VASCULAR REACTIONS TO PRE AND POST TRANSCUTANEOUS ELECTRICAL STIMULATION OF SPINAL CORD AND NERVE ROOTS

Frank Canosa, M.D.
Donald M. Dooley, M.D.
Edwin Boyle, Jr., M.D.

INTRODUCTION

During the past several years, many surgeons have applied electrostimulation to different portions of the nervous system in an effort to diminish pain and improve neurological function.[1,2,3,4]

Many of the patients who had electrostimulation of the spinal cord reported that their lower extremities felt warmer on the third or fourth day of electrostimulation. It seemed reasonable to assume that this was due to augmentation of blood flow to the extremities.

An early report concerning electrostimulation of nervous tissue, and changes in blood flow to the extremities, was that of Stricker in 1876.[5] Bayliss, in 1901, substantiated his observations, and concluded that "there are neurofibrils in the posterior roots of the 5th, 6th, 7th and 1st Sacral Roots of the dog, excitation of which, when cut away from the spinal cord, give rise to vascular dilatation in the hind limb of the same side. The vasodilators of the forelimb of the dog are situated in the posterior roots of the 6th, 7th, and 8th Cervical and 1st Thoracic Nerves, and perhaps to a small amount, also in that of the 5th Cervical." Foerster recorded similar observations in 1933, as did Pabst in 1960.[7,8]

Preliminary investigative studies with a one channel Plethysmograph and a small number of patients confirmed these clinical and laboratory observations.[9] Further correlation between electrostimulation of the spinal cord and blood flow to the extremities, in a larger number of patients, and with more sophisticated methods of measurement of blood flow, seemed to be in order. This publication is the result of our efforts to do so.

METHOD OF INVESTIGATION

Ninety-six patients, some of whom were used as controls, were evaluated for the effect of electrostimulation of the spinal cord on the arterial tree of their extremities. Fifty-one (51) patients had Peripheral Occulusive Vascular Disease; two (2) had Varicose Ulcers; ten (10) had Raynaud's Disease, or Phenomenom; fifteen (15) had Hypertension; eighteen (18) had symptoms of coldness and pain of extremities, but no clinical or oscillometric evidence of vascular disease.

The electrodes of the transcutaneous electrical nerve stimulators, manufactured by Medtronics, Inc., and STIMTECH, Inc., were placed on either side of the spinous processes of C6 and also from T10 to L2.

An objective evaluation of the vascular status was performed in all patients prior to treatment. Simultaneous recording of the blood flow to all extremities with a 2-lead ECG by means of a Mingograph 81 Multichannel Fluid Jet Recorder (Frequency Response: Linear 0-500 Hz, 3db -down at 650 Hz), special sphygnomanometric cuffs embodying a built-in Piezo Electric Transducer (Buffington's Cuffs) with a standardized volumetric air system, were used to obtain the recording. The plethysmographs were connected to four (4) lmv

inputs - ECG leads of the multichannel recorder. The equipment was standardized at 1mv/10mm. All tests were performed in the same room at a controlled temperature of 78^0F ($\pm 1^0F$). A waiting period of ten (10) minutes was maintained before recording controls. The control baseline was recorded at certain time intervals for at least ten (10) minutes to detect for spontaneous variations. The electrical stimulation was turned on and increased until the patients detected the paresthesias. The plethysmographic, blood pressure, and ECG tracings were recorded at specific time intervals for one (1) hour. The time of stimulation varied from five (5) to 20 minutes. The patients with Varicose Ulcers were treated daily with application of electrodes to the Thoracic Region, and either side of the ulcer.

The patients were evaluated in this manner on a weekly basis for three (3) weeks. The effect on oscillometric and thermographic measurements of blood flow were also recorded in certain patients. On the fourth week, the patients took a transcutaneous electrical nerve stimulator home and applied the current for 30 minutes twice a day. They were re-examined at specific intervals over the following three (3) months, and queried in regards to symptomatology.

RESULTS

Thirty-five (35) of the 51 patients with Occlusive Vascular Disease of the lower extremities had 25%, or more, increase in blood flow to the lower extremities as measured by Plethysmography. (Chart #1) Twenty-three (23) of the 35 persons reported subjective improvement in their symptoms. None of the patients with no change, or less than 25% change in the Plethysmographic record, reported any improvement in symptoms.

