PROCEEDINGS OF THE SEVENTH BIOMECHANICS SEMINAR

1993

Editor: Christian Högfors
Gunnar Andréasson

CENTRE FOR BIOMECHANICS
Chalmers University of Technology
and
Gothenburg University

Biomech. Sem. vol 7, (1993) ISSN 1100-2247

The Effect of Total Hip Replacement on Lower Limb Blood Flow

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ABSTRACT

Total hip replacement is a widely performed and highly successful operation. It is however often complicated by the occurrence of thrombosis (blood clot) within the veins of the leg. This is a serious complication accounting for the death of 0.5-1.0% of patients and causing later disability in others. It has been postulated that reduction in blood flow during and after surgery is a major cause of these thrombi but this situation of 'venous stasis' has not been demonstrated objectively. This study was designed to explore the effect of total hip replacement on venous haemodynamics.

Venous blood flow in the lower limbs was investigated using a new computerised plethysmograph (The Belfast DVT Screener). An Indium-Gallium liquid metal strain gauge was used to monitor the changes in calf volume during and after a two minute period of venous occlusion using a pneumatic thigh cuff inflated to 55mmHg. The venous capacitance (%) was calculated from the fractional change in calf girth and the venous outflow (ml/100ml/min) by measurement of the rate of emptying between 0.5 and 2.0 seconds after rapid cuff deflation. Software was produced to execute the test and present calibrated quantification of blood flow.

Four hundred and thirteen patients were screened before total hip replacement, on days three, five and seven after surgery and at at a six week review.

A significant reduction in both venous capacitance (Vc) and venous outflow (Vo) occured in both legs after surgery, particularly affecting the operated leg ($p<0.0002$). Vc and Vo remained below the preoperative level in the operated leg at six week review ($p<0.02$ and $p<0.05$ respectively).

There was also a significant correlation between the degree of reduced blood flow and the development of thrombosis in the deep venous system after total hip replacement in this series of patients. This would suggest that measures employed to improve blood flow may reduce the incidence of postoperative deep venous thrombosis.

INTRODUCTION

Deep vein thrombosis remains a serious complication after hip surgery. Anticoagulant prophylaxis with low-molecular-weight heparin has not resolved the problem in orthopaedic surgery. Incidences of 25-33% have recently been reported in total hip replacement (Lassen, Borris and Christiansen 1991, Eriksson et al 1991, GHAT 1992), and 30% in hip fracture (Monreal et al 1989, Jørgensen et al 1992). Concern over potential bleeding complications and high cost, has restricted widespread use of these agents in the UK (Laverick, Croal and Mollan 1991). These factors and the introduction of the A-V impulse system (Novamedix, Andover, UK) have generated a renewed interest in the role of venous stasis in the development of deep vein thrombosis.

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

The effect of operation on lower limb blood flow has been investigated in a number of ways. The clearance of ^{125}I hippuran from the leg veins was shown to be reduced after abdominal surgery by Harvey-Kemble (1971). Browse (1962a) performed water plethysmography on 45 patients undergoing a wide range of general surgical operations, and showed that arterial inflow was reduced in 75% of patients after surgery. This finding 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 Tripolitis et al (1979) using a mercury strain gauge plethysmograph. Venous capacitance was shown to decrease in a small number of patients tested on the morning after surgery. Changes in venous outflow were less conclusive.

This study was designed to determine the effect of total hip arthroplasty on venous haemodynamics in both legs. The effect was followed after discharge from hospital, to a review clinic at six weeks. The association between venous flow and development of deep vein thrombosis was also investigated.

PATIENTS AND METHODS

The response of the venous system was assessed in 413 patients undergoing primary total hip arthroplasty with a cemented Charnley prosthesis. Only those with previous venographically confirmed deep vein thrombosis were excluded. All operations were performed using the posterior approach to the hip. Spinal anaesthetic was employed in 348 patients, and a general anaesthetic in 65. All patients followed similar early postoperative mobilisation. This consisted of sitting out on the first postoperative day, standing non-weight bearing on the first or second day and partial weight bearing walking on the second or third day. All but 49 of the patients were able to mobilise in this way. The mean age of the series was 67.5 years (range 25-94). The presence of deep vein thrombosis was confirmed with venography when symptoms or signs were present, or if non-invasive screening with The Belfast DVT Screener (Advanced Medical Technology Ltd, UK) suggested the presence of a clot. A group of patients were also selected at random for venography.

