REHAB Tech

Monash Rehabilitation Technology Research Unit

Skin Perfusion Behavoir in the posterior stump skin of a trans tibial amputee

Shaun Fealey

Supervisor
Dr Andrew Nunn

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REHAB *Tech*- Monash Rehabilitation Technology Research Unit
C/- C.G.M.C.
260 - 294 Kooyong Road
CAULFIELD VIC 3162
AUSTRALIA
Email rehab.tech@eng.monash.edu.au

The Skin Response study aimed to better understand changes in the re-perfusion behaviour of the small blood vessels in the posterior stump skin of a trans tibial amputee in weeks post operation. Using the Skin Pressure Monitor developed by previous Maskiell Research fellow, Tom Churchwood. Subjects were tested weekly over a 5 - 6 week period.

Hypothesis

- ◊ Baseline blood flow would be greater in stump than normal side in the initial phase of amputation.
- ◊ Hyperaemia would be greater in stump than normal side at least initially after amputation.
- ◊ This difference between the stump and the normal sides would reduce over time.

Results showed

- ◊ .Tendency for Hyperaemia to increase to a maximum with respect to baseline flow, between weeks 2 - 4 post operation, then a periodic decrease over following weeks to correlate with normal side.
- ◊ Blood flow and hyperaemia were variable week to week
- ◊ Caffeine and Nicotine vary both the Hyperaemic Response and Baseline blood flow.
- ◊ Pseudo ephedrine effects both the Hyperaemic Response and baseline blood flow.

INTRODUCTION

Skin Physiology

Blood flow to the skin has two functions

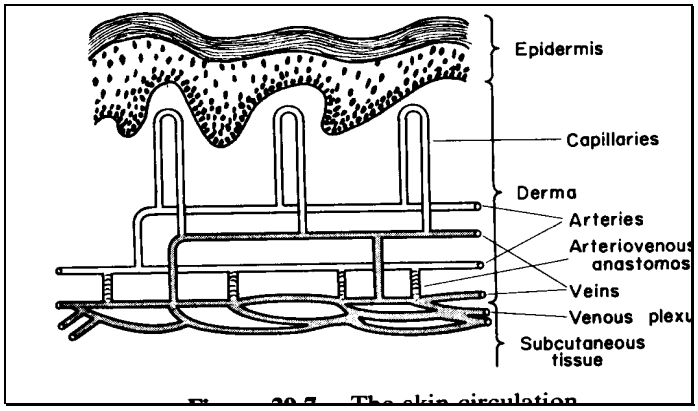

fig 1 *The Skin Circulation*

Regulation of blood flow

Blood flow can vary from as little as 50ml per minute in severe cold to 2 - 3 litres per minute in extreme heat, through regulation of vascular structures in subcutaneous tissue

Supplying Nutrition

Normal blood flow greatly exceeds the required amount to supply nutrition. This function does not alter blood flow.

Concept of Reactive Hyperaemia

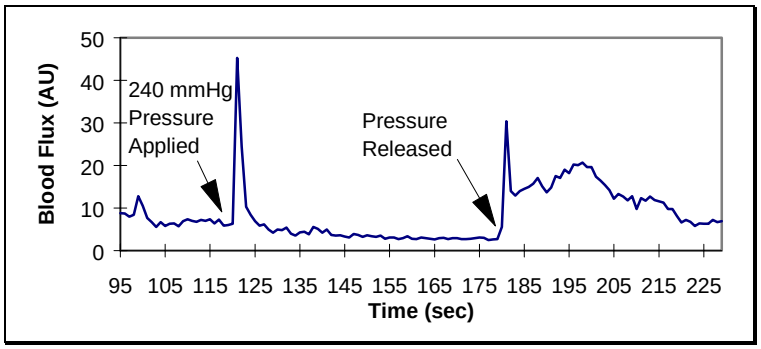

Fig 2 *Typical Reactive Hyperaemic Response Observed*

When an area of tissue is compressed so hard that blood is forced out of small vessels suppling the skin. The lack of blood rejuvenation creates a build up of CO_2 and Lactic Acid. This in addition to neural effects bought on by the compression, creates an exaggerated influx of blood when pressure is released, coursed directly by the dilation of smaller vessels and the constriction of larger vessels. This provides skin with the blood supply required to regain homeostasis.

Relevance to Prosthetic Industry

The re- perfusion of skin is of particular importance in the Prosthetic Industry as amputees commonly suffer from pressure related complications. A better understanding of how re - perfusion is affected by the amputation, and the period needed for recovery, and vulnerability of a particular individuals skin to load would assist in the amputee management, and provide a potiental stress test for skin.