The two (2) patients with Varicose Ulcers were observed to have healing of the ulcers within three (3) weeks of the institution of the therapy.

Five (5) of the 10 patients with Vasospastic disorders who reported improvement in symptoms, also had over 30% increase in blood flow. The greatest increase in blood flow (90%) in all of the patients was noted in this group.

There were physical changes observed in the extremities of patients whose clinical subjective improvement correlated with the laboratory objective improvement. These were diminution of swelling and changes in skin color and temperature consistent with a regional increase in blood flow.

All seven (7) patients with intermittent claudication reported over 50% lessening of pain with electrostimulation at T10, but not at C6.

The control subjects (the electrodes were applied, but the transmitter was not turned on) showed no change in blood flow, pulse rate, ECG or clinical symptoms.

There were no changes in the pulse rate or ECG of any patient. None of the patients were disturbed by the paresthesias produced by the stimulation, and no complications were observed.

The patients were evaluated in this manner on a weekly basis for three (3) weeks. The effect on blood pressure, oscillometric, and thermographic measurements of blood flow were also recorded.

Beginning the fourth week, the patients took a T.E.N.S. unit home, and applied the current for 30 minutes twice daily. The patients were re-examined at specific intervals over the following months, and queried regarding symptomatology. Fifteen (15) of 15 patients had a 10-15% drop in systolic and diastolic blood pressures.

EXAMPLES OF CLINICAL STATUS AND PLETHYSMOGRAPHY

Patient K.R. (Figure #1) was a 61 year old female with intermittent claudication, which was more severe in the left lower extremity. She was able to walk one/half (½) city block without pain. She was treated with electrostimulation for 15 minutes on a weekly basis. Figure #1 shows a pulse wave of 10mm on the right, and 4mm on the left; with a rounded configuration. During electrostimulation there is bilateral increase in the pulse wave, but more on the left than right. Ten (10) minutes after electrostimulation at T10, the pulse wave is about the same on each side and are 50% higher than the control. After four (4) months of therapy, she has no complaints of leg pain and walks one (1) mile without pain.

Patient G.L. (Figure #2) was a 67 year old male. The pre-stimulation wave forms show the upper extremities to be equal and the right toe pulse wave to be 56% less than the left. During electrostimulation at T10 for 20 minutes, there is a generalized pulse wave amplitude increase when compared to the controls, although the asymetry between the toe pulses remains unchanged and the peak delay is stable at 0.14 sec. After stimulation, the amplitude decreases although the right toe pulse is still 40% above the control.

Patient P.C. (Figure #3) was a 73 year old male, who had noticed that his walking distance was reduced by pain in his left calf. Pre-stimulation plethysmography revealed that the left toe amplitude was decreased over the right, and the left/right ratio is o.70. After stimulation, the amplitude reverts back to the control level, but the crest time has improved on each side by 0.04 sec. The crest time is now 0.18 sec. on the right and 0.22 sec. on the left, which is within normal limits as compared to a crest time of 0.26 sec. before stimulation.

Patient P.E. (Figure #4A) was a 67 year old female with intermittent claudication of the right lower extremity. Plethysmography revealed a low amplitude of the pulse wave of the right toe, and also an abnormal configuration. The right/left ratio was 0.26. There is a slight increase in amplitude and a change in the right/left ratio to 0.33 with electrostimulation at T10. After stimulation, the amplitude of the right side is 60% above the control,

and the right left ratio is 0.40. The patient received sporadic weekly treatments with lessening of symptoms for a few days after each treatment. One (1) year later, the pulse amplitude increased with electrostimulation and the crest time was still abnormal (Figure 4B). However, the right/left ratio was 0.75 after stimulation.

Patient M.C. (Figure #5) was a 52 year old female with Raynaud's Disease. Thermography without stimulation showed only both thumbs and the right little finger. All other digits of the upper extremities were below 24^0. Electrostimulation at C6 was performed for 20 minutes, first at 20 pps and later at 90 pps. Thermography after stimulation revealed a generalized increase in the temperature of all fingers.

