

Original Article

**SUPERFICIAL TEMPORAL
ARTERY BLOOD FLOW UNDER
+6Gz ACCELERATION WITH
DOPPLER BLOOD VELOCIMETER**

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The availability of a reliable method of determining +Gz tolerance is very important in acceleration studies. Among the various methods tried out, determination of peripheral light loss (PLL) has been the most favoured. With the availability of rapid response ultrasound blood velocimeters, it has become possible to detect blood flow at the eye level non-invasively. This paper discusses the introduction of this technique in human centrifuge studies at the Institute of Aviation Medicine, Indian Air Force. This objective technique of detection of disappearance of blood flow at the eye level was found to correlate well with the subjective PLL.

Keywords: Positive acceleration, G tolerance, high sustained G, aircrew evaluation, human centrifuge.

The difficulty in conducting acceleration studies, for very long, has been the absence of a reliable method of obtaining the end point to +Gz. In the past, many methods have been utilised by different workers. The only end point which has stood the test of time and continues to be the favourite method in most laboratories around the world is the determination of peripheral light loss (PLL), i.e., 'grey out' or central light loss (CLL), i.e., 'black out'. However useful this method has been over the years for short term experiments and for lower levels of +Gz, its reliability and repeatability have always

been of some concern. Its dependability is further reduced during simulation of high onset rates with higher magnitudes of G sustained for long periods (HSG). Under such conditions the subject may directly reach a stage of unconsciousness and when this happens without a visual warning, PLL or CLL as end points serve little useful purpose. In any case, the visual end points are largely subjective and are dependent on the co-operation of the individuals being tested. The need for an objectively assessable end point has always been felt.

Various methods of objective assessment of +Gz tolerance have been used by different workers. Some of these are oximetry, limitation of ocular motility under acceleration (LOMA) and direct measurement of blood pressure at eye/head level. All these methods have their inherent limitations. A reliable and repeatable objective technique employed by some of the workers in the West is the detection of blood flow at the eye level through non-invasive rapid response blood velocimeters. It was considered appropriate to attempt establishing such a facility on the human centrifuge at Institute of Aviation Medicine, Indian Air Force.

* **The Equipment**

The equipment is a directional blood velocimeter BV 381 manufactured by M/s. Sonicaid Ltd., UK. It is basically a clinical equipment which is portable and mains-operated. The instrument has a loud speaker which gives an audible note which increases in pitch as the velocity of blood increases and a meter to indicate changes in velocity and direction of flow. It also has a two channel four speed chart recorder. The blood velocity wave form is internally connected to channel 1, while channel 2 displays an ECG wave form from the built in fully isolated ECG/PCG preamplifier.

Installation on the Human Centrifuge

The BV-381 blood flow meter could not be

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mounted inside the gondola of the human centrifuge, i.e., in close proximity to the subject, for three main reasons:-

a. The instrument being primarily a clinical equipment is not 'G-rated' and any of its components could well fail under high levels of +Gz built up at rapid onset rates.

b. It requires a power supply of 230 volts which is not provided in the gondola for considerations of subject safety. The maximum power permitted at present is 12 volts DC for the gondola lighting required for closed circuit TV camera pick up.

c. Restricted space available inside the gondola.

The main equipment, therefore, had to be mounted near the centre of rotation of the centrifuge so that the G forces acting on it would be negligible and the requisite power supply is available. This meant that the subject and the equipment were no more in close proximity as desirable, but were separated by a distance of almost 7 m. The standard cable length provided with the probe is only a little above one meter. The cable itself is a very specific one designed to carry very low voltage signals (the output of the receiving crystal in the probe is only 10 microvolts). The major stumbling block for a long time was the acquisition of the additional cable itself. A large variety of cables was tried. The noise levels were very high and completely masked the original signal. The desired length of the cable was finally produced (very close to the specifications) by a local manufacturer. With this cable, though there was some drop in the signal voltage, the quality was undisturbed.