DRT4 and Instrumentation

Laser Doppler Perfusion and Temperature Monitor

The DRT4 is a dual channel Laser Doppler Perfusion and Temperature Monitor. It incorporates Laser Flowmetry to measure local blood flow, speed or concentration at two separate sites simultaneously. Skin temperature can also be measured simultaneously at the same site.

Laser Doppler Flowmetry

Laser Flowmetry is a noninvasive method of blood flow measurement. A low powered laser is emitted to the skin at a set frequency through an optic fibre, where the frequency is altered by the concentration and speed of the blood cells it contacts. A beam is returned to the monitor via another optic fibre and the change in frequency used to calculate blood flow.

Skin Pressure Monitor

[Original Set up see Appendix 2.]

Modifications of Original set up

Stand was discarded, and arm rest was clamped to an adjustable table.

Criteria for change

- *Measurement of specific site*
- *Reduction of movement of area tested and fibre optic probe movement artifact.*

Measurement of specific site.

All subjects were of different size with different length stumps. Initial stand had been designed for use on a wide range of sites. With a specific site to test protocol was able to be improved.

Adjustable table enabled all subjects to remain in their wheelchairs while being tested.

Test Protocol

- ***Wheelchair position in front of table***
- ***Subject stump placed on rest plate and positioned directly over probe.***
- ***Table height adjusted so probe and stump were at 90°.***

Reduction of Movement

Laser Doppler Flowmetry is extremely sensitive to movement. To obtain accurate results both probe and subject had to be as stationary as possible.

Movement was reduced in 2 ways.

- ***Enabling patient to stay in wheelchair meant they stayed comfortable and could remain still longer.***
- ***Probe and rest plate clamped to a solid base meant probe remained still.***

METHODS

◊ *Selection*

Subjects were chosen from the CGMC Rehabilitation ward. All were trans tibial amputees in the first weeks post amputation. Subjects were chosen irrespective to age and sex, with medical conditions such as diabetes and pulmonary vascular disease noted.

◊ *Protocol*

As a participant, subjects were tested at the same site at the same time weekly for a period of 4 - 6 weeks. An infrared tympanic thermometer was used to measure skin and room temperature before each test.

A. Pressure Response

◊ *Test Protocol*

1. *Stump placed on probe*
2. *Baseline monitored for 100 seconds*
3. *240 mm Hg pressure applied for 60 seconds*
4. *Pressure released*
5. *Hyperaemic response recorded for 30 seconds*
6. *3 - 5 repeated three times*
7. *1 - 6 repeated on normal leg*

