references:
DVT related literature

collected references, June 2010

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Effect of leg exercises on popliteal venous blood flow during prolonged immobility of seated subjects: implications for prevention of travel-related deep vein thrombosis.
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Department of Surgery, University of Sydney, Westmead Hospital, Westmead, NSW, Australia.

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Electrical foot stimulation and implications for the prevention of venous thromboembolic disease.
Kaplan RE, Czynny JJ, Fung TS, Unsworth JD, Hirsh J.
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University of Maryland Medical College, Division of Nuclear Medicine, Baltimore, USA.

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A hemodynamic study of popliteal vein blood flow: the effect of bed rest and electrically elicited calf muscle contractions.

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Venous stasis, due to lack of activation of the calf muscle pump of postoperative patients, can result in the development of a thrombus which, in turn, can lead to a potentially fatal pulmonary embolism. The presented study investigates the effects that four hours of bed rest has on the lower limb hemodynamics of healthy subjects and, to what extent electrically elicited contractions of the calf muscles can alleviate these effects. Results indicated that the non-stimulated group experienced a decline in popliteal venous blood flow of approximately 45 % and a 10 % decrease in heart rate. The stimulated group maintained a higher venous blood flow and heart rate. The results suggest that even short periods of bed rest can significantly reduce lower limb blood flow which could have implications for DVT development in post-operative patients. Electrically elicited calf muscle contractions significantly improves lower limb blood flow and can alleviate the debilitating effects of bed rest.

PMID: 19963532 [PubMed - in process]


Effect of leg exercises on popliteal venous blood flow during prolonged immobility of seated subjects: implications for prevention of travel-related deep vein thrombosis.

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Background:

Venous stasis is an important contributing factor in the development of travel-related deep vein thrombosis. This study examined factors affecting popliteal venous blood flow in order to determine the most effective exercise regimen to prevent venous stasis.

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Methods:

Twenty-one healthy subjects were randomly assigned to various activities over a 9-week period. Subjects remained seated throughout the investigation and 3660 duplex ultrasound examinations were performed by a single examiner using a SonoSite 180 Plus handheld ultrasound. Baseline popliteal vein blood flow velocity, cross-sectional area and volume flow in subjects sitting motionless were assessed in the first 3 weeks. The remaining 6 weeks involved subjects performing airline-recommended activities, foot exercises, foot exercises against moderate resistance and foot exercises against increased resistance in order to determine the most beneficial method for enhancing popliteal venous flow. Sitting with feet not touching the floor and the effect of sleeping were also assessed.

Results:

The median age of the subjects was 22 years (range: 18-25.5 years), height 171 cm (162.5-180.5 cm) and body mass index 25.3 kg m\(^{-2}\) (23.2-26.3 kg m\(^{-2}\)). Blood volume flow in the popliteal vein was reduced by almost 40% with immobility of seated subjects and by almost 2-fold when sitting motionless with feet not touching the floor. Foot exercises against increased resistance positively enhanced volume flow (P < 0.0001).

Conclusion:

Leg exercise regimens enhanced popliteal venous flow during prolonged immobility of seated subjects, reinforcing the importance of regular leg movement to prevent venous stasis during prolonged sitting, such as in long-distance travel.

PMID: 17723128 [PubMed - indexed for MEDLINE]


Haemodynamic study examining the response of venous blood flow to electrical stimulation of the gastrocnemius muscle in patients with chronic venous disease.

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Objectives:

The aim of this study was to explore the option of stimulating calf muscle contraction through externally applied neuromuscular electrical stimulation (NMES) and to measure venous blood flow response to this stimulation.

