Draft P.I. Presentation

LEG BLOOD FLOW
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There can be little doubt of the primary role played by the lower limbs in LBNP induced changes or for that matter in tilt tests. Altered blood flow in these areas may well play a major role in altered exercise response after return to one-g.

Several mechanisms could act to reduce venous flow from these areas. First, of course, active (local, neurological and hormonal) and passive venous compliance may be altered under weightlessness. This passive compliance may be extrinsic as intrinsic. For example, the pressure on superficial veins by supporting structures is probably altered by changes in bulk and composition of surrounding tissue. Deep veins may be affected by muscle tone and active tension, as well as by changes in tension from variations in enclosed volume and composition; e.g., muscle loss or replacement by fat. In active exercise under one-g, reduced muscle forces and size may also reduce the effectiveness of muscle pumping.

As an attempt to document changes, some of these studies were started inflight on SL-3 to measure the change incircumference of the leg produced by a brief period of isometric contraction during exposure to a period of LBNP. Such contractions in many normal subjects usually expel a large part of the accumulated blood, or at least produce a drop-in calf circumference, usually to near the baseline established prior to exposure to decreased pressure.

Also of general interest are changes in leg arterial blood flow during exposure to weightlessness. A standard method of blood flow measurement temporarily occludes venous outflow from a limb segment by a low pressure cuff. Since arterial flow is relatively unhindered, blood collects in veins. A plethysmograph is used to measure this change in volume, and when related to time a flow may be calculated. There are many potential sources of error in this measurement, especially in absolute terms; but it has become a standard method. Experiment M092 uses a capacitance leg segment volume indicator, and this combined with blood pressure cuff occlusion of the leg above the knee allowed collection of inflight and postflight data for study. It is apparent that only relative flow measurements can be obtained; i.e., absolute values will be no better or worse than knowledge of absolute volume changes. These two studies were combined and usually performed after completion of M092 inflight during the latter part of SL-3. Two postflight studies have been made on each crewman.

Methodology - Muscle Pump Studies - With the crewmember in the LBNPD, LVMS bands were placed on both legs and calibrated; i.e., the left band was left in place, and the right removed from its adapter and used on the leg. Eight and sixteen mm, Hg negative pressure was applied respectively for 1 minute periods, and then pressure was lowered to -30 mm Hg. Three minutes later the crewman makes a maximum isometric contraction for 2 seconds without valsalva or movement. He relaxes and 45 seconds later repeats the procedure. At the end of this time pressure is dumped, a zero is established and calibration is repeated.

Records and Analysis - This procedure was performed two times by each crewmember inflight after MD-50 and at R+5 and R+9. Right leg records made with bands that are normally used as zero references have been uniformly bad. Conversely, most recordings using the left leg and normally used bands were good with only occasional obvious artifacts. There were inflight cal problems in some records, and not all data has been received. Only strip charts for monitoring have been received from postflight measurements to data, and amplitudes are too low and speeds too high for optimum reduction.

Reduction and Results - These must be considered preliminary, but measurements have been taken from some records as follows. Figure 1 is an inflight record of the left leg of the SPT on his first attempt at this procedure. Figure 2 is a ground record of the PLT on R+5 at much higher chart speed. The inscription of the maneuver is characteristic with an upward deflection, assumed to be muscle shortening, followed by a drop to some lower value considered to be the volume reduction caused by muscle pumping action. Inflight the initial contraction was frequently followed by a small overshoot. At first this overshoot was thought to be a mechanical artifact, and this impression was enhanced by the digital plotter, however, a baseline through the mean signal level as in Figure 1a shows the true situation. This overshoot may represent reactive hyperemia since contractions usually lasted 4 seconds or more rather than 2. So far the only analysis that has been attempted was measurement of reduction of volume in terms of percentage of limb volume; i.e., in terms of the same calibration as used on M092, and as a percentage of the volume change produced by exposure to 30 mm Hg. See Figure 2. Some results are shown in Table 1.

Inflight CDR contractions produce an effect too small to be seen, except for the increased volume from the contraction itself. It appears that the effects are larger postflight, but the reduced amplitudes of the monitor tapes make measurement impossible. Proper records should be available shortly. With the exception of the SPT's 2nd effort on R+9, the other results were reasonably consistent, though the available postflight records are difficult to read even with magnification. Unfortunately, or possibly fortunately, the SPT gave results both different from the PLT and from those expected. His ability to remove blood from the legs decreased sharply postflight, although the percentage removed was relatively constant. Conversely, the PLT removed approximately the same amount inflight as postflight, but a much larger percentage of the accumulated blood postflight.