◊ *Analysis*

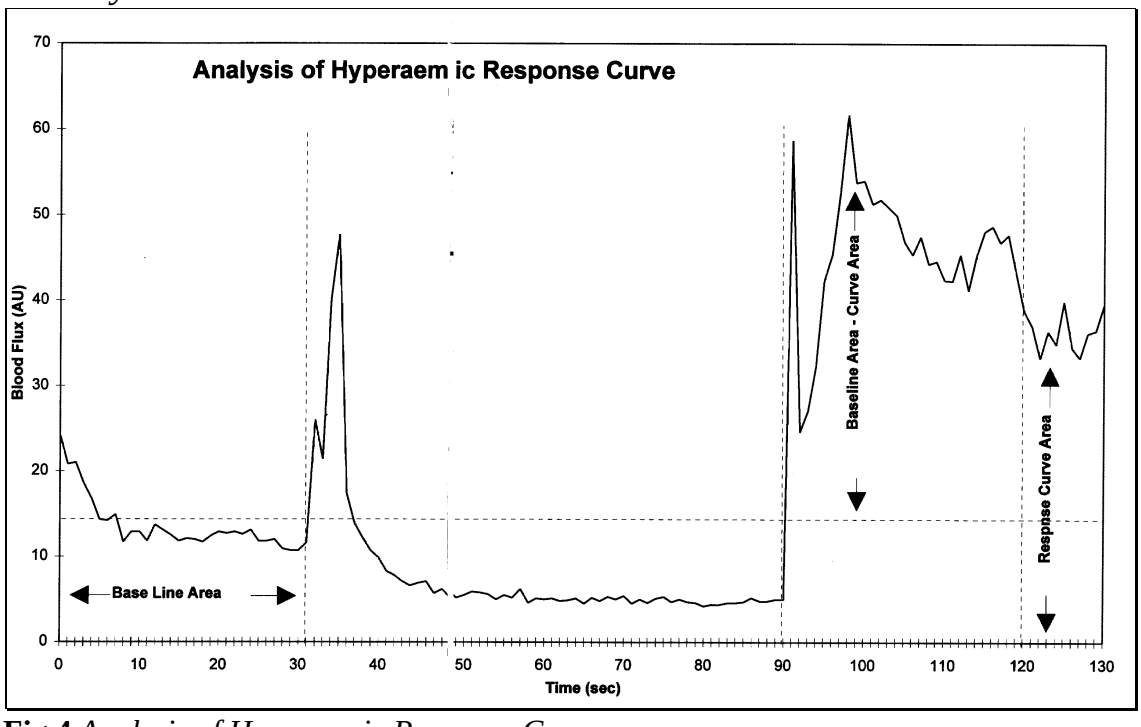

Fig 4 *Analysis of Hyperaemic Response Curve*

Using DRTSOFT the following were calculated from respective 30 second time slices

- Mean Baseline Blood Flow
- Baseline Area
- Response Curve Area

To find the most useful representation of the hyperaemic response recorded two calculations were recorded

- Response curve area
  [Average of the three 30 second response curves recorded
- Response Curve Area - Baseline Area
  [Above value minus Baseline Blood Flow Area]
  [See Fig 4]

For direct comparison between sides a ratio of stump side with respect to normal side was produced. This made observation of changes simpler

- Ratio less than one
  ⇒ *Normal side greater than Stump side*
- Ratio equal to one
  ⇒ *Normal side equal to Stump side*
- Ratio greater than one
  ⇒ *Normal side less than Stump side*

Two final ratios were calculated

- Response Curve Area / Baseline Area
  ⇒ *[R / B]*
- (Response Curve Area - Baseline Area) / Baseline Area
  ⇒ *[(R - B) / B]*

These gave a better idea of the relationship of baseline to response irrespective of the values which tended to vary week to week.

Table 1 *Example of Analysis Spreadsheet*

	Baseline	Baseline Area	Area Curve 1	Area Curve 2	Mean Area	Diff B/w areas	(Cu-Ba)/Ba	Curve/Base
Sub1AmpR	14.90	448.00	766.70	697.50	732.10	284.10	0.63	1.63
Sub1NormL	8.90	267.60	387.10	333.80	360.45	92.85	0.35	1.35
Amp/Norm	1.67	1.67	1.98	2.09	2.03	3.06	1.83	1.21
Sub2AmpR	5.10	151.80	379.80	310.40	345.10	193.30	1.27	2.27
Sub2NormL	5.80	174.50	228.20	221.40	224.80	50.30	0.29	1.29
Amp/Norm	0.88	0.87	1.66	1.40	1.54	3.84	4.42	1.76

Selected results were then plotted for each subject against weeks post amputation, and comparisons made.

Problems

The position of the subject and the probe stand during testing proved to be of great importance.

Two factors

1. Angle of Probe

For accurate results it was found extremely important that the site being tested was at right angles with the probe. If this was not the case the site at which pressure was applied and that of the measurement were separate. If this was the case an increase in flow was witnessed when pressure was applied, and response curve was not witnessed at all

2. Movement of Patient and Probe

Previously mentioned.

Repeatability of Test Protocol.