For on-line monitoring of the temporal artery blood flow, the doppler audio beats from the equipment mounted on the centrifuge arm had to be transmitted to the monitoring room. For this, the audio output from the blood velocimeter was tapped and connected to the slip ring assembly and from there through selected channels to the monitoring room, over a distance of almost 25 m. In the monitoring room, the beat sounds could be heard by the medical monitor through a stereo head set.

With this arrangement, there was a very large drop in the intensity of audio signals both because of the large transmitting distance as well as the involvement of slip rings in between. The doppler sounds were totally masked by the high level of noise generated at the slip ring assembly and external noise pick up by the transmitting channels. To overcome this problem, it was decided to amplify the doppler audio signals before being fed to the slip ring assembly so that their intensity would be higher than the masking noise, and selectively filter out the external noise after the slip ring assembly. For this, a constant output narrow band audio amplifier and selective filters were designed and assembled by the engineering staff at the Institute. The audio amplifier mounted above the velocimeter received its input from the audio output of the latter and its own output was fed on to the slip ring channels. With this set up, doppler sounds from the superficial temporal artery of a subject seated in the centrifuge gondola could be heard clearly over the head set by the controller in the monitoring room while the centrifuge was following an acceleration profile.

Centrifuge Trials

The existing system of obtaining the end point for +Gz tolerance on the human centrifuge is a subjective one and uses the graduated dynamic end point system (GRADEPS) of restriction of the peripheral visual field (grey out) to mark the G tolerance (4).

A total of 14 subjects participated in the centrifuge trials after the doppler system had been installed and made fully functional. All were healthy, and had previous experience on the human centrifuge. All were quite familiar with GRADEPS and had experienced PLL on the centrifuge previously. They could subjectively describe a grey out when they experienced one. Before selecting the subjects, it was ascertained that their superficial temporal arteries were easily palpable and enough area was clear of hair for the flat doppler probe to be positioned. They were given the usual verbal briefing for the PLL ride. The flat probe was

positioned on the left superficial temporal artery after applying a generous amount of contact gel. The position of the probe was gently shifted around over the artery till the best audio signal was heard over the loud speaker of the velocimeter. The probe was then anchored in position by a light stretch band going around the circumference of the subject's head. The cable from the probe was routed through the head band so that there was no shift of the probe due to tug on the cable during the G runs. With the probe in position and audio beats clear, the audio amplifier was connected to the output of velocimeter so that the sounds could now be clearly heard over the head set in the monitoring room.

In all the experimental protocols, the rate of onset of G was 0.5 G/sec, the duration at peak G was 15 sec and the decay was maintained at 0.1 G/sec. About 4 to 8 runs were required for each subject to reach his end point. The subject was deemed to have reached his tolerance when a PLL restricting the visual fields to 56/52 deg was achieved. In addition, the reaction time recorded was analysed and the symptoms described by the subject noted. During all the runs, the doppler sounds were listened out independently by another medical monitor who intentionally did not observe the PLL system.

Results

All the 14 subjects completed the centrifuge runs for which they volunteered. All of them were taken upto their tolerance levels which ranged from 4.0 to 5.3 G in a relaxed state. These values coincided with an observed PLL of 56/52 degrees by the medical monitor on the control desk. All individuals reported a subjective grey out with the observed PLL values ranging from 60 deg to 52 deg. This was also confirmed by the increased reaction time on the chart recorder. The doppler sounds being listened by the independent monitor were clearly heard through all the runs. The intensity of the beats did not vary much, but what was very discernable was their changing quality (change

of pitch) as the runs proceeded. A marked change in the quality of beats was noticeable just before the disappearance of sounds. As soon as the sound disappeared, the monitor called out that the beats had stopped. In 13 out of the 14 subjects, this call coincided with the observed PLL of 56 deg while in the 14th subject the call came when he had crossed the 52 deg PLL mark. The doppler beats reappeared after a few seconds in all cases and correlated with the recovery from the observed PLL which usually coincided with the last few seconds at peak G and the initial phase of deceleration. The beats came back to their normal intensity very rapidly during the recovery and were still well heard throughout the deceleration phase.