DISCUSSION

There is adequate reason to conclude that electrical current, whether delivered by transcutaneous or percutaneous method, applied to the spinal cord or nerve roots can increase blood flow to the extremities of selected patients.

Persons who have little blood going into their extremities are not likely to be aided by this therapy. The exact amount of blood flow below which this treatment is not applicable is unknown at the present time. Certainly, a patient with a gangrenous extremity cannot be helped by this therapy. A rough dividing point is when little or no pulse wave can be detected on the Plethysmograph.

Transcutaneous electrical nerve stimulation is benign, and can be applied several times a day and the patient evaluated by clinical and laboratory means. If there are no changes in three (3) or four (4) days, then the surgeon may elect to try percutaneous stimulation since this technique will deliver more of the electrical energy to the nervous system. If this is not effective, then this type of therapy should be abandoned.

How much augmentation of blood flow and individual patient needs in order to function better is difficult to determine. The percentage of increase in blood flow recorded in this article is that amount over the control tracing. How much more the arterial tree can dilate in a specific patient cannot be determined from this publication.

The largest percentage of increase occurred in a patient with Raynaud's Disease. The most striking clinical improvement was observed by the patients with Vasospastic disorders, and those with intermittent claudication.

The mind of the curious person naturally turns to thought of attempting to apply electrostimulation to the nervous system of other organs. Our preliminary efforts in attempting to dilate the coronary arteries of two (2) dogs, by electrostimulation of the Upper Thoracic Spinal Cord and Roots, were not successful. We anticipate making renewed efforts in this direction, and also initial efforts in electrostimulation of the Lower Thoracic Cord and Roots in an endeavor to increase the renal blood flow.

These investigative studies will be by the percutaneous technique in man, and operative method in the experimental laboratory.

The lowering of the blood pressure in patients with Hypertension is intriguing. This is deserving of more accurate and prolonged investigation.

Electrostimulation is not meant to replace standard medical or surgical measures. If a specific operative procedure can reasonably be expected to relieve the symptoms of impairment of blood flow, then by all means it should be performed. At the present state of our knowledge, electrostimulation for vascular disease should enter the strategy of therapy when the usual methods have failed or are not appropriate.

This investigative effort has probably raised more questions that it has answered, but this serves only to point out the potential of this innovative treatment.

CONCLUSIONS

Transcutaneous electrical stimulation of the Spinal Cord and/or Posterior Nerve Roots resulted in a 25%, or more, increase in blood flow to the extremities in 35 of 51 patients with Occlusive Peripheral Vascular Disease. Twenty-three (23) of the 35 patients observed a decrease in symptoms.

Five (5) of 10 patients with Vasospastic Disorders reported a lessening of symptoms which correlated with an increase in Plethysmographic and Thermographic measurements of blood flow.

The two (2) patients with Varicose Ulcers were observed to have healing of the ulcers within three (3) weeks of the beginning of therapy.

The control subjects and the patients who had no laboratory evidence of increase of blood flow reported no change in symptoms.

Five (5) of 15 patients with Hypertension had lowering of systolic and diastolic blood pressures by 10-15% mean drop in mm of Hg.

There were no changes in the pulse rate or ECG of any patient. There were no complications, and no patient reported any discomfort from the application of the electrical current.

Electrostimulation of the Spinal Cord and/or Nerve Roots is an appropriate adjunctive therapy for patients with Peripheral Vascular Disease who have not been aided by conventional therapy.

All seven (7) patients with intermittent claudication reported relief of pain, with electrostimulation at T10.

A criticism is that the patients should be treated, and followed for at least one (1) year. Also, a comparable group of patients with similar syndromes, who were not treated, should

also be followed over the same time and comparisons made between the two (2) groups.

It would be of great interest to measure the blood flow by a Plethysmograph which recorded in cc's per minute.

