

# Aerobiotelemetry from a Fighter Aircraft

Sqn Ldr M M Singh\*, Air Cmde S Krishnamurti†,

Air Cmde S P Verma‡, and B R S Reddy§

## Abstract

**F**IRM diagnosis and final assessment of aircrew with abnormal electrocardiograms (ECGs) has always been a vexatious problem. Even though there are many sophisticated non-invasive methods for assessment of the cardio-vascular system (CVS) and evaluation of abnormal ECGs, all such methods suffer from the drawback of being carried out in the laboratory, different from the work environment. It is in this context that an air to ground telemetric system capable of transmitting and receiving ECGs in flight was developed by one of us (Air Cmde SP Verma).

We have used this system and successfully recorded ECGs from sixteen airborne subjects. Eight of them were "normal" in all respects and eight had "non-specific" ECG abnormalities. The crew performed a set flight manoeuvre pattern in all cases while ECG was being recorded in the ground laboratory. The two groups of subjects were comparable in terms of age, weight and flying experience.

Sinus tachycardia was the commonest abnormality noted, with T inversion, during +Gz manoeuvres. Supra-ventricular (SVER) and ventricular ectopic beats (VEB) and ST-T changes were also found in some. All these changes were transient and cleared up as soon as the +Gz manoeuvre was stopped. Taking into consideration the mechanism of these changes in ECG, we are of the opinion that such changes are only physiological and have no pathological importance.

## Introduction

ECG monitoring of CVS for intrinsic heart disease like ischaemic heart disease (IHD) is meaningful only

when it is done continuously for at least a few hours if not for whole day<sup>6</sup>. Such long term monitoring has revealed many a dangerous situation not at all picked up by routinely used ECG studies including stress - ECG. White<sup>10</sup> was the first to record inflight ECG of pilots to study the effect of anoxia in high altitude flights. Several other workers have recorded the ECG of pilots from helicopters, transport and fighter aircraft<sup>5, 11-14, 16, 17</sup>. Most of these studies, where heart rate was the parameter of interest, were carried out on healthy pilot volunteers. Brown<sup>1</sup> et al have studied two subjects with midsystolic click/late systolic murmur syndrome under inflight +Gz manoeuvres to precipitate cardiac arrhythmias. The study that is presented here is perhaps the first ever from a fighter aircraft where the pilots with ECG abnormalities are tested under actual flying conditions.

The two major problem areas in the ECG assessment of CVS are (i) assessment of known cases of coronary artery diseases and, more important, (ii) assessment of cases with non-specific ST-T changes in the ECG recordings of asymptomatic, healthy, young aircrew. This second problem is indeed one that causes much anxiety and anguish if arbitrarily dealt with. Unnecessary grounding or denial of flying status for any length of time are both undesirable. While one does not wish to compromise flight safety, one should also make effort to conserve trained man power. Morale is an important factor in our military activities and military flying is no exception.

## Materials and Methods

In the present study which was carried out during

\* Specialist in Medicine, Institute of Aviation Medicine, Bangalore-560017

† Consultant in Medicine, Command Hospital AF, Bangalore-560007.

‡ Consultant in Aviation Medicine & Air Officer Commanding (Retd) Institute of Aviation Medicine, Bangalore-560017.

§ Senior Scientific Officer, Gde. I & Head of the Dept. of Bio-Engineering, Institute of Aviation Medicine, Bangalore-560017.

Feb-May 1978, 8 normal aircrew and 8 "abnormals" i.e. with non-specific ECG abnormalities were used as subjects. The ECG abnormalities of the subjects consisted of:—

- (i) Isolated T inverted in L3, avF or avL
- (ii) T inverted or T biphasic in V2, V3, V4 or V5
- (iii) T inverted in L3, 3(R), avF but T upright in avF (R)
- (iv) T flat in L3 but upright in L3(R), avF and avF(R)
- (v) ST depression less than 1 mm in post exercise records after Master's Exercise.

These eight cases have been under surveillance for average duration of 18 months.