Methodology - Blood Flow Studies - Prior to entering the LBNPD a standard arm cuff was placed around the subject's left leg above his knee. He then entered the device, and a LVMS band was placed on this leg at the point of maximum calf girth. This was zeroed and calibrated, and the cuff was rapidly inflated to 30 mm Hg and held at this pressure for 2 minutes.

Pressure was then released and after 1 minute, zero and calibration are checked and recorded and pressure reapplied for 2 more minutes. At the end of this time pressure is released and zero and calibration are again recorded.

Records and Analysis - Four inflight records were obtained with usually good results. Records for the SPT are missing at this time. There were some initial calibration difficulties. Postflight recordings were made at R+5 and R+9, but this data has not been received in a usable form. The monitor charts are too compressed to be used, and only "major medical experiment" records are being processed at this time. Typical inflight recordings are shown in Figure 3 and 4. Slope is obtained by approximating the initial linear portion by a straight line. The only value which can be assigned is relative, in this case change in percentage of leg volume with time. Although visual approximation of line slopes can be risky, two different individuals drew separate slopes to each flow curve whose value is shown in Table 2. As soon as possible they will be machine calculated from original digital data. In addition to the occluded flow curves, the initial slope (i.e., just after application of negative pressure) of the muscle pump curves were also approximated.

Discussion - With one exception which has yet to be accounted for, the slopes appear surprisingly consistent, especially on the second attempt at this procedure. I will be willing to assign absolute flow values to the data with confidence whenever anyone can show me the relation between the segmental volume sensor and the entire leg. Probably of more interest than "flow" from this test are the inter-subject comparisons and comparison to the same data produced by application of negative pressure to the limb. The latter were remarkably consistent on the 2^{o} series of tests. Although only 8 mm of Hg is initially applied, there is an appreciable period before it becomes alinear; and after application of another change of negative pressure, it again becomes linear and of the same slope. This is often repeated at the 16 to 30 mm pressure step as well. If this relationship should be shown to hold, as indeed it theoretically should, then the transient portions of small lower body negative pressures can provide flow data; e.g., routine M092 records hold this information. Although there was a marked difference in leg size which coupled with an arm cuff would produce differences in leg pressures between PLT and CDR, with earlier runoff in the PLT's veins, there is also another possibility. A simple model of this flow arrangement has a large compliance in parallel with a resistance. A second low resistance becomes active at some pressure threshold. Such a model has an exponential volume curve. Differing compliances will produce a curve with markedly different initial approximations of linearity[1]. Anyone familiar with such curves cannot help but note the comparison of the PLT's short time constant; i.e., less compliant volume reservoir to that of the long linear segment of the CDR. This could also explain the virtual absence of a pumping effect in the case of the CDR, especially when one is familiar with their anatomical differences. If this apparent difference

[1]This is the familiar RC curve in electricity.

in compliance is true, it should have predictable physiological implications. What is now needed is a larger study population with good preflight measurements and indoctrination. It is hoped that at least one more postflight record will be obtained from SL-3, and that complete records will be obtained from SL-4. Further, the detailed transient portions of M092 records for these subjects should be correlated with this data.

Although these studies may not yield independent answers to disturbed leg flow patterns, there is obvious reason to believe that they will aid in the next crucial step of the study of men in space, investigation and measurement of the mechanisms of altered response.

Dr. Hoffler and others of the M092 team performed postflight studies and made this portion possible. It is hoped that this study can be integrated with M092.