Two parameters of venous function were measured using venous occlusion strain gauge plethysmography. The venous capacitance (Vc) was assessed as the percentage change in calf volume during a two minute period of venous occlusion. Venous capacitance is a measure of the ability of the venous volume to expand under a simple stress as occurs during exercise. Venous outflow (Vo) was determined by the method of Cramer (1983). This represents an actual volume of blood flowing between 0.5 and 2.0 seconds after release of the occlusion. It is expressed as ml/100ml of tissue/minute. Vc and Vo were measured in both legs, preoperatively, at day 3, day 5, and day 7 after surgery. Four hundred and thirteen patients were examined preoperatively. After one early postoperative death 412 were assessed at day 3 with 311 at day 5 and 186 at day 7. Two hundred and eighty-one patients were assessed at a review clinic six weeks after operation.

All measurements were made with the patient at rest on their own bed. Both feet were placed into a foot rest and the maximum circumference of both calves measured. A broad thigh cuff was placed around both thighs and Indium-Gallium strain gauges (Medasonics, Mountainview CA) applied to the measured circumferences. The point of measurement was marked at the preop. test with an indelible skin marker, and all subsequent tests were performed with the strain gauges at the same site. The thigh cuff was inflated to 55mmHg for 120 seconds and the increase in calf volume (Vc) recorded from the strain gauges. After this time, the cuff was rapidly deflated and the outflow determined.

Statistical analysis was performed using a two-tailed, paired t-test. When comparing patient sub-groups an unpaired t-test was used. Values of $p<0.05$ were regarded as significant.

RESULTS

All patients were successfully tested without complication. A total of 3140 strain gauge plethysmographs were recorded. Venography was performed in 76 patients and deep vein thrombosis was confirmed in 20 limbs (15 operated legs and 5 unoperated legs, with 8 proximal and 12 distal thromboses).

The effect of total hip replacement on mean venous capacitance and venous outflow is illustrated in figures 1 and 2. It was noted that both Vc and Vo were lower in the operated leg than the unoperated leg, even before operation. This difference was statistically significant with $p<0.04$ for Vc and $p<0.0002$ for Vo. There was a highly significant fall in both parameters in both legs after surgery (operated leg: Vc and Vo $p<0.0002$, unoperated leg: Vc and Vo $p<0.0002$). This fall was maximal at day 3 for venous outflow, but the fall continued for capacitance, in the operated leg, to a minimum Vc at day 5. The values then increased over the 41 days of the study period. At review at six weeks, mean Vc and Vo in the operated leg were still significantly below preoperative levels ($p<0.02$ and $p<0.05$ respectively). In the unoperated leg mean 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 the unoperated leg (Vc: $p<0.002$, Vo: $p<0.0002$).

The correlation between deep vein thrombosis and venous flow was established by comparing the response in limbs with and without thrombosis. Figures 3 and 4 demonstrate the difference in response. The pattern of reduced flow was seen in both groups. The patients who developed DVT after surgery had very different venous parameters before operation. They had significantly lower Vc and Vo compared with those operated legs without DVT (Vc $p<0.009$, Vo $p<0.04$). The mean reduction after surgery was 15.7% for Vc (2.95 to 2.49) and 9.0% for Vo (49.43 to 44 95) in operated legs without DVT. In limbs which subsequently developed clot, mean fall in Vc was 24.8% (2.19 to 1.65) and Vo, 35.3% (39.07 to 25.29). Limbs with DVT did not recover preoperative venous outflow 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 is this group had evidence of deep vein thrombosis either clinically, or venographically.