All the sixteen subjects were not only subjected to thorough and rigorous clinical and laboratory examination, they were specially screened for IHD, diabetes and any other recurrent illness. A careful history regarding smoking, alcohol consumption, use of medication, habits of exercise, family history of IHD, diabetes and hypertension was also taken.

The laboratory tests included a peripheral blood examination, urine analysis, standard oral GTT, estimation of cholesterol, urea and uric acid as well as an X-ray of the chest. The subjects were assessed with the following tests:—

- (a) ECG at rest and after Masters Double Two Step exercise<sup>8,9</sup>
- (b) ECG during and after maximal or sub-maximal treadmill exercise
- (c) ECG during hyperventilation, fasting and after a Glucose load during and after valsalva manoeuvre
- (d) ECG under hypoxia at rest and after exercise, during + Gz in a human centrifuge, and on tilt-table
- (e) ECG at rest and after exercise while on drugs, especially Beta Blockers.

If at any stage any one of the above ECG recordings were found abnormal, the individual was excluded from this study. Standard and universally accepted criteria were used to decide whether an ECG under a set circumstance was normal or not.

### Telemetry System

The Biotelemetry system used by us for recording ECG of a pilot under actual flying stress from a fighter aircraft is outlined in the block diagram (fig. 1). Floating silver electrodes<sup>13</sup> were used to pick up ECG from the MX-5 lead position<sup>4</sup>. The leads were brought out and terminated in phonojacks for plugging into the Encoder (fig. 2), carried by the subject over his thigh pocket of the flying overall (ENC in fig. 3). The Encoder amplifies the ECG signal and frequency modulates a sub-carrier of 1 KHz. This is essential as the communication trans-receiver

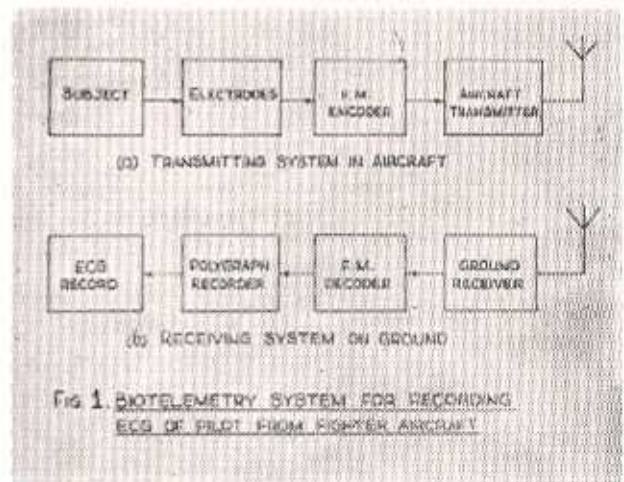


Fig 1. BIOTELEMETRY SYSTEM FOR RECORDING ECG OF PILOT FROM FIGHTER AIRCRAFT

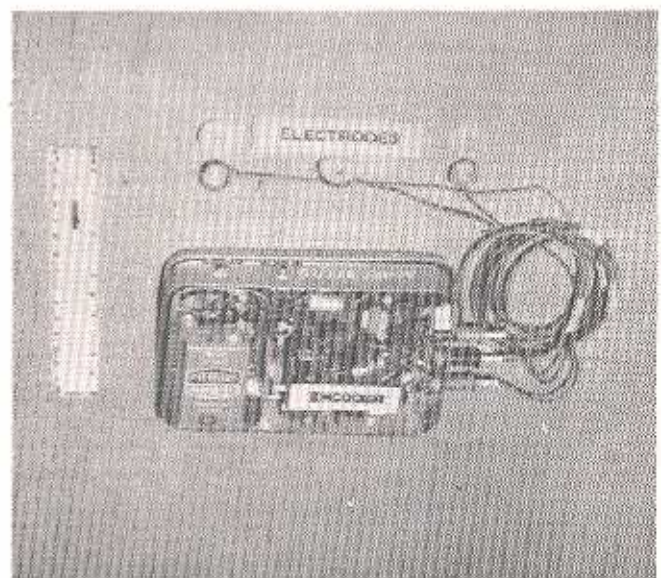


Fig. 2  
Encoder carried by the subject with electrodes and leads terminated in phonojacks plugged into the encoder.