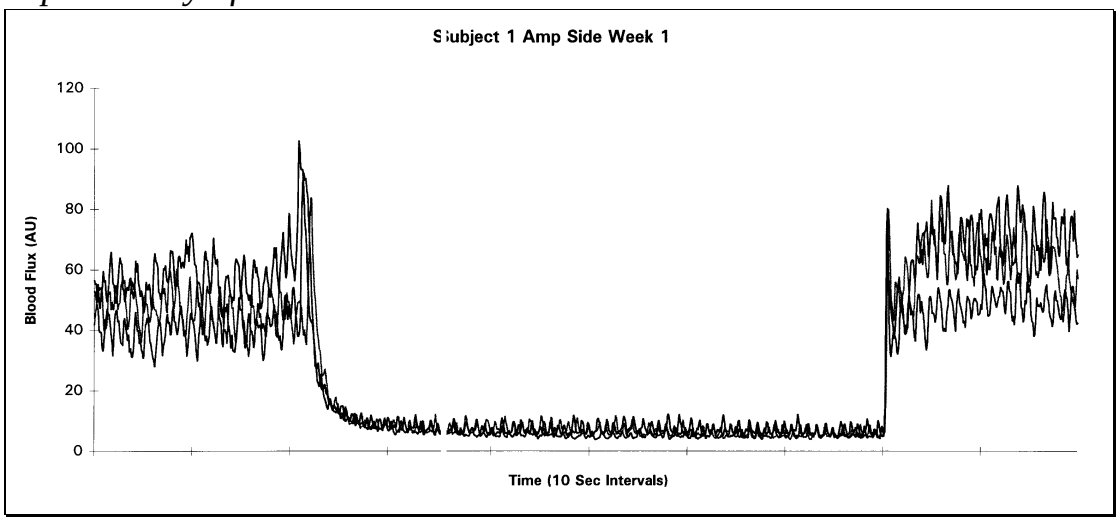

Fig 5 *Overlay of 3 consecutive Pressure Tests trials*

As demonstrated in fig for all 6 subjects in this study (+ 9 subjects in a prior study) were consistent on 3 consecutive trials on the same day. Variations day to day will be discussed.

Other Tests Performed

B. Caffiene Tests

Following earlier work showing fluctuation in other amputee subjects tested after tea, coffee, and cigarettes, a study was performed on three subjects (21,22,24 yrs, 2 male 1 female) to study the effect.

Caffeine Test Protocol

1. Baseline Blood Flow 30 seconds each leg
   [same test site as pressure test.]
2. nodose 100mg pure caffeine tablet ingested
3. Step 3 - 5 of ***test A*** protocol on each leg at 5 minute intervals

Pulse rate was taken at each 5 minutes interval to determine whether increase cardiac output was the contributing factor.

C. Nicotine Tests

Nicotine Test Protocol

1. Baseline Blood Flow 30 seconds each leg
   [same test site as test A.]
2. *10 mg cigarette ingested.*
3. Step 3 - 5 of ***test A*** protocol on each leg at 5 minute intervals.

