Original Article

Evaluation of in-flight G-LOC

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Aeromedical evaluation of a case of G-LOC assumes importance as it is one of the causes of episodi loss of consiousness (E-LOC)/sudden incapacitation/ episodic neurological dysfunction (END). Th dilemma is as to whether the problem is physiological or pathological. Evaluation at the Squadro level is as important as is the evaluation done in a specialised centre. The role of the human centrifug assumes importance in specialised centres, when evaluating such cases. The disposal of an unex plained case of loss of consciousness becomes difficult and complex especially when an eye witnes account is not available. The evaluation and disposal of such episodes of G-LOC therefore have to b dealt within the spectrum of E-LOC/END. The current methods, with a special emphasis on the rol of the human centrifuge, in the evaluation and disposal of G-LOC are discussed.

Keywords: Episodic unconsciousness, aircrew performance, acceleration forces, tolerance, anti-G suit.

G-LOC has been defined by Burton [1] as : "a state of altered perception wherein one's awareness of reality is absent as a result of a sudden critical reduction of cerebral circulation caused by increasing G force". The incidence of G-LOC varies in anonymous surveys from 10.8% [2] to 12.4% [3]. However during centrifuge training it is found that 50% have amnesia for the G-LOC event, thereby implying an increased incidence from that quoted above. In-flight LOC of a fully trained aircrew due to an underlying medical condition is a rather infrequent event. However, any condition causing partial or temporary LOC carries a greater significance in aviation because of the potential to cause a fatal mishap. Sudden LOC is of perennial interest to aeromedical specialists not only because of its potential for disaster but also as its study may reveal trends amenable to correction.

Implications of G-LOC are far reaching and include flight safety, individual safety, loss of trained manpower and financial loss. Though the actua number is not exactly known aircraft accidents due to G LOC have been observed in the IAF. To make matters worse, the psychological and physiological changes occurring after the episode reduce the capability of the aircrew and further compromise flight safety. Only by uncovering the etiology can risk or recurrence be defined and it is upon this that recommendation for return to flying status rests.

Aeromedical specialists looking into the problem of evaluation of G-LOC have been studying various clinical parameters to find out if aircrew with low-G tolerance can be detected and eliminated [4]. During training feedback from operational flying units to know the manoeuvres most apt to cause

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G-LOC would aid in its evaluation and protection [5]. To eliminate this G-LOC problem to some extent the IAF started its Centrifuge Training in 1991 and such training has become essential for aircrew flying the air superiority fighter (ASF). In a study done in the USAF in 1982 it was found that those who cleared 7G-15s, G-LOC in-flight was not reported [6]. Therefore, these standards were adopted by NATO and to be in keeping with STANAG, IAM IAF also follows the same 7G-15s as the qualifying level for clearing the course and proceeding for ASF training.

G-LOC has always been considered to be a physiological event. Factors predisposing towards G-LOC are an improperly performed AGSM, rapid onset of $+G_z$ forces, surprise onset in 2nd aircrew (relevant in the SU-30), disconnected anti-G suit (AGS), improper diet and fatigue, and low G tolerance. However, the good news is that experiencing one episode of G-LOC induces rapid recovery in the next.

Evaluation

Knowing that G-LOC is physiological, is there a need for an evaluation ? When one considers the flight safety implications, evaluation of in-flight G-LOC must be considered - but to what extent and at which centre remains an engima. G-LOC forms one of differential diagnosis of an episodic loss of consciousness (E-LOC) in flight. When an eye witness account is available, the cause of LOC becomes seemingly apparent and investigations, if required may be directed towards it. However, when such accounts are not available then the aeromedical specialist is forced to rely on the aircraft data parameters and investigations. The problems for which a dilemma is faced is whether the LOC is a result of a seizure or syncope and if a syncope whether it is physiological or pathological.

As brought out, the role of the aeromedical specialist begins in the field at the Squadron level where a meticulous history and interpretation of flight data should allow him to come to a reasonable conclusion whether the LOC was due to $+G_z$ forces and whether it should be investigated further. Table 1 would certainly help in differentiating cases of seizure from syncope. However, it must be kept in mind that convulsive syncope [7] and non-convulsive seizure are also well known entities.