Fig. 3

Instrumented subject carrying the Encoder (ENC) over the thigh pocket of his flying overall.

fitted in the aircraft can handle signals in the speech frequency range only and ECG is of much lower frequency. Frequency modulation gives better signal-to-noise ratio than amplitude modulation systems. Encoder output is fed to the transmitter (STR 9X) in the aircraft, which radiates in a very high frequency (VHF) range through the antenna mounted on top of the fuselage next to ADF antenna of the aircraft.

The receiver in the ground station at IAM which is tuned to the radiating frequency of the aircraft transmitter, amplifies and demodulates the VHF signal and gives out the frequency modulated 1 KHz tone to drive the F. M. discriminator. The discriminator being sensitive only to the frequency variation of the subcarrier eliminates any variations in the amplitude due to noise or other factors and reproduces the

original ECG of the subject as sensed by the electrodes. This is recorded on the ECG channel of polygraph.

Provision is made in the aircraft through a minor modification to have either normal speech communication with the ground station or transmission of ECG on the same VHF frequency. The subject has to select either of the two by switching ON/OFF toggle-switches mounted in front of him in the cockpit. This enables the ground station to have continuous contact with the subject and order remedial action in case of emergency.

#### Flight Profile

The monitoring lead in all the cases was MX 5 as discussed earlier. A resting tracing was recorded before taking the aircrew to the aircraft. He was subjected to Master Two Step exercise and ECG recorded with the monitor lead immediately, 3 and 6 minutes after the exercise. The subject was then taken to the aircraft and after connecting the lead to the Encoder, ECG tracing was recorded while the aircraft was on ground.

After the aircraft was airborne the pilot started transmitting the type of aerobic manoeuvre he was preparing to undertake so that experimenters were ready on the ground to record the ECG during the manoeuvre. A continuous ECG recording was obtained throughout the sortie. ECG was continuously monitored by the physician on the ground, so as to avoid any untoward incident. The flight profile followed in each case is given below :-

- (a) Climb from 5,000 ft to 15,000 ft.
- (b) Steep turn right at 15,000 ft (Max. 5G)
- (c) Steep turn left at 15,000 ft (Max. 5G)
- (d) Level flight 2 minutes at 15,000 ft.
- (e) Loop Max. 4G
- (f) Loop Max. 5G
- (g) Roll off the top.
- (h) Climb 3 minutes.
- (j) Roll left.
- (k) High G-Barrel left 5G.
- (l) Upward/Downward clover.
- (m) Descent to 6,000 ft.

The time from take off to landing was about 50 minutes.

## Results

In Table I are given the mean and range of the age, weight and basal systolic and diastolic BP of the subjects.

Analysis of the ECG taken during the flight showed variations from the records made at ground

level. They are tabulated in Table II.

The 16 cases showed a total of 29 abnormalities while in flight. Figures shown in brackets in Table II indicate abnormalities noticed in the 'normal' subjects.

TABLE I  
Age, weight and basal blood pressure of subjects.

Group	Nos.	Age			Weight			Basal Blood Pressure (mm Hg)					
		Yrs.			Kg.			Systolic			Diastolic		
Normal	8	24	30	34	64	67	70	110	120	134	70	76	80
Abnormal	8	22	30	39	64	66	70	110	121	130	70	77	84

TABLE II  
Changes in ECG during flight

Abnormality	No. of Cases
Sinus Tachycardia with T-inversion	6 + (4)
Shifting base line	1
J-point depression	1
ST depression (1-1.5 mm)	3
Sinus Tachycardia	— (1)
T inverted without Tachycardia	3 + (1)
Diminution of amplitude of T	2 + (1)
T Biphasic	2
Supra ventricular ectopics (Atrial & Junctional)	2
Ventricular ectopics	1
Sinus arrest	1

Table III brings out the following important observations :-

- (i) More than one abnormality was recorded in most of the subjects.
- (ii) Maximum abnormalities were recorded while undergoing loop, roll off the top and high G barrel.

