Hospital Topics

Optimal Electrical Stimulus for Prevention of Deep Vein Thrombosis

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Summary

The most effective electrical stimulus to the calf muscles which prevents stasis in the soleal veins during operation was determined. This was subsequently used in a clinical trial and was shown to produce a 92% relative reduction in the incidence of deep vein thrombosis as determined by the ^{125}I -fibrinogen test.

Introduction

Most thrombi start in the soleal veins at the time of operation or soon after.¹⁻³ Stasis is most pronounced in the soleal veins especially during operation⁴, and can be prevented by electrical stimulation of the calf muscles.⁵⁻⁶ Attempts, however, to prevent deep vein thrombosis using peroperative electrical stimulation of the calf muscles in patients screened with the ^{125}I -fibrinogen test produced only a 61% relative reduction in the incidence of deep vein thrombosis in one study and none in another.⁷⁻⁸

The purpose of the present study was to determine the most effective electrical stimulus in preventing stasis in the soleal veins and to use it in a clinical trial to evaluate its effectiveness in preventing deep vein thrombosis.

Material and Methods

OPTIMAL STIMULATION TO PREVENT STASIS

This part of the study was concerned with determining the most effective form of electrical stimulation of the calf muscles to prevent stasis in the soleal veins. A Doppler blood flow detector (Doptone) was placed at a constant angle and fixed to the skin over the femoral vein in the groin. A continuous recording of mean blood velocity was obtained via a pen recorder. The response of this instrument has been shown to be linear,⁸⁻⁹ and although blood velocity cannot be measured in absolute units changes in the mean velocity can be measured with an accuracy greater than 90%. It was thus possible to record changes in the mean blood velocity of the femoral vein as a result of each calf muscle contraction while square wave electrical stimuli of different intensity and duration with different resting periods between them were applied to the calf muscles. The electrodes were in contact with the upper and lower part of the gastrocnemius muscle and the legs were kept horizontal. They were covered by four layers of lint impreg-

nated with normal saline. The current was provided by a stimulator (selective treatment unit). Ten consecutive patients were studied during operation. The operating table and the patients' legs were kept horizontal.

EFFECTIVENESS OF OPTIMAL PEROPERATIVE STIMULATION

In this part of the study the optimal electrical calf stimulus, as determined above, was used in a clinical trial in an attempt to assess its effectiveness in preventing deep vein thrombosis.

Selection of Patients

A total of 116 patients over the age of 30 undergoing a variety of operations (Table I) were investigated. Patients undergoing surgery on the legs or thyroid gland and those who required the lithotomy position were excluded. The patients were comparable with regard to the distribution of factors which affect the incidence of venous thromboembolism (Table II). Fifty-six of

TABLE I—Operations Performed in 116 Patients Studied

Operations	Control Group	Test Group
Gastric	21	18
Biliary	17	19
Laparotomy	5	6
Large bowel	6	6
Hiatus hernia	2	3
Miscellaneous	5	8
Total	56	60

TABLE II—Distribution of Factors predisposing to Deep Vein Thrombosis

	Mean Age in Years ($\pm$ S.D.)	Obesity	History of D.V.T.	History of P.E.	Varicose Veins	Malignancy
Control group	56 $\pm$ 12.4	12	3	1	7	14
Test group	52 $\pm$ 13.8	16	3	2	5	11

D.V.T. = Deep vein thrombosis. P.E. = Pulmonary embolism.

them acted as controls, while the remaining 60 had the calf muscles of one leg electrically stimulated during operation.

In the control group no specific measures were taken to prevent deep vein thrombosis other than the traditional hospital routine of physiotherapy.¹¹ In the test group, as soon as the patient was anaesthetized two padded electrodes (6 by 15 cm) were applied to the upper and lower part of the posterior aspect of one calf, the right if the patient was born in an even year and the left if born in an odd year. A 50-millisecond square wave

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current was applied every five seconds. Each alternate pulse was automatically reversed in polarity to avoid tissue ionization. The stimulating current was applied by a mains-operated Thrombophylactor (Stanley Cox Medical Equipment Division of Rank Precision Industries Ltd.) according to the above specifications (Fig. 1). The intensity was always adjusted to

FIG. 1—Thrombophylactor.

produce a brisk plantar flexion of the foot without violent movement of the leg. This was discontinued at the end of the operation just before the patient woke up.

Diagnosis of Deep Vein Thrombosis

All the patients were screened by the ^{125}I -labelled fibrinogen test.¹² The thyroid gland was first blocked with sodium iodide (100 mg) and the ^{125}I -fibrinogen was given intravenously before operation. The legs were scanned before and immediately after operation, and on the first and then on alternate days up to the tenth postoperative day. By using the Pitman 235 isotope localization monitor the radioactivity at the various positions on the legs was expressed as a percentage of the heart count. A thrombus was diagnosed if there was a difference of 20% or more of the radioactivity at the same position on two different days or between adjacent positions on the same day if it persisted for more than 24 hours.¹²

Results

OPTIMAL STIMULATION TO PREVENT STASIS

There was a brief but pronounced increase of the mean velocity of blood in the femoral vein with every calf contraction. Fluoroscopic and cinephlebographic studies have already shown that each calf muscle contraction forces proximally a large volume of blood (stroke volume) out of the soleal and tibial veins.¹³ It is reasonable to assume that the greatest stroke volume will be produced by the stimulus which also produces the greatest increase in femoral vein velocity.