Table 1. Differences between Seizure and Syncope

Function	Seizure	Syncope
Emotional stressor	Unimportant	Important
Prodrome	None	Lightheadedness nausea, dryness of mouth, epi gastric distress
Posture	Any position	Usually erect
General appearance	Flushed	Pale, sweating
Pulse	Tachycardia	Bradycardia
Injury	Frequent	Infrequent
Convulsions*	Most often	Seldom
Recovery	Delayed	Rapid
Amnesia	Prominent (min)	Minimal (sec)
Incontinence	Frequent	Uncommon

* In the case of convulsive syncope the convulsions are clonic, of short duration without being reflected in the EEG, i.e., spike and sharp wave.

The diagnosis of a cause of syncope can be easily made from the history, physical examination and ECG in at least 60-70% of cases (8). Therefore the evaluation of a case of G-LOC begins in the Station Sick Quarters (SSQ) i.e., at the Squadron level.

This evaluation should have incorporated into it:

I (a) History to include:

Pre-morbid illness

Pre-flight meal

Drug ingestion

Physiological factors-heat, hypoxia, hyperventilation

(b) Sortie profile to include

Type of sortie - combat or not

G meter reading at end of sortie

Air Field Tape Recorder (AFTR) recording (for voice recording to know the physiological or psychological state [9]).

Flight data print out

Type of aircraft and hours on type.

(c) Personal factors related to G-LOC

AGS type

AGS disconnection

Poor anti G straining manoeuvre (AGSM) technique

Delayed start of AGSM

2nd Pilot syndrome

II. Physical Examination.

(a) Cardiological - Abnormal pulse rhythm

- Clicks and murmur

(b) Neurological

(c) Physiological - Passive standing

BP (includes lying and standing)

- Evidence of sinus arrhythmia

BP response to sustained hand grip.

III. Electrocardiography

(a) Routine

(b) Hyperventilation for 15 s

(c) ECG 15/30 ratio after standing

(d) ECG after Valsalva manoeuvre.

The aeromedical specialist, therefore, with the help of the nearest Armed Forces Hospital can arrive at a reasonable conclusion as to whether further investigation is warranted.

Inconclusive evidence would necessitate a referral to a specialised centre i.e., Institute of Aerospace Medicine (IAM IAF). Apart from the evaluation by the team of clinicians, the evaluations by the aeromedical departments includes:

70° HUT/Cold pressor test

Vestibular functions

Centrifuge evaluation

When the first two tests along with clinical evaluation are normal, the aircrew who has had an episode of LOC in flight undergoes centrifuge evaluation. During such evaluation the most important physiological parameter being recorded is the ECG.

There have been a variety of dysrhythmias which are described coincident with G-LOC [10, 11, 12]. Therefore this aspect must be evaluated carefully.

A new Digital Acquisition and Retrieval Equipment (DARE), indigenously made in 1996 at the Department of Acceleration Physiology, IAM IAF, allows for such evaluation during the complete centrifuge run. The ECG signal is acquired and transcribed into a digital format within the centrifuge and sent out via the slip rings to a computer console and thereafter via software to the centrifuge controller's TV screen, for on line recording. Subsequent analysis and software development is being progressed as the expertise and experience advances.

Centrifuge evaluation

From 1984-1997, 15 cases of LOC reported to the IAM, Bangalore, for centrifuge evaluation. A few of these cases are reported as below:

Case 1: A 23 year old aircrew who had 10 h of flying on Iskra was sent to IAM for evaluation of 5 episodes of G-LOC. 3 episodes occurred during a roll-of-the top manoeuvre when the maximum +Gz force was 4.5 -5G. One episode occurred during a +4 Gz loop manoeuvre and the last during a Kiran sortie when +6 Gz was pulled. Centrifuge evaluation revealed that the Rapid Onset Rate (ROR) RELaxed TOLerance was 4.1 G. The Gradual Onset Rate (GOR) RELaxed TOLerance was 4.2 G and STRaining was 5.8 G. He was then given indoctrination in the anti-G straining manoeuvre (AGSM) i.e., the L_1 manoeuvre after which he underwent a 5 G - 30s centrifuge run without the AGS for practice of the AGSM. Subsequently during the next run, i.e., 6 G, in the 11th second he went into G-LOC. He was further indoctrinated in the AGSM and the next day he successfully completed the Simulated Aerial Combat Manoeuvre (SACM) centrifuge runs of 4 G / 6 G and 4.5 G / 7 G, while using the AGS.