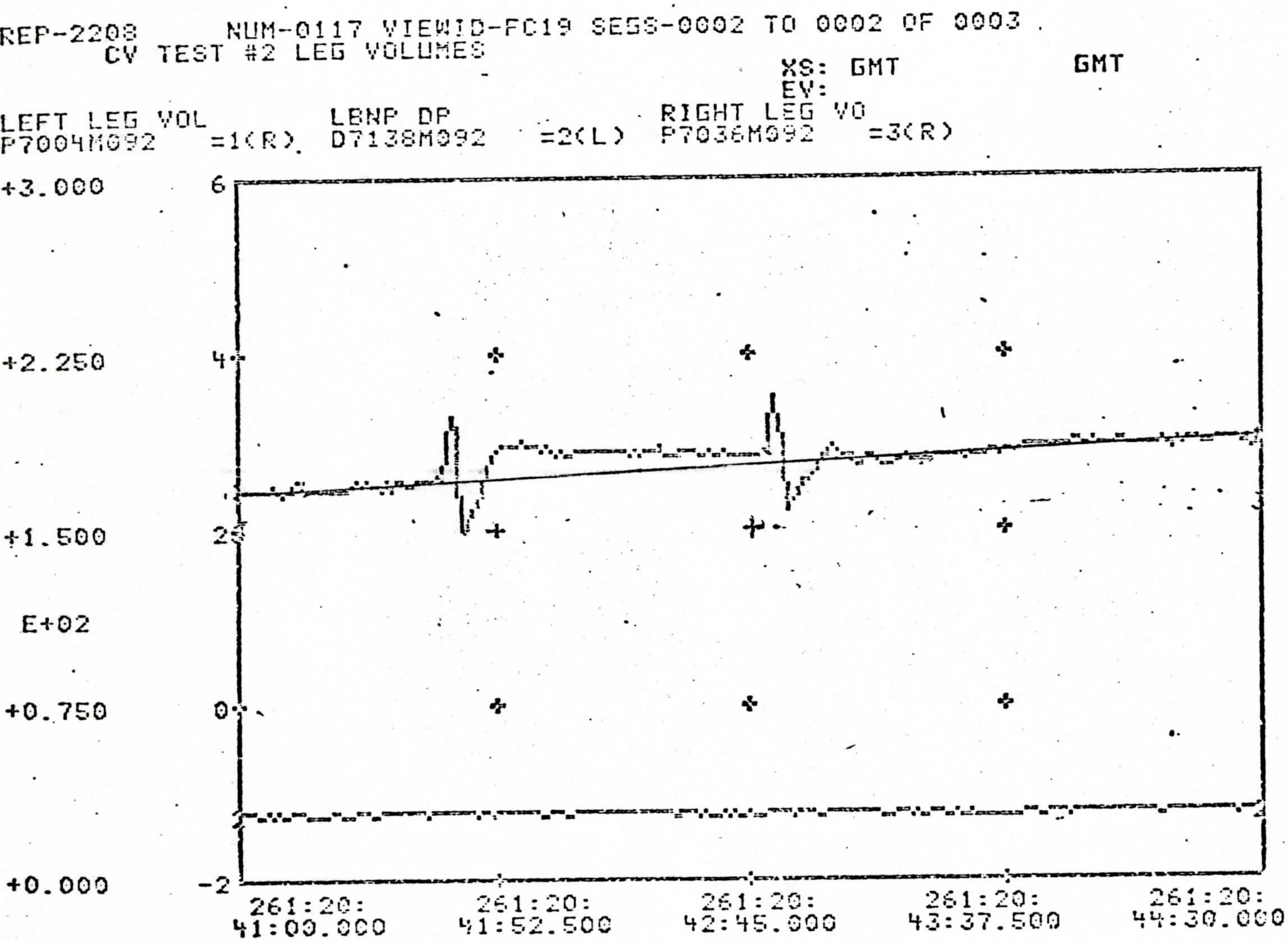

Figure 1a - Same as 1 except a mean volume line has been added to show slow drift and overshoot.

TABLE 1

MUSCLE PUMP EFFECTS

SUBJECT	DATE	TOTAL VOLUME %	VOL. %	% VOL./TOTAL VOL.
SPT				
	MD-51-1	2.6	.6	23
	2	2.8	.6	30
	R+5-1	1.2	.33	28
	2	1.2	.47	39
	R+9-1	1.55	.46	30
	2	1.32	1.03	77(?)
PLT				
	MD-57-1	2.2	1.1	50
	2	2.4	.64	26
	R+5-1	.98	.98	100
	2	1.11	.86	78
	R+9-1	1.22	.98	81
	2	1.1	.79	72