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Methods:
Ten patients with class 6 chronic venous disease (CEAP clinical classification) were recruited. Measurements of peak venous velocities in the popliteal vein were recorded by Duplex scanning in response to six test conditions; 1. Standing, 2. Voluntary calf muscle contraction, 3. Standing with NMES applied, 4. Standing with compression bandaging applied to the leg, 5. Voluntary calf muscle contraction with compression bandaging applied to the leg, 6. Stationary with compression bandaging applied to the leg and NMES applied. Comfort assessment was completed using visual analogue scales at each test stage and on study completion each patient completed a short structured interview to determine comfort and acceptability of NMES. Statistical analyses were carried out using SPSS, Version 9. Non-parametric testing was used in all analyses using the Wilcoxon Signed Ranks Test for paired samples.

Results:
There was a significant increase in venous velocities on voluntary contraction of the calf muscle (median resting vel 7.3 cm/s; voluntary contraction median 70 cm/s) and with the introduction of NMES, both with compression (median velocity 15 cm/s, p = 0.005 Wilcoxon) and without compression (median velocity 13 cm/s, p = 0.005 Wilcoxon). The greatest increase with NMES was when combined with compression bandaging. All patients reported the stimulus as an acceptable treatment option with 90% reporting NMES as comfortable.

Conclusions:
Healing rates in venous ulceration with the application of compression bandaging remain between 50 and 70%. This study shows a positive haemodynamic response to NMES. Further research is needed to quantitatively measure the effect of NMES on ulcer healing.

PMID: 16242978 [PubMed - indexed for MEDLINE]


Electrical foot stimulation and implications for the prevention of venous thromboembolic disease.

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Background:
Venous stasis caused by immobility is an important risk factor for deep vein thrombosis following surgery and lower limb trauma, in bed-ridden medical patients, and in high-risk long distance air travelers. A safe cont.
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and convenient method for reducing venous stasis would be useful in patients while in hospital and after discharge during their rehabilitation.

**Subjects and methods:**

49 healthy subjects aged 51-76 were seated for 4 hours during which they received mild electrical stimulation of the calf, or sole of the foot (plantar muscles). Popliteal and femoral venous blood flow velocities were measured via doppler ultrasound. The non-stimulated lower extremity served as the simultaneous control. Subjects completed a questionnaire regarding their acceptance and tolerance of the electrical stimulation.

**Results:**

There was a significant increase in venous femoral and popliteal blood flow for both calf (p < 0.035, p < 0.003), and plantar muscles (p < 0.0001, p < 0.009) on the stimulated side compared to the unstimulated side. The magnitude of the effect was similar for calf and plantar muscle stimulation. Subjects did not find the experience uncomfortable, and would use an electrical stimulator if told by their physician that they were at risk for developing blood clots.

**Conclusions:**

Mild electrical stimulation of the feet, as well as the calf, is a safe effective and convenient method for counteracting venous stasis and therefore has the potential to reduce the risk of deep vein thrombosis and pulmonary embolism for subjects who are immobilized.

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Pathophysiology and diagnosis of deep venous thrombosis.

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Lower-limb deep venous thrombosis (DVT) affects between 1% to 2% of hospitalized patients. These thrombi disrupt the vascular integrity of the lower limbs and are the source of emboli that kill approximately 200,000 patients each year in the United States. The causes of thrombosis include vessel wall damage, stasis or low flow, and hypercoagulability. These factors favor clot formation by disrupting the balance of the opposing coagulative and fibrinolytic systems. The symptoms and signs of venous thrombosis are caused by obstruction to venous outflow, vascular inflammation, or pulmonary embolization. About 70% of patients referred for clinically suspected venous thrombosis, however, do not have the diagnosis confirmed by objective testing. Among the 30% who have venous thrombosis, about 85% have proximal vein thrombosis, and the remainder have thrombosis confined to the calf.
Physicians cannot rely on signs and symptoms to make the diagnosis of DVT and must depend on imaging studies to guide treatment. Patients with proximal vein thrombosis who are inadequately treated have a 47% frequency of recurrent venous thromboembolism over 3 months. In contrast, clinically detectable recurrence occurs in less than 2% of patients with proximal vein thrombosis if an adequate anticoagulant response is achieved. Of the diagnostic procedures for DVT, venography is the only invasive test of proven value, and ultrasonographic (US) studies are the most commonly used noninvasive modality. Other procedures are occasionally used to diagnose DVT, including impedance plethysmography, computed tomography, and magnetic resonance imaging. US examinations are noninvasive, they are rapidly obtained, and they can be performed serially. In symptomatic patients, venous US is sensitive and specific for proximal DVT; however, US is insensitive to calf vein thrombosis and to asymptomatic DVT occurring after surgery. Patients with symptoms of recurrent DVT also can present a difficult diagnostic problem. Only about 20% to 30% of these individuals actually have the disease; the rest have symptoms arising from chronic venous insufficiency or from any of the causes of lower extremity pain. After an acute episode, up to 50% of patients have compression ultrasound abnormalities for 6 months that are indistinguishable from the original findings of DVT. Hence, there are a significant number of patients and clinical circumstances in which the diagnosis of DVT is difficult. 99mTc-radiolabeled peptides that target the molecular biology of thrombosis should aid in the management of the disease, particularly in asymptomatic patients at high risk, in patients with recurrent symptoms, in patients with active DVT in the calf and/or pelvis, and in patients with intermediate- or low-probability lung scans.