(iii) Next in order of frequency are abnormalities recorded during the steep right and left turns.

(iv) It can be concluded from this table that maximum stressful manoeuvres responsible for abnormalities while flying in a fighter aircraft are loop, roll off the top and steep right and left turns, i.e. on those flight profiles involving a fair degree of G-loading.

TABLE III  
Exercise-wise breakdown of ECG changes.

Abnormality	Climb	Steep Turn Right	Steep Turn Left	Level Flight	Loop 4g	Loop 5g	Roll off Top	Climb 3 Mts	Roll Left	High G Barrel	Up- ward Clover	Decent 6,000 ft.
1. Sinus Tachycardia with T inversion	1	2+(2)	3	—	4+(2)	1+(2)	1	—	1	1	2	—
2. T inversion alone	—	—	—	—	—(1)	2	2	1	3	2	1	1
3. Sinus Tachycardia alone	(1)	—	—	—	—	—	—	—	—	—	—	—
4. ST-Segment depression (1-1.5 mm)	—	3	—	—	2	2	2	—	—	1	—	—
5. Diminution in the amplitude of T-wave	—	1	—	—	—	1+(1)	—	—	—	—	—	—
6. T-Biphasic	—	1	—	—	1	—	—	—	—	—	—	—
7. Supra Ventricular Ectopics	1	—	1	—	1	—	1	—	—	—	—	—
8. Ventricular Ectopics	—	—	—	—	1	—	—	—	—	—	—	—
9. Sinus Arrest	—	—	1	—	—	—	—	—	—	—	—	—
10. 'J' Depression	—	—	1	1	—	—	—	—	—	—	—	—
11. Shifting of Base Line	—	—	—	—	—	—	—	—	—	—	—	—

Shift in Base line was observed in one case throughout the flight profile. Figures in brackets indicate abnormalities recorded in the control subjects.

Figures 4,5 and 6 are ECGs of airborne subjects with various ECG changes recorded during the flight preceded by normal ECG's recorded on ground.

#### Discussion

Brown found various cardiac arrhythmias during Gz manocuvres<sup>2</sup>. T-wave inversion of ECG of healthy individuals has been described by Iglesias et al, which reverts after exercise or atropine<sup>7</sup>. This has been attributed to vagotonia or changes in cardiac

rhythm during sustained high levels of +G<sup>10</sup>. Transient ST-T changes and tachycardia have been described from a fighter pilot by Pircher<sup>10</sup>.

The significance of frequent VPB's during the sustained +G exposure is not clear. Possibly, it may be due to sympathetic nervous system stimulation, increased catecholamine levels, changes in cardiac filling, changes in positive and mechanical stresses on the heart, inadequate coronary blood flow, or superadded hypoxia during the sustained or repeated high +Gz exposure. There does remain the possibility of these ectopic beats developing into a sustained run of rhythm disturbances.

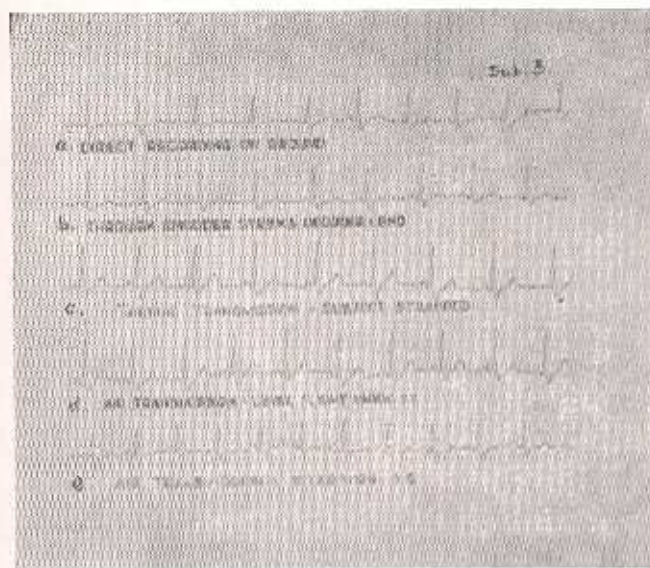


Fig. 4

Electrocardiograms recorded on ground (a) direct on polygraph (b) through the system (c) from tarmac and, (d) and (e) during flight.