RESULTS

A. PRESSURE TEST ON AMPUTEES

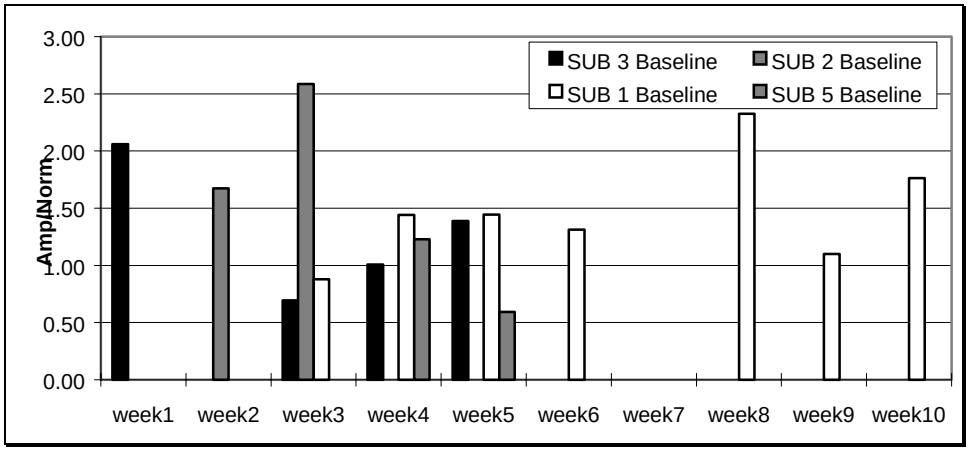

Fig 6 *BaselineBlood Flow Vs Post Weeks Amputation*

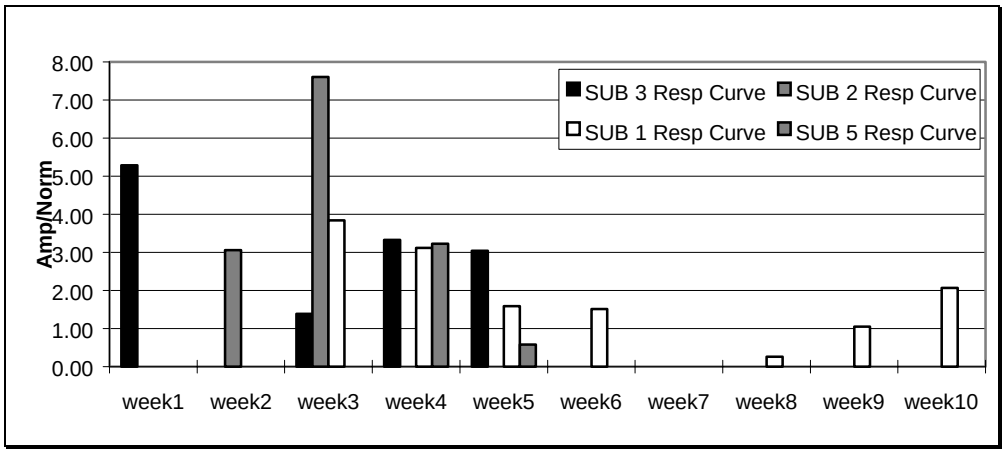

Fig 7 *Response Curve Area Vs Post Weeks Amputation*

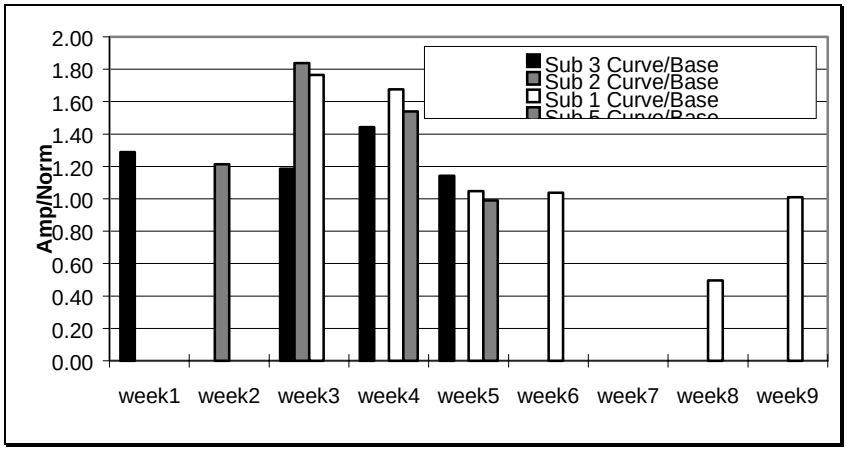

Fig 8 *Curve Area / Baseline Area Vs Weeks Post Amputation*

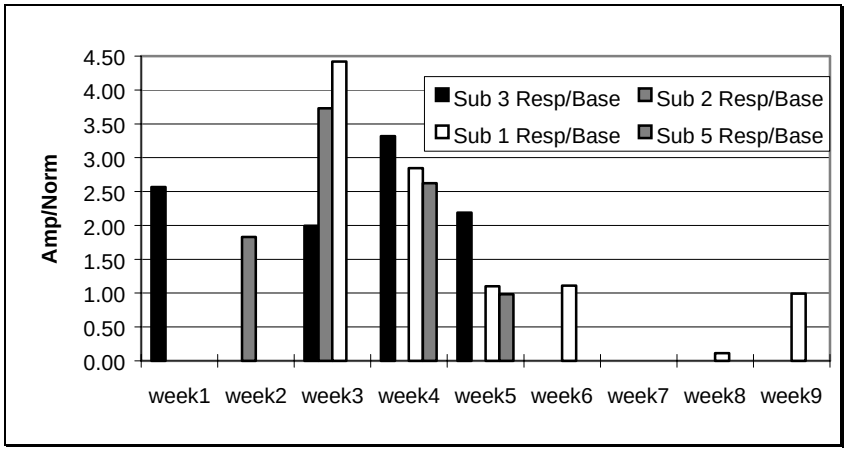

Fig 9 *Response Curve / Baseline Vs Weeks Post Amputation*

As discussed variation occurred day - day, not unexpectedly given the multiple local and particularly environmental variables. As such variation in baseline needed to be accounted for, the comparison was drawn between the amputated and intact side for a given individual.

There was a overall trend in figs 6 - 9 plotting results against weeks post amputation. All involved peaking of the response between weeks 2 - 4.

The baseline blood flow over time fig 6 showed a similar trend.
The area response curve fig 7 was similarly increased.

Only one subject (3) was tested in the first week post amputation with elevated responses immediately post operatively. figs 6 - 9

The response in subject 1 at weeks 8 - 9 did not follow the pattern, but coincided with stump inflammation due to infection and wound breakdown.