The heart rate recorded was within normal limits and so was his G-TOLerance. The aircrew was routed back to flying without any change in his medical category.

Case 2: A 21 year old Flight Cadet had two episodes of G-LOC both during roll-of-the-top manoeuvre (4-5 G), while flying Iskra. His evaluation at IAM revealed that the tilt table study and aerobic fitness were normal. The centrifuge evaluation was as under:

ROR	REL	4.1 G
GOR	REL	4.7 G

AGSM indoctrination given:

5 G ROR with AGSM	30 s tolerated
6 G ROR with AGSM and AGS	30 s tolerated

G-TOL was declared as normal and the Flight Cadet was advised to pursue a physical conditioning programme which would better his performance of the AGSM. He was routed back for flying.

Case 3: A 21 year old Flight Cadet, on a dual sortie, while tightening the bank called out that he was becoming faint and then recovered only 8 min later, i.e., after the aircraft had landed. Centrifuge evaluation revealed:

ROR	REL	4.1 G
GOR	STR	6.68 G

G-TOL was found to be normal. However, due to the prolonged nature of the LOC in-flight he was placed in low medical category.

Case-4: A 38 year old Squadron Leader while flying a 2 vs 2 combat in a MiG 21 failed to perform an adequate AGSM and went into G-LOC at 7.8 Gz. His centrifuge evaluation revealed:

ROR REL	4.8 G	
9 G	tolerated	5 s
4G / 7 G SACM	"	158 s
4G / 8 G SACM	"	215 s

The G-LOC was considered physiological and the aircrew was routed back to flying.

Case-5: A 22 year old Flight Cadet reported to IAM for evaluation of air sickness. On centrifuge evaluation he experienced G-LOC at 3 G and this was followed by nausea and vomiting. The next day he had G-LOC at 3.4 G (0.5 G/s ROR) and on recovery he again experienced nausea. He was declared as having low G tolerance.

Case-6: A 22 year old Flight Cadet reported after 3 episodes of G-LOC at 4.5 +Gz, while flying Kiran. It was uncovered when it was noted that the aircrew was not in control of his aircraft and calls of "Black out" were heard over the RT, during the last episode. Centrifuge evaluation revealed that the ROR REL was 4.3 G. During the ROR STR he blacked out at 4.9 +Gz and later explained that it was similar to what he had experienced. His ROR STR was improved to 5.9 +Gz by indoctrinating him in the correct performance of the AGSM. The G-LOC was therefore due to faulty performance of the AGSM and he was routed back to flying.

Centrifuge evaluation, therefore, plays an important role not only in the diagnosis but will also eventually help in the disposal. The protocol which is being followed at the Department of Acceleration Physiology for Centrifuge Evaluation in cases referred for evaluation of E-LOC and G-LOC is given as under:

Day 1
- ROR REL
- GOR REL/STR
- Review of G-LOC in theory
- Indoctrination in AGSM - L_1 manoeuvre

Day 2
- 5 G - 30 s with AGSM
- 6 G - 30 s with AGS and AGSM
- 7 G - 15 s with AGS and AGSM
- SACM: 4 G 15 s / 8G - 10 s

Another important aeromedical investigation required in a case of G-LOC is the tilt table study. The pathophysiological mechanism for syncope during upright tilt testing is given in Figure 1. In studies of passive tilt a mean positive response of 49% is present (13). Specificity has been reported to be 90% for passive testing but the range is wide and test protocols using isoproterenol increase the positive response only marginally.

