombosis is at least six weeks in many patients. Tremaine, Choroszy and Menking (1991) have shown that DVT can occur after discharge from hospital after total hip replacement. In our series, five asymptomatic thromboses were diagnosed at six weeks in patients who had been screened non-invasively up to the time of discharge, and had no clinical or objective evidence of thrombosis at that time.

Browse (1962a) and Bird (1972) found that surgery caused a reduction in the arterial supply to both legs, together with an increase in peripheral resistance. Combining this with the results of our study, a mechanism of active vasoconstriction affecting both the muscular arterioles and the deep veins is suggested.

Recent reports of the prophylactic efficacy of a simple system based on sequential emptying of the foot venous plexus are encouraging (Fordyce and Ling 1992; Stranks et al 1992). The reduction in DVT as a result of the increased venous flow produced by this device supports the role of stasis as a major factor in venous thrombogenesis after hip surgery.

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