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CHART #1

DIVISION OF PATIENTS ACCORDING TO PLACEMENT OF ELECTRODES

	Electorde Placement	Electrode Length	Stimulation Duration in Minutes	Pulse Width	Rate
				Mean A.V.	Mean pps.
I	C6/T1	4 Inches	5 to 10	200	20 or 70
II	T-10	4 Inches	10 to 15	200	70
III	T-10/12	8 Inches	15 to 20	250	20 & 70
	Through		15 to 20	250	20 & 90
	Lumbar		15 to 20	250	20
	or S.		15 to 20	250	90
IV	C6/T1 Simult. with T/10	4 Inches	10	250	20
	T/12 Through Lumbar	8 Inches	10	250	90
V	L4 - S1	4 Inches	10	250	20
		8 Inches	10	250	90
					20/90

S = Subjective

O = Objective (measurements & figures obtained through Oscillometrics and/or Plethysmography)

U = Undetermined

CHART #II

PATIENTS WITH OCCLUSIVE VASCULAR DISEASE
(Lower Extremities)

	I		II		III		IV		V	
PATIENT	S%	O%	S%	O%	S%	O%	S%	O%	S%	O%
1. A., G.	-	-	-	-	+	30	-	-	+	20
2. A., H.	0	10	-	-	-	-	-	-		
3. B., A. (Ulcer)	-	-	-	-	+	45	-	-	+	Heal
4. B., S.	0	10	+	60	-	-	-	-		
5. B., R.	0	20	+	35	+	20	+	25	+	0
6. B., S.	-	-	+	30	-	-	-	-		
7. B., L.	U	34	-	-	-	-	-	-		
8. B., C.	U	50	-	-	-	-	-	-		
9. B., G.	0	23	-	-	-	-	-	-		
10. B., F.	U	50	-	-	-	-	-	-		
11. C., O. (Paget's)	0	15	0	15	+	15	+	15	+	
12. C., H.	-	-	0	40	-	-	-	-		
13. C., G.	-	-	-	-	+	25	-	-	+	15
14. C., M.	-	-	-	-	+	40	-	-	+	10
15. De La T., O.	0	0	-	-	-	-	-	-		
16. D., O.	0	0	-	-	+	25	-	-	+	U
17. D., M	-	-	-	-	+	25	+	25	+	15
18. D., M.	-	-	-	-	+	25	-	-		
19. D., J.	-	-	-	-	+	10	-	-		
20. D., B.	-	-	U	0	-	-	-	-		
21. F., G.	-	-	+	30	-	-	-	-		
22. G., E.	0	44	-	-	-	-	-	-		
23. G., A.	0	20	-	-	-	-	-	-		
24. G., L.	-	-	+	30	+	30	+	40		

CHART #II

PATIENTS WITH OCCLUSIVE VASCULAR DISEASE
(Lower Extremities)

	I		II		III		IV		V	
PATIENT	S%	O%	S%	O%	S%	O%	S%	O%	S%	O%
25. G., M.	-	-	+	15	-	-	-	-	+	Walk
26. G., H.	0	0	0	0	-	-	-	-		
27. G., M.	0	20	+	0	-	-	-	-		
28. H., M.	0	0	U	50	-	-	-	-		
29. J., W.	-	-	+	30	-	-	-	-		
30. K., R.	-	-	+	25	-	-	-	-		
31. K., S.	-	-	-	-	+	-	-	-		
32. L., A.	-	-	U	40	-	-	-	-		
33. M., C.	0	10	0	10	+	15	+	20		
34. M., M.	0	10	-	-	-	-	-	-		
35. P., R.	0	30	+	30	+	30	-	-		
36. P., E.	-	-	0	30	+	30	+	40		
37. P., C.	-	-	+	30	+	35	+	25	+	20
38. P., L.	-	-	+	15	+	30	+	45		
39. P., M.	+	20	+	40	+	-	+	50		
40. R., P.	-	-	-	-	+	25	+	25	+	
41. R., R. -(Sciatic)	-	-	-	-	+	25	+	30	+	
42. R., J.	0	0	-	-	-	-	-	-		
43. S., J.	0	0	+	0	+	20	+	40		
44. S., W.	-	-	+	0	-	-	-	-		
45. T., H.	-	-	-	-	0	20	0	25		
46. V., S.	0	0	-	-	-	-	-	-		
47. V., J.	-	-	-	-	+	30	+	30	+	20
48. W., H.	-	-	0	25	-	-	-	-		