B. Effects of Caffeine On Normal Subjects

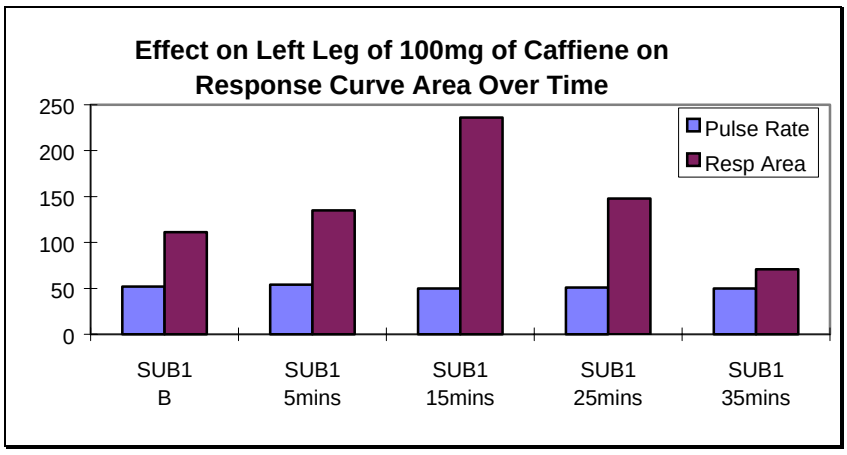

Fig 10 *100 mg Caffeine Affect On Response Curve Area*

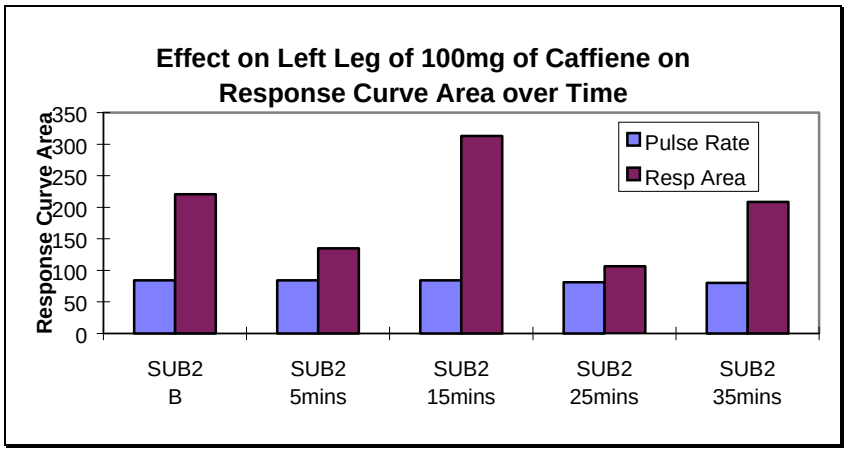

Fig 11 *100 mg Caffeine Affect On Response Curve Area*

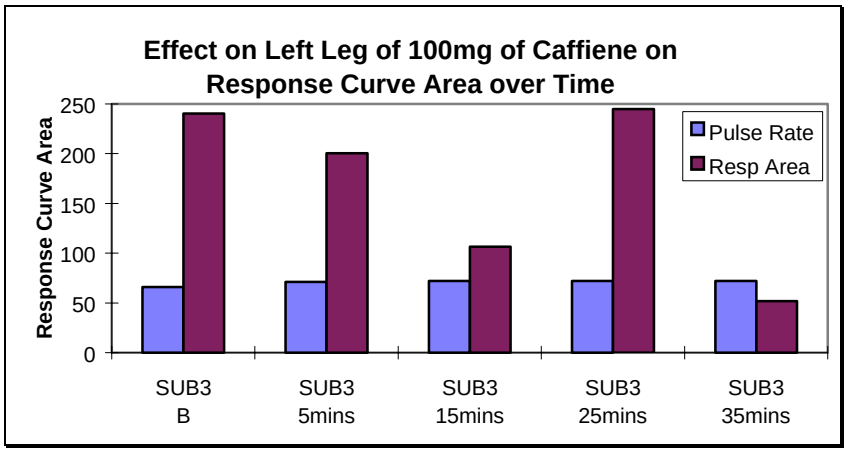

Fig 12 *100 mg Caffeine Affect On Response Curve Area*

An increase in blood flux observed in all subjects lasted approximately 30 minutes peaking at 15 minutes. fig 10 - 12

Radial pulse rate did not increase significantly.