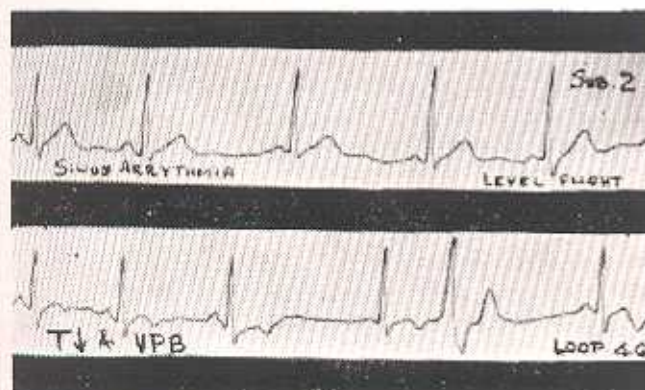


Fig. 5

Ventricular premature beats and T inversion recorded during loop 4g.

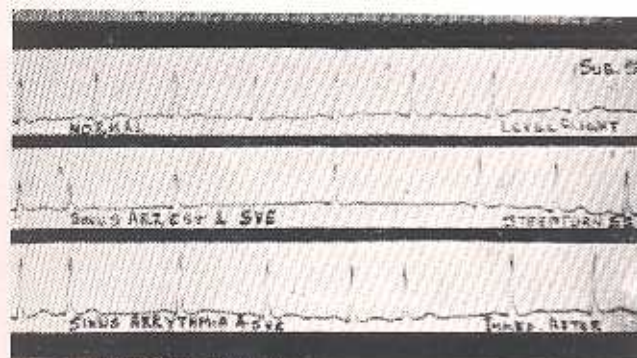


Fig. 6

Sinus arrhythmia, sinus arrest and supraventricular ectopics recorded during steep turn 5g.

In the present study, we have been able to record various abnormalities as mentioned in Table II. It is to be noted that all these have been recorded whenever the pilot was under the effect of positive G. The commonest abnormality noted was sinus tachycardia and T-wave inversion followed by supraventricular ectopics. Next common were ST segment depression and 'J' point depression. In one case, a single ventricular premature beat was recorded. There were transient T wave changes in 3 cases. In these the amplitude of T wave became less or it became biphasic. None of these changes observed can be called or attributed to myocardial ischaemia, because various workers have found them during the Gz manoeuvres<sup>3, 19, 20</sup>. In our series, arrhythmias were transient and they disappeared immediately after easing off the particular manoeuvre. Three main factors that modify the action of the heart and changes consequently the ECG are (1) variation in the tone of the extra cardiac nerves, (2) variation in the filling of the individual chambers of the heart, and, (3) change of position or configuration of the heart during acceleration. Roscoe is of the opinion that stresses like emotional factors, anxiety, etc. may cause increased heart rate in inexperienced pilots<sup>14</sup>. This is more likely due to catecholamine effect. In the present study, we have also found various rhythm disorders. They are considered to be non-pathognomonic of IHD. Because of the small number of subjects, no definite conclusions can be drawn. Further studies of similar cases are necessary before any firm conclusions can be drawn and recommendation made.

#### Conclusions

Flying conditions impose many stresses on the human body. The CVS, especially when the pilot is exposed to +Gz acceleration, bears the brunt. On this account, its rate increases and some minor transient electrical abnormalities such as ectopic beats and repolarisation defects arise. From our study of 16 cases having air-to-ground telemetry we have concluded that the ECG changes only reflect transient physiological changes.

Extension of this study to "stable" cases of CV diseases like IHD may have to be undertaken before its exact place as a non-invasive modality is established in the assessment of aircrew.

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