CHART #II

PATIENTS WITH OCCLUSIVE BASCULAR DISEASE
(Lower Extremities)

	I		II		III		IV		V	
PATIENT	S%	O%	S%	O%	S%	O%	S%	O%	S%	O%
49. Werksman, Ida	-	-	-	-			-	-	+	Walk
50. W., B.	-	-	-	-	+	30	+	30	+	20
51. Z., C.	0	0	+	34	+	34	-	-		

CHART #III

PATIENTS WITH VARICOSE ULCERS

1. C., J. — Ulcer healed completely after two (2) months of daily stimulation.

2. DM., G. — Ulcer healed, no recurrence.

CHART #IV

PATIENTS WITH RAYNAUD'S DISEASE

PATIENTS NAME	IMPROVEMENT SUBJECTIVE	OBJECTIVE
1. G., W.	20%	Variable
2. G., C. (Ulcerative Hodgkins Disease)	20%	0
3. M., C.	60%	40%
4. O., M. T. (Traumatic Accident)	60%	30%
5. G., I.	40%	60%
6. Sister B.	50%	50%
7. K., S.	20%	18%
8. M., M.	None	10%

PATIENTS WITH RAYNAUD'S PHENOMENOM

1. C., C. (Scleroderma - Ulcers)	20%	None
2. H., S. (Nerve Comp.)	90%	Normal

CHART #V

MISCELLANEOUS GROUP OF PATIENTS

PATIENT	DIAGNOSIS	ELECTRODE PLACEMENT
1. B., M.	Leriche's Syndrome Advanced Arteriosclerosis	T10
2. B., L.	Vasospastic	Cervical
3. DeJ., A.	Poss. Int. Claudication (Pending Special Test)	C6
4. D., R.	Poss. Int. Claudication (Pending Special Test)	T10
5. F., L.	Claudication (Walking Test)	T10
6. J., N.	Normal- Pilot (Treadm.)	Cervical
7. J., F.	Nerve Compression	T10
8. K., B.	Malabsorption	T10
9. L., M.	Vasospastic (Treadm.)	Cervical
10. P., F.	Vasospastic/Electric Shock	Cervical
11. P., R.	Poss. Int. Claudication (Pending Special Test)	Cerv./T-Lumbar
12. R., A.	Normal- Pilot (Treadm.)	Cervical
13. R., M.	Int. Claudication	C6 and T10
14. S., A.	Poss. Int. Claudication (Pending Special Test)	Cervical
15. S., S.	Poss. Int. Claudication (Pending Special Test)	Cervical
16. T., R.	Normal- Pilot (Therm.)	T10
17. V., M.	Normal- Pilot (Therm.)	Cervical
18. Y., F.	Hip Necrosis/Vas. Occlus. Post-Surgical	T10/Lumbar Local

CHART #VI

PATIENTS WITH HYPERTENSION

PATIENT	MEAN DROP PERCENTAGE mm Hg.	
	SYSTOLIC	DIASTOLIC
1. A., L.	14.8%	6.8%
2. A., M.	71.0%	71.0%
3. B., A. (OVD)	5.0%	8.0%
4. B., R. (OVD)	8.1%	5.1%
5. C., J.	71.0%	71.0%
6. C., M. (OVD)	6.5%	4.5%
7. D., M.	7.5%	5.4%
8. D., M. (OVD)	9.0%	3.0%
9. P., M. (OVD)	11.5%	3.0%
10. R., R. (OVD)	5.0%	4.0%
11. R., P. (OVD)	10.0%	3.0%
12. T., B.	12.0%	7.0%
13. V., J. (OVD)	71.0%	71.0%
14. W., B. (OVD)	10.0%	4.2%
15. Z., C. (OVD)	71.0%	71.0%