Low yielding tests

No discussion on evaluation of E/G-LOC is complete without mentioning some of the commonly

Fig. 1 Pathophysiological mechanism for syncope in upright tilt testing

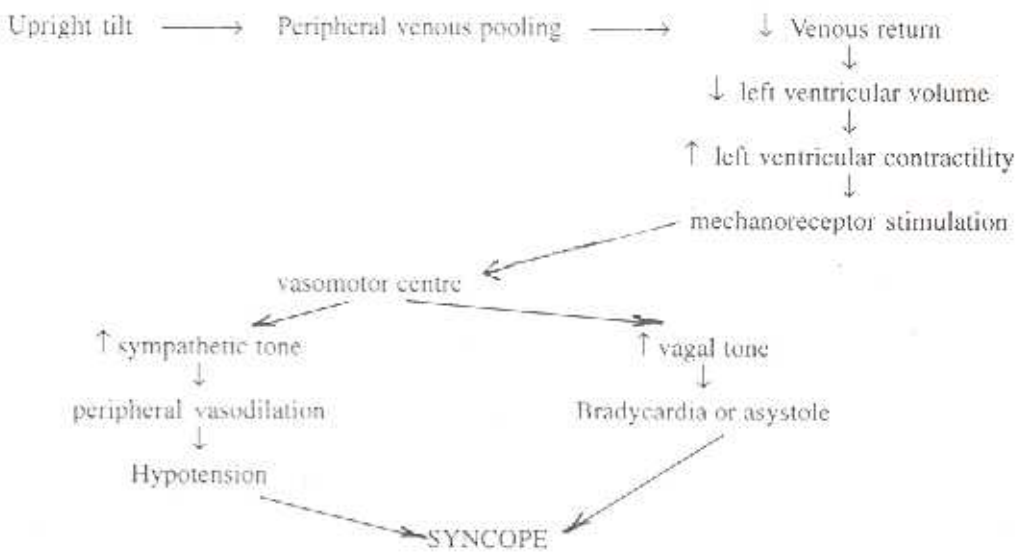
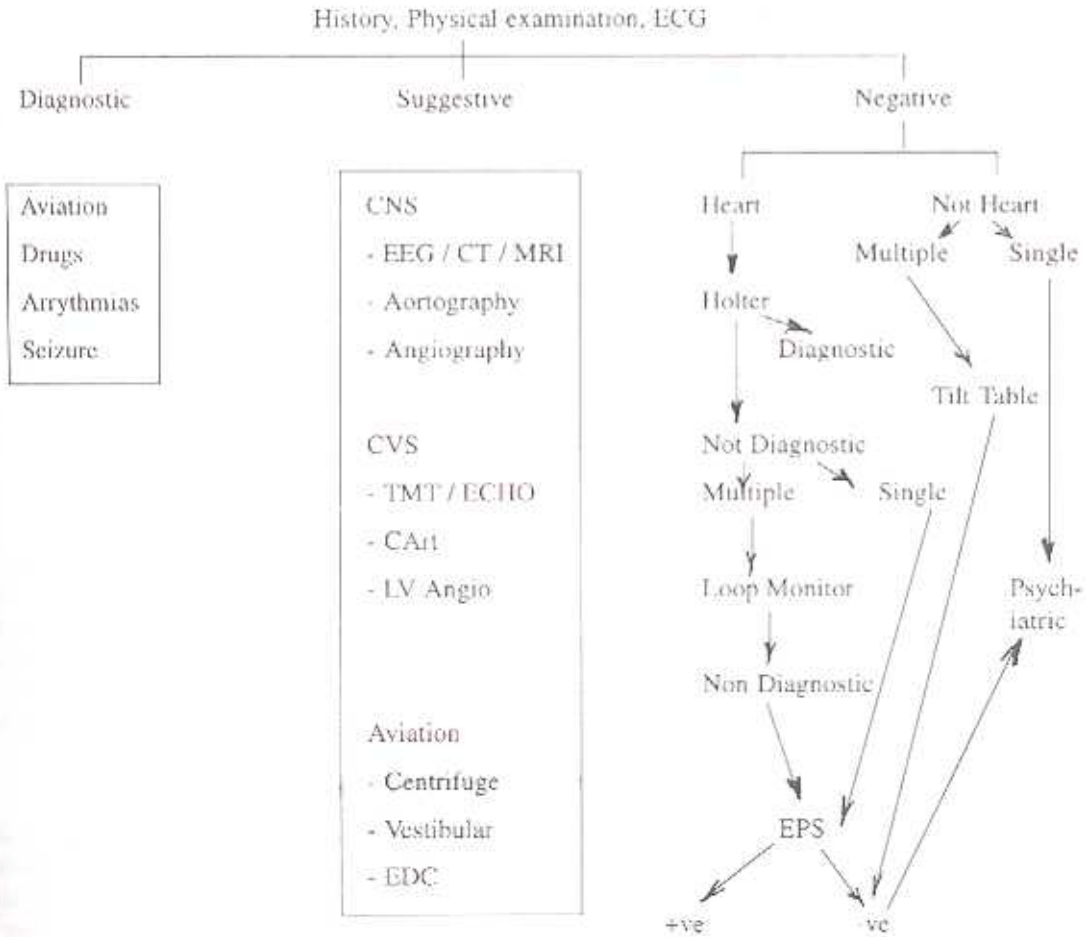