C. EFFECTS OF NICOTINE

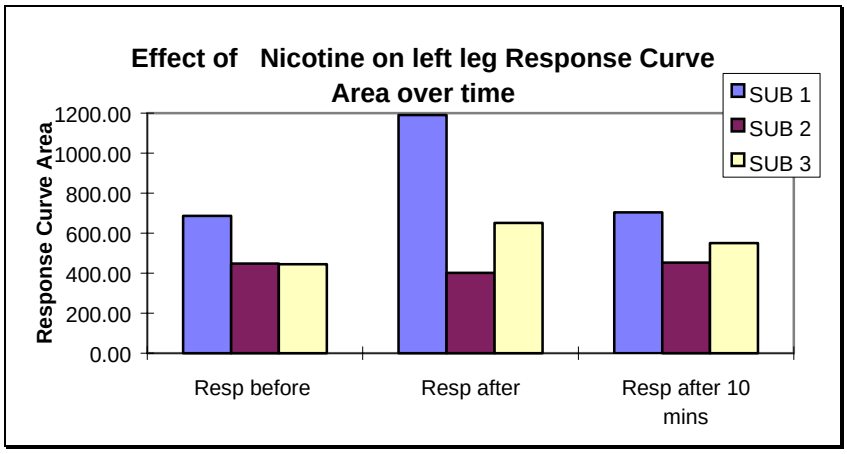

Fig *Effect Of Nicotine on Response Curve Area Over Time*

Similarly nicotine effect has been shown in prior studies and has confounded at prior studies. The study of 3 subjects showed the most marked increase in subject 1 a smoker.

D. Effect of PseudoEphedrine

2 subjects in a prior study did not follow the trend were on PE 60 mgms TDS for phantom pain. The effect on this alpha agonist was variable but significantly altered responses.

DISCUSSION

A. Pressure Test On Amputees

The increase and peaking blood flow in the 2 - 4 week period may reflect changes in the balance between sympathetic and parasympathetic influences on vasomotor tone and needs further work.

B.Caffeine Effect

Results indicated an increase in blood flux in two normal subjects consistent with prior results which appeared to be independent of heart rate and possibly a peripheral action of caffeine on acetyl choline receptors. This may have implications for not only confounding study results, but also may be helpful in increasing peripheral blood flow where appropriate.

C. Effects Of Nicotine

Again Nicotine increased the peripheral blood flux with the smoker possibly having sensitised nicotinic receptors and greater response.
The time course was a peak response at 5 minutes with return to baseline in approximately 10 minutes.

D. Effect of Pseudoephredrine.

Both subjects were on PE for phantom pain and significant hyper algesia with some effect and further raises the possibility of its action on sympathetically mediated responses in this case in the posterior flap of tran tibial amputees with the stump more affected than the normal leg.

CONCLUSION

The development of the PPR Monitor and the results in this pilot project suggest that reactive hyperaemia occurs and then reduces post amputation

Appendix 1

SUBJECT 1

	Baseline	Baseline Area	Mean Area	Diff B/w areas	(Cu-Ba)/Ba	Curve/Base
Sub1AR1	5.10	151.80	345.10	193.30	1.27	2.27
Sub1NL1	5.80	174.50	224.80	50.30	0.29	1.29
A/N	0.88	0.87	1.54	3.84	4.42	1.76
Sub1AR2	7.2	162.9	431.10	268.2	1.65	2.65
Sub1NL2	5	148.7	234.75	86.05	0.58	1.58
A/N	1.44	1.10	1.84	3.12	2.85	1.68
Sub1AR3	7.80	233.20	459.80	226.60	0.97	1.97
Sub1NL3	5.40	162.00	304.85	142.85	0.88	1.88
A/N	1.44	1.44	1.51	1.59	1.10	1.05
Sub1AR4	6.70	202.50	314.50	112.00	0.55	1.55
Sub1NL4	5.10	149.00	223.20	74.20	0.50	1.50
A/N	1.31	1.36	1.41	1.51	1.11	1.04
Sub1AR5	10.70	320.00	367.70	47.70	0.15	1.15
Sub1NL5	4.60	138.20	320.05	181.85	1.32	2.32
A/N	2.33	2.32	1.15	0.26	0.11	0.50
Sub1AR6	7.1	212.2	469.9	257.70	1.21	2.21
Sub1NL6	6.1	182.7	245.3	62.60	0.34	1.34
A/N	1.16	1.16	1.92	4.12	3.54	1.65
Sub1AR7	10.40	312.40	493.12	180.72	0.58	1.58
Sub1NL7	5.90	175.80	263.15	87.35	0.50	1.50
A/N	1.76	1.78	1.87	2.07	1.16	1.05

SUBJECT 2

	Baseline	Baseline Area	Mean Area	Resp area	(Cu-Ba)/Ba	Curve/Base
Sub2AR1	14.90	448.00	732.10	284.10	0.63	
Sub2NL1	8.90	267.60	360.45	92.85	0.35	1.35
A/N	1.67	1.67	2.03	3.06	1.83	1.21
Sub2AR1	22.50	530.20	1404.90	874.70	1.65	2.65
Sub2NL1	8.70	260.30	375.30	115.00	0.44	1.44
A/N	2.59	2.04	3.74	7.61	3.73	1.84