OVD = Occlusive Vascular Disease

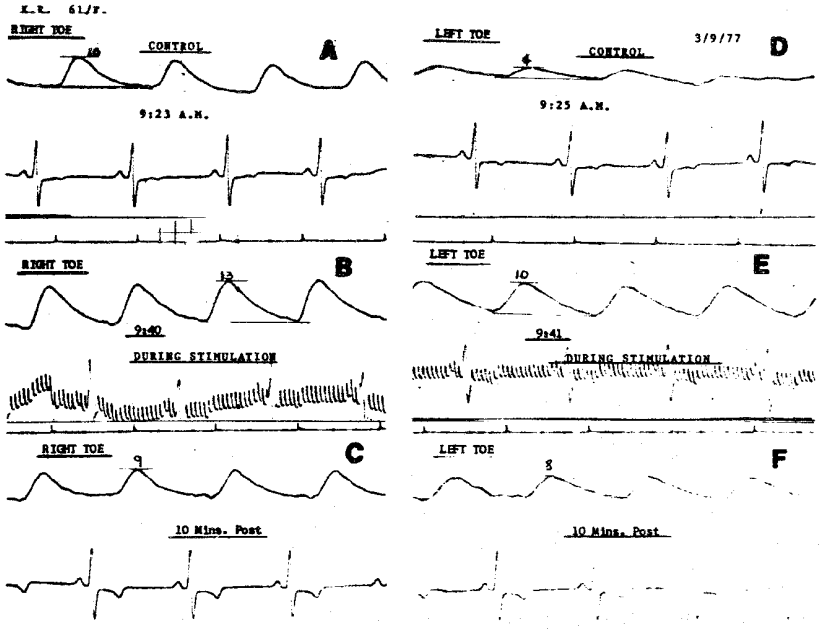

Figure 1: Plethysmographic tracing of patient K.R. with electro-stimulation T-10 through T-2.

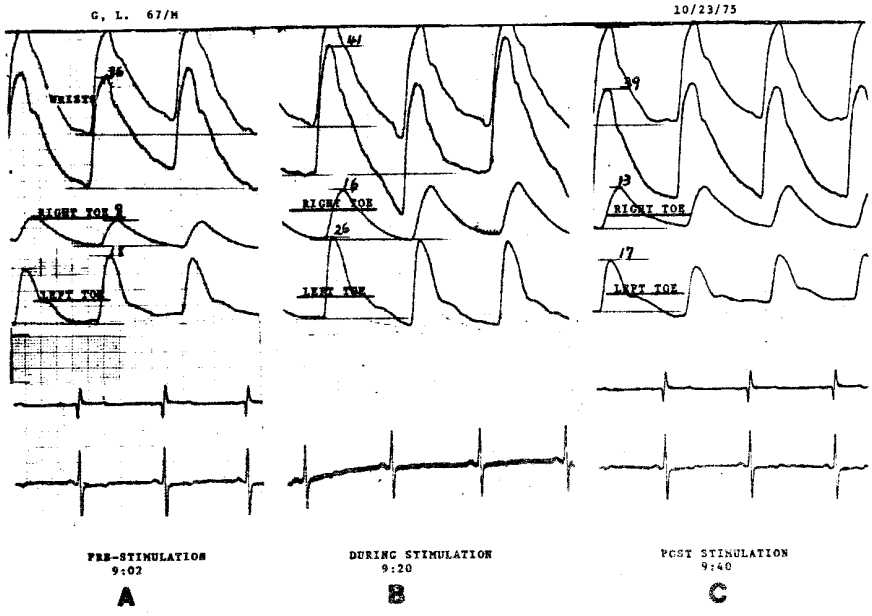

Figure 2: Plethysmographic tracing of patient G.L. with electro-stimulation at T10 - L2.