The most appropriate intensity/duration combination was that which produced a brisk plantar flexion of the foot without violent movement of the leg. More powerful stimuli produced violent leg movements and only a small additional increase in femoral vein velocity. A stimulus of less than 50 milliseconds' duration required a higher intensity to have the same effect, and a stimulus of more than 100 milliseconds' duration tended to produce two muscle contractions, one at the make and one at the break. The optimal duration was therefore 50 milliseconds. A resting period less than four seconds did not allow the soleal

veins to fill completely before the next stimulus and resulted in a progressive reduction in stroke volume (Fig. 2 c). A resting period longer than five seconds allowed the soleal veins to fill in the interval between stimuli so that successive stimuli resulted in the same maximum stroke volume (Fig. 2 b). The optimum rate of stimulation was therefore 12–15/min.

EFFECTIVENESS OF OPTIMAL STIMULATION

In the control group 18 (32%) of the 56 patients developed deep vein thrombosis. In seven patients the thrombi were bilateral. There were thus 25 limbs with deep vein thrombosis, 13 right and 12 left (Table III). All thrombi had started in the calf. Two

FIG. 2—*a*, Normal recording of femoral vein velocity; blood velocity is diminished during inspiration. *b*, Sustained effect of calf stimulation; rate 13/min. *c*, Effect of calf stimulation not sustained; rate 24/min.

TABLE III—Results of Calf Stimulation Trial

	No D.V.T.	D.V.T.	Total	Fisher's Exact Test
Control group { Right leg Left leg	43 44	13 (23%) 12 (21%)	56 56	
Test group { Stimulated leg Unstimulated leg	59 51	1 (1.6%) 9 (15%)	60 60	P = 0.00028 P = 0.10

D.V.T. = Deep vein thrombosis.

extended into the popliteal and one into the femoral vein. The time the thrombi formed is shown in Fig. 3.

Of the 60 patients who had calf stimulation on one leg during operation nine (15%) developed deep vein thrombosis (Table III). In only one patient were the thrombi bilateral. In the remaining eight the thrombi occurred in the unstimulated leg. The time of formation is shown in Fig. 3.

If in the test group of patients the unstimulated leg is used as control, then in a sequential analysis with $2\alpha = 0.5$, $1 - \beta = 0.95$, and $\theta_1 = 0.85$ (probability of 5%) the trial is concluded in favour of calf stimulation (Fig. 4). If the incidence of deep vein thrombosis in the stimulated leg in the test group is compared with either the right or the left leg of the control, the difference is also significant (Fisher's exact test, $P = 0.00028$; Table III).

In the test group the incidence of deep vein thrombosis in the unstimulated leg (15%) was less than in the control group. Although this is not significant (Table III) Fig. 3 shows that this is due to the absence of any thrombi occurring during the operation. If this is compared with the relatively high incidence of deep vein thrombosis on the day of operation in the control group (Table IV) this is significant.

None of the patients in this trial had any complications as a result of the method of investigation described.

FIG. 3—Effect of electrical stimulation on incidence of deep vein thrombosis.

FIG. 4—Sequential analysis of effect of electrical stimulation of one leg.

TABLE IV—Incidence of Thrombi occurring on Day of Operation

		No D.V.T.	D.V.T.	Total
Control group	Right leg	50	6	56
	Left leg	50	6	56
Test group	Unstimulated leg	60	0*	60

*Fisher's exact test, $P = 0.011$.

Discussion

Cinephlebographic studies have shown that the soleus muscle and its veins act as a peripheral pump,¹⁴ filling during relaxation and emptying during contraction. The optimal electrical calf stimulus is defined as that which produces the maximum output from the calf (stroke volume) which can be maintained during the operation. This can be maintained only if the stimulus is applied at a rate of not more than 15/min. Stimuli more frequent than this produce a progressive fall in the stroke volume, because the short interval between them does not allow complete filling of the soleal veins.

The stimulus used in the second part of the present investiga-

tion proved effective, producing a 92% reduction in the incidence of deep vein thrombosis in the stimulated leg (Fig. 3). This is the greatest decrease in any study so far reported where an attempt has been made to eliminate stasis by electrical stimulation during operation. These results are likely to arise from the fact that the most effective stimulus for preventing stasis was established and used in this study.

There is some indication that the stimulus used also prevented the formation of thrombi in the unstimulated leg during operation (Table III, Fig. 3). Muscular contractions increase the fibrinolytic activator in the blood which acts not only locally but also systemically.^{15, 16} The same occurs in patients having electric convulsion therapy without relaxants, but not if muscle relaxants are administered before electric convulsion therapy.¹⁷

The preliminary results of this trial show that an optimal electrical stimulus, when used to contract the calf muscles during operation, effectively reduces the incidence of deep vein thrombosis. Better results still might be expected if both legs were stimulated simultaneously during operation. Before the worth of this form of physical prophylaxis can be judged with precision, however, the results must be confirmed under more difficult circumstances in high-risk patients. These include older patients undergoing major operations, very often with additional risk factors which are known to be associated with a high incidence of venous thromboembolism.¹⁸ Again, there are certain disadvantages in the use of physical methods. They cannot be used conveniently in patients undergoing orthopaedic procedures on their legs or those in the lithotomy or other awkward positions during surgery. Further, electrical stimulation cannot be used during the postoperative period in conscious patients. Possibly simple methods that prevent blood hypercoagulability^{19, 21} will prove more practical to be adopted for routine use on a wide scale.

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