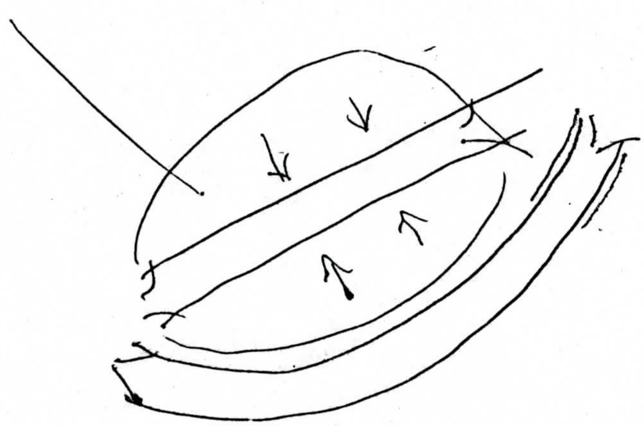

TABLE 2

SUBJECT	MD	TEST	TRIAL NUMBER	SLOPE (Relative Arterial Flow) %/Sec
CDR	52	Blood Flow	1	.0143
	52	Mus. Pump	1	.0172
	55	Blood Flow	1	.0123
			2	.0127
	55	Mus. Pump	1	.0127
SPT	Blood Flow Data Not Received			
PLT	54	Blood Flow	1	.0184
			2	.0200[1]
	57(?)	Blood Flow	1	.0167
			2	.0165
	57(?)	Mus. Pump	1	.0183

[1] Av. of two slopes from two people.

5L-3 Initial D/O
MMT + FMT - Approved

INVESTIGATION OF BLOOD FLOOD FLOW IN LIMBS

PART I

A standard, method of blood flow measurement in limbs is to occlude venous return by means of a relatively low pressure in a standard cuff around the segment. This pressure does not hinder the inflow of blood to the segment since arterial pressure approximates 100 mm Hg. while venous pressure is only a few mm Hg. Applying say 20 mm pressure * will then stop all venous flow until this pressure is exceeded. In this interval blood accumulates in the vessels increasing the size of the limb. By measuring this increase in size as a function of time rate of volume, change (flow) may be determined. It is common practice to use a single circumferential measurement and infer the total volume change from this as is done in the LBNP experiment.

By using the onboard leg bands and a manual blood pressure cuff, it will be possible to measure flow in the legs of each crewman and possibly the arms of one crewman under weightlessness and again under gravity. Such a measurement will be of great value in assessing the cardio-vascular state, particularly after deconditioning.

PART 2

One of the major factors in return of blood to the heart is the pumping action of muscles in the legs as they contract and squeeze the veins. Since poor venous return is probably a major factor in the deconditioning of weightlessness, evaluation of this mechanism is of great importance.

The efficiency of the muscle pump can be investigated by having a subject under lower body negative pressure isometrically contract his leg muscles for a given period, then relax and observe the effect on leg dimensions by

1. Burch, "Digital Plethysmograph"
2. Abramson, "Circulation in the Extremeties"

means of the leg bands. It is requested that the following procedures be performed at least once by each crewman on SL-3.

Training/procedures- procedures complete- no additional training

Time required

Part 1 - Two crewmen 30 mins each

Part 2 - Two crewmen 15 mins each

Should be scheduled at end of M092 to save setup time.

Consumables - none

Schedule constraints - requires two crewmen

PROCEDURES BLOOD FLOW
PART I

Procedure is to measure blood flow in limbs (by stopping venous flow and measuring increase in limb size)

1. Obtain manual BP cuff and appropriate sized leg (M092) bands for subject.

2. Have the subject enter the LBNP and apply the BP cuff just above the knee. Attach both leg bands and place one band on either leg in normal position and the second two inches below (toward foot) it. Set up the ESS for a normal M092 function balancing and calibrating the leg bands normally. Eliminate the BP and EKG functions.

3. Turn on the recorder, activate high cal and as soon as this cycle is over rapidly inflate the BP cuff to 30 mm Hg. and leave it inflated for 3 mins.

4. Deflate it for 5 mins, zero and recal the leg bands, and repeat 3.

Attempt to perform this procedure using the 12" band on the PLT's arm below the elbow ~~ti~~ with the cuff on the biceps. Record all pertinent comments about the procedure.

BLOOD FLOW

Procedures

PART 2

1. After a normal M092 run is complete do not disconnect the apparatus.

2. Open the LBMP, remove the reference band and adapter and place this band on the other leg following standard procedure, close the LBNPD and cal and balance both bands per normal procedures.

3. Turn on recorder, actuate high cal and when this cycle is complete perform 30 mm step of M093, i.e. apply 8 mm for 1 min, 16 mm for 1 min and 30 mm for 3 mins.

4. At the end of this time leave the pressure on and without movement or valsalva, isometrically contract muscles in both legs maximally for six seconds, relax and 30 secs later repeat. Forty-five seconds later close out experiment normally.