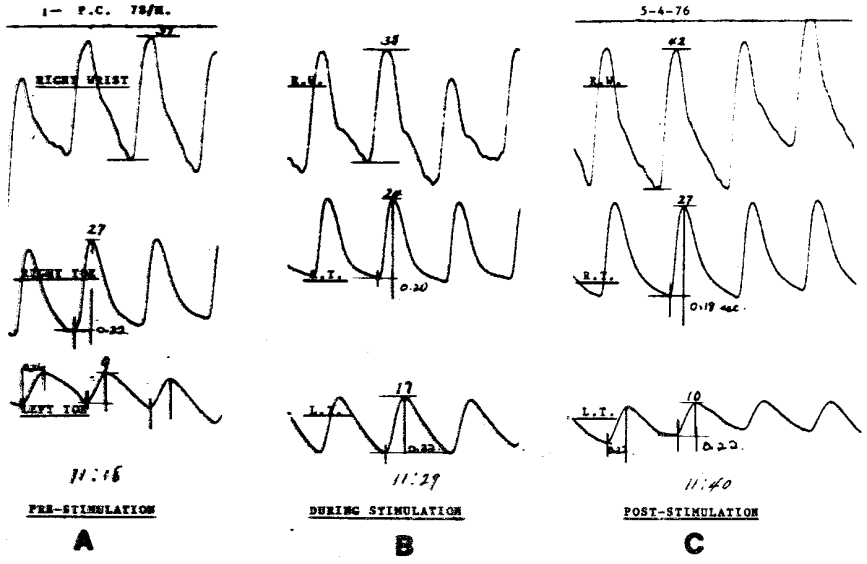

Figure 3: Plethysmographic tracing of patient P.C. during electrostimulation at T10 - L2.

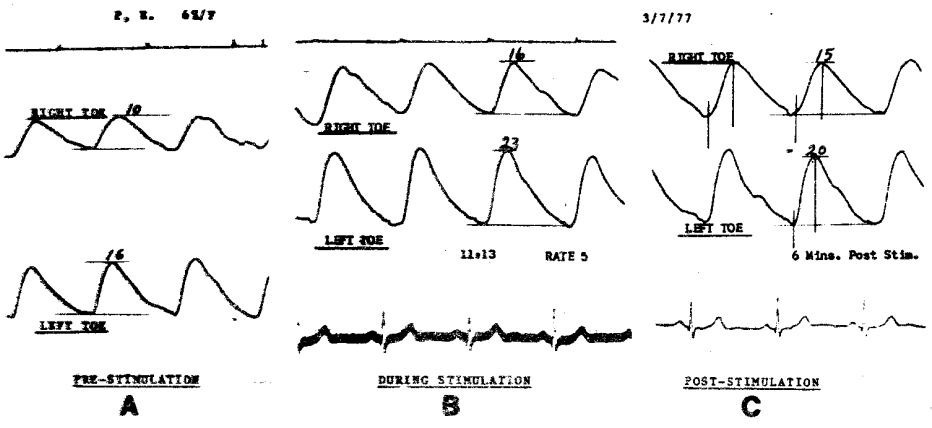

Figure 4A: Plethysmographic tracing of patient P.E. taken on 3/22/76.

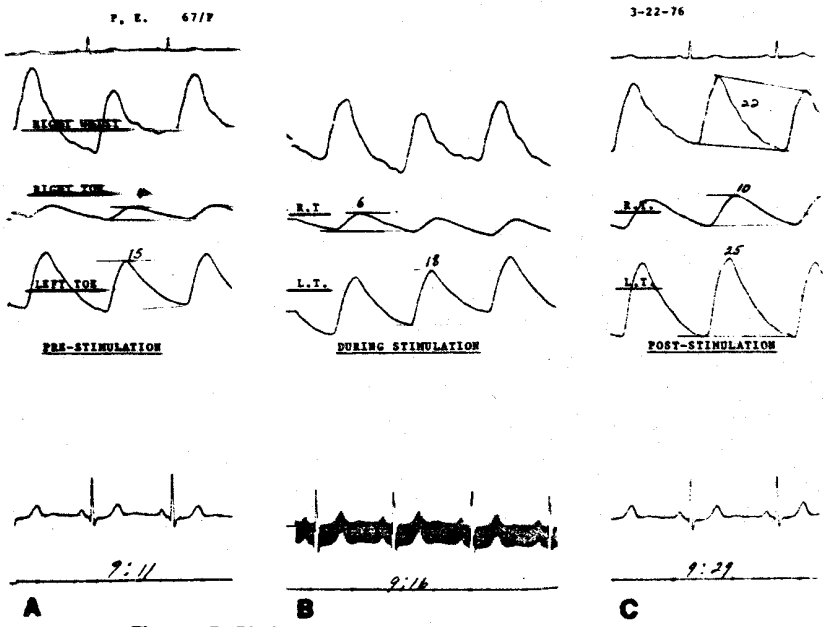

Figure 4B: Plethysmographic tracing of patient P.E. taken on 3/7/77.