The effect of spinal or general anaesthetic was studied but the small number of patients with general anaesthetic did not allow us to demonstrate any significant difference between the groups. Both groups had a similar pattern of reduction in venous flow after surgery and to a similar degree.

DISCUSSION

A central role for venous stasis in the initiation and propagation of deep vein thrombosis has been reported (Thomas 1985, Nicolaides et al. 1972). This study presents the first confirmation of a gross disturbance in lower limb venous haemodynamics after total hip replacement. Previous small studies have established reduced venous and arterial flow in the few days after abdominal and vascular surgery (Browse 1962a, Bird 1972, Tripolitis 1979). This study also demonstrates that venous flow remains below preoperative levels for several weeks after discharge.

The marked difference in Vc and Vo between operated and unoperated legs before operation was unexpected. It can be explained by consideration of the activity of the patient prior to admission. Blood flow to the calf is determined by the metabolic requirements of the muscles and other tissues. Browse (1962b) demonstrated that resting calf blood flow is very constant and that variation is primarily associated with exercise. Venous distensibility and hence a large venous capacitance is only necessary 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 the preoperative period.

The fall in venous capacitance and venous outflow in both limbs was significant. There would appear to be two phenomena affecting the limbs. Firstly there is a general, perhaps humoral, response which affects both limbs. Superimposed on this is a local response, mainly affecting venous capacitance 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 unoperated

leg would suggest that this general effect is less marked. The local effect on the operated leg however continues to cause a fall in capacitance until the fifth postoperative day. These changes in venous flow progressed despite active mobilisation beginning on the day after surgery with early partial weight bearing. There was no difference in the pattern of the venous response between those who mobilised normally and the 49 patients who mobilised more slowly.

The association between reduced flow and subsequent thrombosis was demonstrated. The fall in Vc and Vo was much larger in those limbs which developed DVT. These limbs showed significantly lower Vc and Vo preoperatively suggesting that they were in a high risk state before surgery. In these patients, further disturbance in their venous haemodynamics after operation may have provided the conditions for thrombogenesis. Correlation between disturbed preoperative and postoperative coagulation and fibrinolytic markers with DVT has been difficult to establish (Aberg et al. 1973, Gunn 1979, Layer and Burnand 1985, Paramo 1985, Reilly et al 1980). This study provides a correlation between low venous capacitance and outflow and postoperative thrombosis. None of the 15.3% of patients who had no postoperative fall in Vc or Vo, developed a thrombosis during the study period.

The persistence of low venous flow after discharge was much greater than expected. Operated limbs had not regained preoperative levels by six weeks after surgery. These preoperative levels are also lower than the unoperated side, and it would appear from these results, that initially arthritis, and then total hip replacement cause a profound alteration in venous physiology, lasting many weeks or months. At present, this series of patients is being assessed at three months after surgery, to determine at what point the operated leg achieves values similar to those of the unoperated leg.

These findings would suggest that the 'at risk' period for the development of thrombosis is at least six weeks in many patients. Tremaine et al (1991) have demonstrated that DVT can occur after discharge in patients undergoing total hip replacement. In this series, five asymptomatic thromboses were diagnosed at six weeks in patients who had been screened non-invasively to 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 lower limbs, together with an increase in peripheral resistance. Combining this with the results of this study, a mechanism of active vasoconstriction affecting both the muscular arterioles and the deep veins is suggested.

The 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, by increased venous flow produced by this device, would support the role of stasis as a major factor in venous thrombogenesis after hip surgery.

ACKNOWLEDGEMENTS

The authors would like to thank S.A. Croal, J.S. Birkmyre, B. O'Connell and P. Fox for their help in the data collection, and Dr. Ellis Clarke for his encouragement and help in all matters physiological. M.A. McNally would wish to acknowledge the British Orthopaedic Association Wishbone Trust for their financial support in this work.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