Fig. 2 Evaluation of E-LOC / G-LOC In-flight



used tests for evaluation. Skull films, lumbar puncture, radionucleide brain scan and cerebral angiography have not yielded diagnostic information for a cause of LOC/syncope in the absence of clinical findings (14). Glucose tolerance tests rarely lead to a diagnosis of hypoglycemia. Initial laboratory blood tests also rarely yield diagnostically helpful information. Such tests should only be used to confirm a clinical suspicion. Studies on EEG in syncope have shown that in 1% of subjects an epileptiform abnormality was found (15).

The flow diagram (Fig. 2) summarizes the diagnostic approach and evaluation in any case of E-LOC in-flight, of which G-LOC is one.

Disposal

The dilemma is real as theoretically G-LOC is a physiological phenomenon, but for all practical purposes has to be treated as Episodic Loss of Consciousness. When flight safety and conservation of man power are included into this aspect then the situation becomes more problematic and enigmatic.

The following disposal for cases of G-LOC is therefore suggested:

(i) Evidence of G Onset, magnitude and duration being higher than normal.

(ii) Faulty AGSM from the AFTR.

(iii) AGS disconnection.

(iv) Surprise onset (usually in the 2nd aircrew).

(v) History to include drug ingestion, alcohol consumption, intercurrent illness, pre-flight meal.

(vi) Physical examination to rule out CVS/CNS involvement.

Special Note: When occurring during a centrifuge run, unless neurological sequelae present, the episode of G-LOC should be considered as physiological.

The evaluation and disposal are recorded on Form 7-A and kept with the individual's documents. No lowering of category to be recommended. Cases of recurrent G-LOC, will be referred to IAM, IAF for evaluation.

(b) Cases when the history is not clear or clinical abnormality associated, will be sent to IAM, IAF as soon as possible.

Evaluation at IAM, apart from the routine clinical evaluation will specifically include, cardiological investigation especially TMT / echo-cardiography, vestibular functions, tilt-table studies and centrifuge evaluation. Altitude chamber, neurological, psychiatric/physiological evaluation may be included if considered necessary.

Disposal

(i) No abnormality detected and centrifuge evaluation normal - No lowering of category and individual routed back to unit to continue flying.

(ii) Abnormality detected - disposal and category as per disability detected.

(iii) In cases where a doubt still exists the category may be lowered for 12 weeks to dual flying status - (A_1) to fly with an aircrew qualified on type and an executive report to accompany the individual with a special emphasis an combat manoeuvres, and performance of AGSM. Squadron MO / Aeromedical Specialist should involve in such cases so as to obtain as much ancillary data before and after the combat sorties.

Conclusion

Evaluation of in flight G-LOC has many implications and the decision between compromised flight safety and conservation of trained man power has to be constantly borne in mind. An unambiguous episode of G-LOC may be disposed off at the SSQ by the Aeromedical Specialist, after making every reasonable effort to define the cause.

The evaluation is more complex when a doubt as to the cause for G-LOC / E-LOC is present and requires to be investigated at a specialised aeromedical centre like IAM, IAF. The flow diagram outlined would help in the evaluation process. The extent of investigations must be guided by the initial history, physical examination and ECG. Aero medical evaluation must include tilt table studies, vestibular functions and most important centrifuge evaluation. The protocol being followed at the Department of Acceleration Physiology has been described and becomes useful in detecting cases of low-G tolerance and faulty/inadequate AGSM performance. The remedial measures for the AGSM can then be instituted. The disposal of cases of G-LOC has been recommended with a view so as to conserve trained manpower without compromising flight safety.

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