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Indian Journal of Aerospace Medicine

Case Report

In-flight loss of consciousness in a fighter aircrew – G-LOC or No G-LOC conundrum

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Received : 15 May 2021
Accepted : 11 November 2022
Published : 01 June 2023

DOI
10.25259/IJASM_17_2021

Quick Response Code:

ABSTRACT

The differential diagnosis for inflight loss of consciousness in a fighter pilot is G-induced Loss of Consciousness (G-LOC) as it is physiological and 10–20% of fighter pilots may experience it during their career. However, it is very difficult to establish the diagnosis in many cases. Three cases of in-flight episodes of loss of consciousness (LOC) have been discussed in the paper highlighting how to investigate such cases to establish the diagnosis of G-LOC. Three cases have been discussed in the paper where two cases were considered as a case of G-LOC based on the circumstantial evidence and data from the flight data recorder. However, one case was diagnosed to be of LOC (Inv). One case did not benefit from the high-G training as he repeatedly experienced "GLOC" at very low G levels while wearing Anti-G Suit and performing an Anti-G Straining Maneuver (AGSM). He was recommended unfit for fighter flying. Another aircrew was experiencing G-LOC due to incorrect technique of AGSM as he had not undergone "high-G training." After correction of technique, he could successfully meet the qualifying requirements of 9G for high G training. The third case was considered as a case of inflight LOC, not due to G exposure. Subsequently, he was diagnosed to have Focal Cortical Dysplasia. The paper describes the approach and aeromedical disposition of in-flight LOC among fighter aircrew. The paper also discusses the need for "G tolerance standard" at entry and high G training for fighter aircrew. The first case highlights that not all case of in-flight LOC among aircrew is G-LOC, even if it occurs in conjunction with high-G exposure. Ruling out the presence of any potential cause for inflight LOC is extremely important before labeling a recurrent case of inflight LOC as G-LOC. The second case re-iterates the fact that there are a set of people who will not be able to endure high G exposures due to inherent individual characteristics. These people need to be identified and screened at initial entry into fighter flying itself. The cause for the recurrent episodes of inflight G-LOC in the third case was identified as improper AGSM. The problem could be identified and corrected in the Dynamic Flight Simulator. This highlights the significance of high-G training using High Performance Human Centrifuge before the commencement of operational flying and high-G sorties and also establishes it as a diagnostic tool for such cases. In-flight LOC in a fighter pilot poses a challenge in diagnosis and differentiation from G-LOC. The paper discusses an approach to such a case in detail.

Keywords: G-induced loss of consciousness, Loss of consciousness, Fighter flying, Air force, Navy

INTRODUCTION

Any in-flight Loss Of Consciousness (LOC) is an unacceptable flight safety hazard. However, it does happen in the air. As the incidence of inflight G-induced LOC (G-LOC) is close to 10–20%, the most common cause of inflight LOC in a fighter aircrew may be considered as G-LOC.[1-3] Ruling out G-LOC in an otherwise healthy fighter aircrew experiencing inflight LOC is extremely important as the evaluation and disposal of such cases are different. As per Indian Air Force guidelines, if the cause of inflight LOC in a fighter aircrew has been established as G-LOC then no further medical evaluation is required as it is considered a physiological response to high-G stress. However, base Aerospace Medicine specialist needs to rule out factors reducing the G-tolerance to prevent such incidences in the air. Mostly, the aircrew is brought with a history of inflight LOC in a twin cockpit/trainer aircraft or the aircrew declares onboard an emergency after regaining consciousness and recover the aircraft or ejects. Unlucky few may have been lost due to fatal crashes during such episodes. The hazard of G-LOC is well established, and all possible efforts are taken to prevent it in the air.[4]

Three cases of in-flight LOC, initially suspected to be G-LOC, evaluated at the Institute of Aerospace Medicine Indian Air Force, since December 2018 have been discussed and reviewed in this paper to highlight issues encountered during the evaluation of such cases.

CASE REPORTS

Case 1

A 20-years-old Flight Cadet with 140 h of flying experience, undergoing stage-II fighter training, reported with a history of three episodes of LOC while performing a "Roll off the Top" maneuver involving +4.5 Gz. There were no factors associated that could have reduced G tolerance. As per the history, the flying instructor reported that there was shivering first and then drooping of the head which was unusual for G-LOC. Since the circumstantial evidence was not suggestive of G-LOC, he was investigated thoroughly for cardiovascular and neurological causes of LOC. On evaluation, the Flight Cadet was 172 cm tall and weighed 59 kg. His clinical examination, hematology, biochemical, Treadmill Test, 24 h Holter monitoring, Electroencephalogram, and 2D echo were unremarkable. The magnetic resonance imaging brain showed Focal Cortical Dysplasia (FCD) involving the left frontal operculum and left insula. His evaluation for relaxed G tolerance in the High Performance Human Centrifuge (HPHC) was within normal limits (3.7G at a GOR of 0.1 G/s).