Electrical stimulation-induced contraction to reduce blood stasis during arthroplasty.

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Deep venous thrombosis and subsequent pulmonary embolism due to venous pooling/stasis commonly occur in patients during hip and/or knee arthroplasty (i.e., replacement). This problem may be alleviated by using techniques to promote lower limb blood flow. Electrical stimulation-induced contractions have been shown to activate the skeletal muscle pump, promote limb blood flow, and may be effective for reducing venous pooling/stasis and edema. Therefore, electrical stimulation may reduce the incidence of deep venous thrombosis (DVT) and pulmonary embolism (PE) during and following surgery. The overall goal of this project was to evaluate the clinical efficacy of sequential electrical stimulation-induced leg muscle contractions on the venous blood flow during surgery. The degree of venous pooling/stasis was monitored via electrical impedance changes in the thorax. The changes in the patient's central hemodynamics were then calculated. Thirty patients were recruited and randomly assigned to either a control group (n = 15, mean age = 66.4 +/- 7.3) or experimental group (n = 15, age = 60.7 +/- 9.7). Both groups received the standard medical treatment for prevention of DVT (i.e., coumadin, heparin, etc.)

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and compression stockings (TED, Kendall). The control group used the sequential compression device (SCD + TED) and the experimental group used electrical stimulation (ES + TED). Electrical stimulation was applied via surface electrodes to the lower-limb muscles (tibialis anterior and gastrocnemius) and upper limb muscles (quadriceps femoris and hamstrings). These muscles contracted sequentially, using an eight-channel electrical stimulator. Four seconds of calf (contraction/compression) were followed by 7-s of calf and thigh (contraction/compression) interspersed by 60-s rest period during both electrical stimulation or sequential compression device. This cycle continued throughout the surgery (60-75 min) for both groups. At 15 min intervals, venous return was monitored by impedance cardiograph. Physiologic responses including ventricular stroke volume (SV), cardiac output (CO), heart rate (HR), total peripheral resistance (TPR), as well as mean arterial pressure (MAP) were monitored. These responses were statistically analyzed and compared throughout the surgery within each group and between the two groups. The results show stroke volume and cardiac output to be higher throughout surgery in the electrical stimulation group as compared with the sequential compression device group. The heart rate was consistently lower during electrical stimulation for both groups. Total peripheral resistance did not change in the electrical stimulation group; but increased in the sequential compression device group. The data suggest that continuous electrical stimulation-induced contractions could improve lower leg circulation by eliciting the physiologic muscle pump. This will lead to improved venous circulation and reduction of blood stasis during total hip and/or knee surgery. This technique may offer greater protection against DVT and PE during surgery than the commonly used sequential compression device.

PMID: 9086386 [PubMed - indexed for MEDLINE]

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