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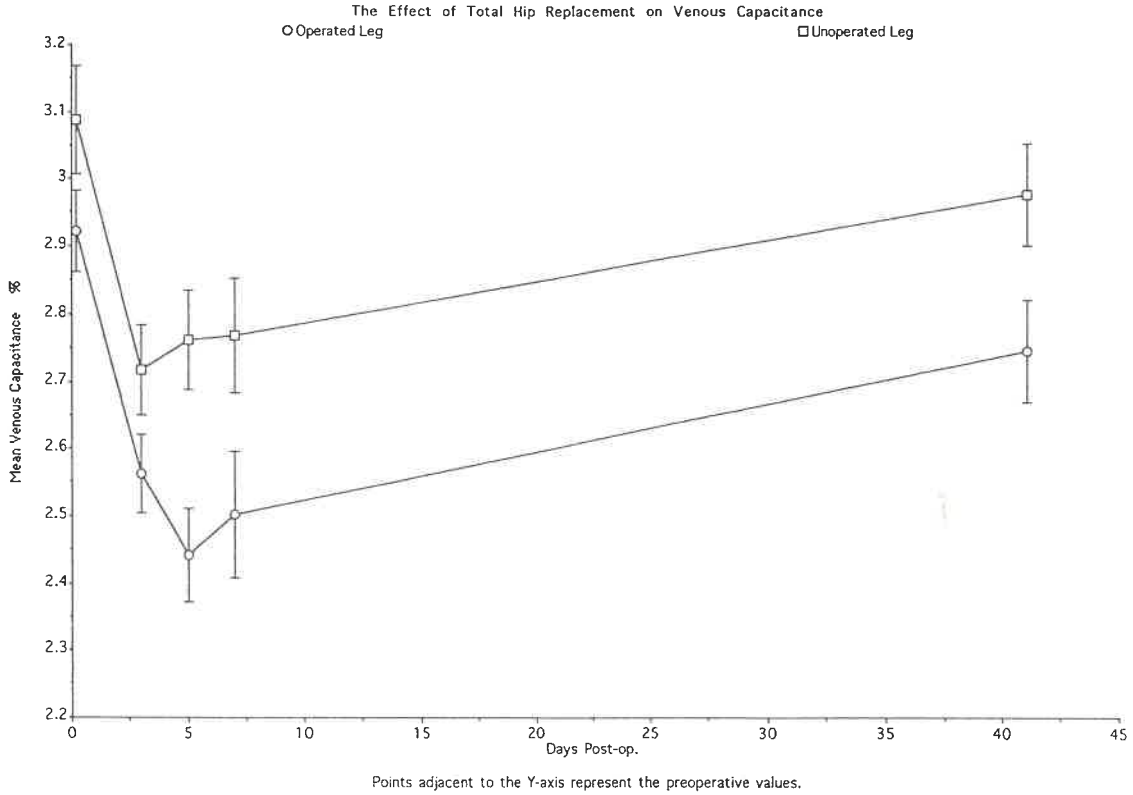
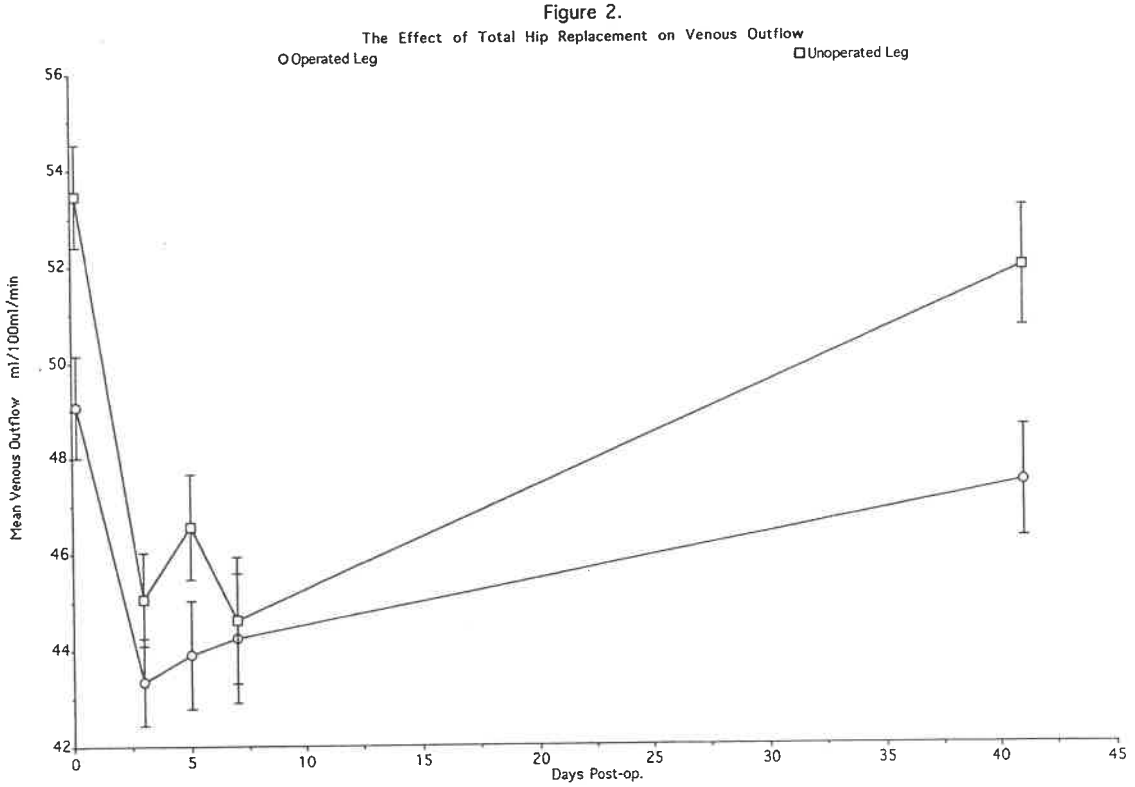
Figure 1.