Discussion

The cardiovascular system is more profoundly affected by +Gz than any other system. There is a progressive fall of blood pressure at the head level and an increase in heart rate. This is mainly due to the loss of circulating blood volume as a result of pooling of blood in the lower parts of the body and lower limbs and an increase of eye-brain hydrostatic distance due to descent of the Diaphragm. If these responses continue, the result is a gradual loss of peripheral vision (grey out) followed by a loss of central vision (black out) and finally unconsciousness (3,8). These changes are as a result of decreased blood supply to the head (1,8).

The measurement of temporal artery blood flow using doppler system has been used as an objective technique for predicting +Gz tolerance. The method is based on the assumption that the temporal artery blood flow reflects the retinal artery flow at a comparable hydrostatic pressure under +Gz (2,6). An objective decrease in the retinal artery flow has been repeatedly demonstrated by direct visualisation and measurement at eye level with increasing G levels (9) and precedes PLL by 5 sec (1,3,8). Retrograde eye level blood flow has been consistently recorded and normal flow precedes return of full vision by 1 to 1.5 sec

(4, 7). Flow cessation precedes black out by 6 to 10 sec - average 9 sec (1,7).

The system of superficial temporal artery flow measurement using an ultrasonic blood velocimeter as in this study works on the same principle as employed by other workers. The main achievement has been matching of the system to the peculiar requirements of the existing centrifuge through modifications. The technique of monitoring employed, is a standard simple one and our findings correlate very well with the PLL system. The repeatability, without a single failure indicates the reliability of the system. The end point in our system is the disappearance of the audio beats under +Gz.

Audio monitoring is the method of choice on the centrifuge as the controller's vision is occupied in monitoring a number of other parameters. The distinctive audio shift warns the observer of the impending end point and allows him to take the requisite actions (3,5). Our methodology and trial results are very similar to those employed by Voge (9) where a comparison was made between the methods of PLL (subjective) and cessation of blood flow in the temporal artery as measured through an externally mounted ultrasonic flow meter using the doppler effect, and it was found that the flow meter resulted in obtaining reliable G tolerance end points in all of a total of 8 cases. This makes this objective technique the method of choice for obtaining G tolerance values on the centrifuge especially when high values of G obtained through high onset rates may give no visual warning before going to blackout or unconsciousness, situations where the PLL system would not be of much value.

References

1. Duane TD: Observations on the fundus oculi during blackout. *Arch Ophthalmol* 51:343, 1954.
2. Krutz RW, Rositano SA and Mancini RE: Physiological assessment of the transcutaneous doppler ultrasonic flowmeter during +Gz accelerations. Preprints, Aerospace Med Assoc Annual Scientific Meeting 1973.
3. Krutz RW, Rositano SA and Mancini RE: Comparison techniques for measuring +Gz tolerance in man. *J Appl Physiol* 38:1143, 1975.
4. Reddy BRS, Rai K and Ali AK: Graduated dynamic end point system for assessment of visual field contraction during +Gz acceleration. *Aviat Med* 25(1):7, 1981.
5. Rositano SA, Krutz RW and Olson RM: Relationship between temporal artery flow velocity and subjective +Gz tolerance. *Proc Aerospace Med Assoc Annual Scientific Meeting 1974*, pp 64-65.
6. Rositano SA, Gillingham KK, Sandler H and Skrettingland KR: Correlation of eye level blood velocity and peripheral light loss during +Gz stress. Preprints, Aerospace Med Assoc Annual Scientific Meeting 1975, pp 123-124.
7. Rusmer RF, Baker DW and Stegall HF: Transcutaneous doppler flow detection as a nondestructive technique. *J Appl Physiol* 21:554, 1966.
8. Sandler H, Rositano SA and McCutcheon EP: An objective determination of +Gz acceleration tolerance. XXVII Congress of the International Astronautical Federation, Anaheim, Ca, 1976.
9. Voge VM: Comparison of several G-tolerance measuring methods at various seat back angles. *Aviat Space Environ Med* 49(2):377, 1978.