W. Thornton, M.D.

Local PI Present. + Hand out

ANTHROPOMETRIC STUDIES FOR SL-4

The value of detailed measurements of crew body size and configuration before, during, and after exposure to weightlessness should be obvious. The multiple circumference measurements of Hoffler, for example, allows volume determinations of limbs to 100 cc. It is now obvious from this data and mass data that fluid shifts occur over the period of a few days after exposure to and return from weightlessness. Documentation of these changes over the entire body will add a great deal to the knowledge of these fluid shifts. Such measurements will also document slower changes that occur in body morphology through fat/muscle derangements.

There have been consistent reports and spotty photographic evidence of acute change and accommodation in body and facial configuration caused by gravitational unloading and possible fluid shifts. Everyone, for example, has seen the "puffy" facies of weightlessness which seems to disappear over a longer mission. Further the crews have reported lumbar and cervical hyperextension as well as other "postural" changes. They have also commented on engorged cephalic veins. These complex changes can best be documented by photography, especially color photography which will enhance the superficial veins' appearance.

Since there is disagreement over body composition postflight, the best methodology available should be added to the existing radioisotope studies. Total immersion specific gravity measurements, properly done, is generally considered the most accurate.

A very simple way of following shifts in body mass and especially fluids is a simple center of gravity (mass) measurement. This should be done preflight and repeatedly postflight. It would also be possible to do inflight.

Girth Measurements

Approved

Methodology - Limb tape jigs which allow accurate girth measurements every three cm. over the entire limb would be accomplished per the enclosed schedule. These plus truncal measurement pre and postflight are currently being accomplished by Hoffler and Rummel. Inflight measurements should be added and will require the addition of tape jigs plus crew familiarization. They should in every case be made in the standard anatomical position. Truncal measurements should include buttocks, abdomen, chest in inspiration and expiration, and also cervical girth. Only one leg and arm would be measured inflight.

Impact - Fabricate and stow tapes, familiarize crew and requires added inflight time which is estimated to be 12 minutes for two men per measurement.

Photography

Approved

Methodology - Associated with each girth measurement, a front, rear and side view of each crewman should be made in shorts against a standard grid and in anatomical position. Inflight this would be against the iso-grid. Also inflight a totally relaxed side view should be made of each crewman. All photos should be made using a so-called IR color film which will enhance the superficial venous pattern. Also the same type camera, a 70 mm Hasselblad, lens, filter and flash should be used, and photos taken by the crewmen pre and postflight for training and uniformity. The schedule is included.

Impact - The qualified 70 mm film must be added to a dedicated magazine and stowed. Crew must be trained at an estimated time cost of 30 minutes/man preflight. The estimated time cost is 5 minutes for two crewmen per series plus 5 minutes stowage and unstowage.

Center of Gravity Measurements

Approved

Methodology - A rigid back board with a foot board and a roller beneath will allow determination of longitudinal center of gravity measurements. The subject simply lies on the board which is moved until balance occurs. Inflight the subject could extend in the same position as preflight without support and with a girth cord which would be repeatedly accelerated until a point of balance was found which would be measured with onboard tape.

Schedule - F-30 and F-1, F+ 7-10 then every 2 weeks. R+0, 1, 2, 3, 7, 30.

Impact - Construction of a simple board. Performance would require approximately 1 minute pre and post and could be combined with a physical. Inflight estimate 10 mins/crewman.

Specific Gravity Study

Dis Approved

Methodology - Immersion specific gravity by a group expert in the field such as the Cooper Clinic in Dallas. Should be done as late as possible pre and early as possible postflight.

Impact - Transport of crew and impact on schedule.

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William Thornton, M.D.
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Preflight

	Leg-1	Arm	Trunk	Photo	Stereo Photo
F-30	+	+	+	+	+
F-15	+	+	+	+	+
F-5	+	+	+	+	+
Inflight					
F+1					
2	+	+	+	+	
3					
4	+	+	+	+	
5					
7	+	+	+	+	+?
14	+	+	+		
28	+	+	+	+	
56	+	+	+		+?
67	+	+	+	+	
Postflight					
R+0	+	+	+	+	
R+1	+	+	+		+
R+2	+	+	+	+	
R+4	+	+	+		
R+5	+	+	+	+	
R+14	+	+	+	+	+
R+28	+	+	+		+