SUBJECT 3

	Baseline	Baseline Area	Mean Area	Resp Curve	(Cu-Ba)/Ba	Curve/Base
Sub3AR1	7	211.1	333.75	122.65	0.58	1.58
Sub3NL1	3.4	102.5	125.7	23.20	0.23	1.23
A/N	2.06	2.06	2.66	5.29	2.57	1.29
Sub3AR2	6.1	183.7	268.1	84.4	0.46	1.46
Sub3NL2	8.8	264.2	325.1	60.9	0.23	1.23
A/N	0.69	0.70	0.82	1.39	1.99	1.19
Sub3AR3	11.8	352.5	628.55	276.05	0.78	1.78
Sub3NL3	11.7	351.2	434.1	82.90	0.24	1.24
A/N	1.01	1.00	1.45	3.33	3.32	1.44
Sub3AR4	9.30	280.00	363.75	83.75	0.30	1.30
Sub3NL4	6.70	201.40	228.90	27.50	0.14	1.14
A/N	1.39	1.39	1.59	3.05	2.19	1.14

SUBJECT 4

	Baseline	Baseline Area	Mean Area	Resp Curve	(Cu-Ba)/Ba	Curve/Base
Sub4AL1	6.00	178.70	314.60	135.90	0.76	1.76
Sub4NR1	6.00	178.90	254.00	75.10	0.42	1.42
A/N	1.00	1.00	1.24	1.81	1.81	1.24
Sub4AL2	16	478.6	584.9	106.3	0.22	1.22
Sub4NR2	11	330.3	479.55	149.25	0.45	1.45
A/N	1.45	1.45	1.22	0.71	0.49	0.84
Sub4AL3	11.40	341.00	486.05	145.05	0.43	1.43
Sub4NR3	13.50	405.40	669.50	264.10	0.65	1.65
A/N	0.84	0.84	0.73	0.55	0.65	0.86

SUBJECT 5

	Baseline	Baseline Area	Mean Area	Resp Curve	(Cu-Ba)/Ba	Curve/Base
Sub5AR1	15.6	467.5	1081.3	613.8	1.31	2.31
Sub5NL1	12.7	379.9	570	190.1	0.50	1.50
A/N	1.23	1.23	1.90	3.23	2.62	1.54
Sub5AR2	7.4	222.2	412.35	190.15	0.86	1.86
Sub5NL2	12.5	376.4	703.85	327.45	0.87	1.87
A/N	0.59	0.59	0.59	0.58	0.98	0.99

SUBJECT 6

	Baseline	Baseline Area	Mean Area	Resp Area	(Cu-Ba)/Ba	Curve/Base
Sub6AL1	5.60	168.50	181.95	13.45	0.08	1.08
Sub6NR1	3.90	115.70	149.75	34.05	0.29	1.29
A/N	1.44	1.46	1.22	0.40	0.27	0.83
Sub6AL2	7.30	218.80	409.50	190.70	0.87	1.87
Sub6NR2	3.90	116.50	126.70	10.20	0.09	1.09
A/N	1.87	1.88	3.23	1.87	9.95	1.72
Sub6AL3	11.20	335.80	365.20	29.40	0.09	1.09
Sub6NR3	4.90	148.00	141.50	-6.50	-0.04	0.96
A/N	2.29	2.27	2.58	4.52	1.99	1.14
Sub6AL4	13.7	409.9	664.45	254.55	0.62	1.62
Sub6NR4	8.7	260.9	314.60	53.70	0.21	1.21
A/N	1.57	1.57	2.11	4.74	3.02	1.34
Sub6AL5	9.30	277.90	623.80	345.90	1.24	2.24
Sub6NR5	11.70	351.50	515.30	163.80	0.47	1.47
A/N	0.79	0.79	1.21	2.11	2.67	1.53

SUBJECT 7

	Baseline	Baseline Area	Mean Area	Resp Curve	(Cu-Ba)/Ba	Curve/Base
Sub7AR1	5.7	169.5	306.9	137.40	0.81	1.81
Sub7NL1	6.2	185.3	229.65	44.35	0.24	1.24
A/N	0.92	0.91	1.34	3.10	3.39	1.46
Sub7AR2	4.4	133.1	348.2	215.1	1.62	2.62
Sub7NL2	5.2	155.1	274.3	119.2	0.77	1.77
A/N	0.85	0.86	1.27	1.80	2.10	1.48
Sub7AR3	7.20	215.00	489.30	274.30	1.28	2.28
Sub7NL3	4.20	125.40	238.40	113.00	0.90	1.90
A/N	1.71	1.71	2.05	2.43	1.42	1.20

Appendix 2
Skin Pressure Monitor