Points adjacent to the Y-axis represent the preoperative values.

Figure 2.



There is no statistical difference between Vo at days 5 and 7 in the unoperated leg ($p>0.4$).

Figure 3.

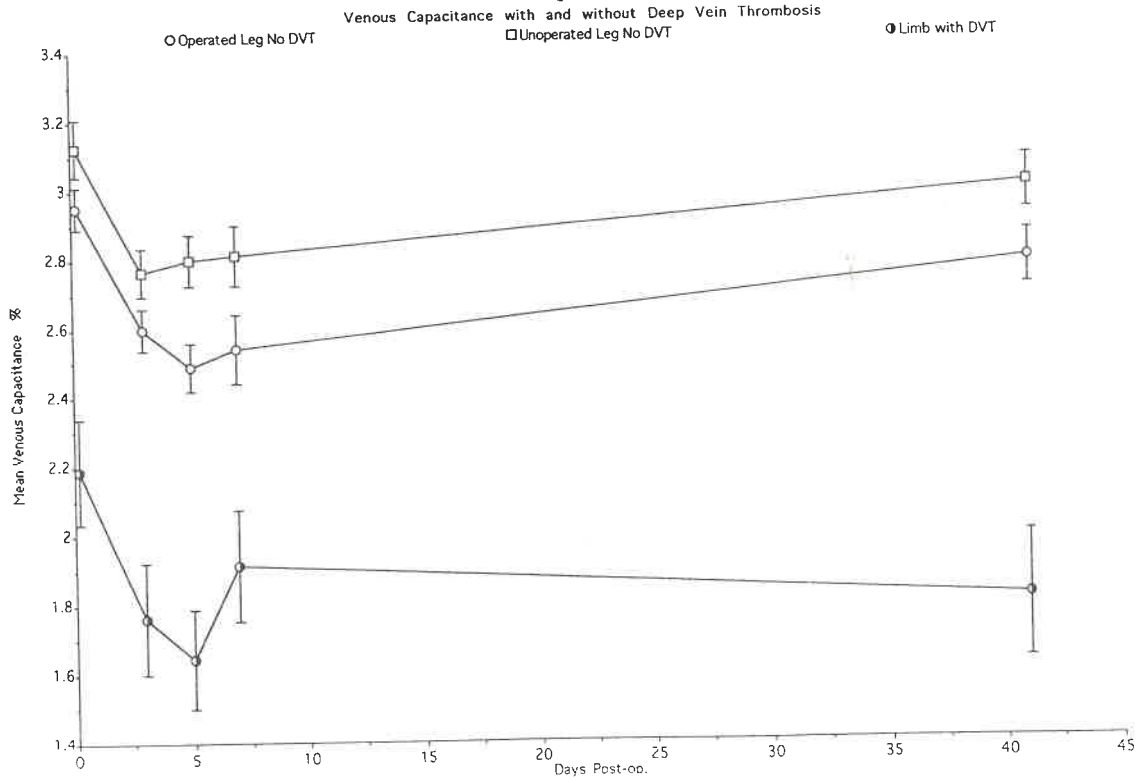
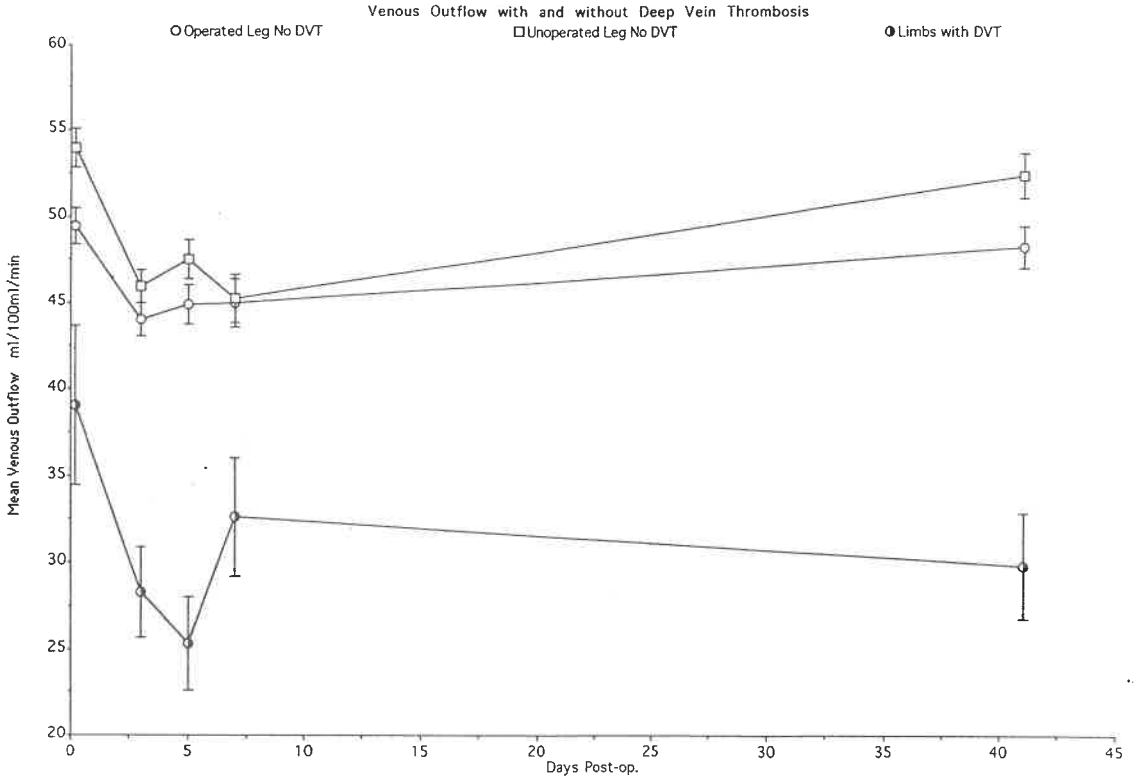


Figure 4.


Venous Outflow with and without Deep Vein Thrombosis
O Operated Leg No DVT
□ Unoperated Leg No DVT
◑ Limbs with DVT
Mean Venous Outflow ml/100ml/min
60
55
50
45
40
35
30
25
20
0
5
10
15
20
25
30
35
40
45
Days Post-op.