FCD is a malformation of cortical development which is the third most common etiology of medically intractable seizures in adults which could even be refractory to medical treatment.[5-7] Hence, he was considered unfit for flying as well as military duties.

Case 2

A 29-years-old averagely built and nourished serving Naval Officer with 350 h of flying experience, undergoing training on Advanced Jet Trainer, was referred for evaluation for recurrent inflight LOC at 5G-6G. There were no factors reducing G tolerance. On evaluation, the officer was 170 cm tall and weighed 68.5 kg with a resting pulse of 88 beats/min and blood pressure of 130/86 mm Hg. A thorough clinical evaluation revealed no organic cause for LOC. His relaxed GOR tolerance was 3.5 G. He continued to experience G-LOC at 4.5 G despite adequate training on the Anti-G Straining Maneuver (AGSM). His AGSM technique was good. He was diagnosed with a case of Low G tolerance.

Case 3

A 24-year-old fighter aircrew with 360 h of flying experience reported with a history of two episodes of inflight LOC at +6G to +7G while undergoing Operational Syllabus Training. The instructor took over the control of the aircraft during both episodes. Subsequently, the aircrew regained consciousness and landed the aircraft safely. The aircrew was wearing a working anti-G suit and performing AGSM during both episodes. He did not have any dreams/numbness/tingling during both episodes. There were no associated factors reducing G tolerance. The above manifestations were corroborated by the G-levels from the flight data recorder and history from the Instructors. The base Aerospace Medicine specialist diagnosed both episodes as G-LOC. He was referred for evaluation of G tolerance.

Since the manifestations, history by the eye-witness (Instructors), and G-levels of Flight Data Recorder indicated the LOC as G-LOC, he was not evaluated for any secondary causes. His relaxed and straining Gradual Onset Rate tolerances were found to be 4.1 G and 6.8 G, respectively. His relaxed Rapid Onset Rate tolerance (ROR at onset/offset rate 1 G/s) was 3.9 G. He experienced almost LOC at 5.1 G while assessment of straining ROR tolerance at 1 G/s. During evaluation in the Dynamic Flight Simulator, it was observed that he tended to hold his breath during AGSM.

DISCUSSION

The clinical evaluation of inflight LOC is a critical one, not only to ensure flying safety but also because of its impact on the course of a professional career. It also has far-reaching implications affecting medical aviation standards.[8] Since the fighter aircrew is screened for any health issues at very regular intervals through pre-flight medicals and annual medical examinations, secondary causes for in-flight LOC are not that common. However, if the manifestations of LOC simultaneous to sustained G exposure with immediate and complete recovery are suspected, other causes for LOC must be investigated. The G-LOC has been reported to occur at as low as 4 s of exposure to sustained G exposure. The functional buffer period for neuronal tissue is estimated to be 2 s. At very high onset rates, G-LOC can occur any time after 2 s of the functional buffer period has been exhausted.[9] In the presence of factors reducing G tolerance, the G-level at which G-LOC occurs may be reduced significantly. A list of such factors is placed in Table 1.[10,11] In addition, over-the-

Table 1: List of factors affecting G tolerance.[10,11]

Factors	Remarks
Temperature	Exposure to heat reduces G tolerance. 1° rise in core body temperature reduced G tolerance for PLL by 30–40%
Blood glucose concentration	Tolerance to+Gz acceleration reduces with falling glucose concentration. A 50% reduction of glucose concentration below the resting value reduces the blackout threshold by 0.6 G
Alcohol	Ingestion of alcohol reduces G tolerance. A dose of 110 ml of whisky was found to reduce the grey-out threshold by 0.1–0.4 G
Hyperventilation	Hyperventilation reduces+Gz tolerance. Reduction of arterial carbon dioxide tension to 20–25 mm Hg reduces the grey-out threshold by 0.6 G. Moderate hyperventilation was found to precipitate unconsciousness in some individuals at 3 G
Hypoxia	Hypoxia reduces+Gz tolerance. A reduction in black-out threshold of 0.5 G has been demonstrated when breathing air at the equivalent altitude of 10000 ft
Distension of the stomach	Distension of the stomach increases+Gz tolerance. Ingestion of 1.5 l of water has been shown to increase the threshold of black-out by 0.6–1.3 G
Active Infection	Active infection reduces+Gz tolerance
Hydration	Dehydration reduces+Gz tolerance.
Time off from flying	Time off from flying for more than a few days can result in reduced G tolerance (G lay-off)
Preceding−Gz exposure	Exposure to−Gz (footward) acceleration reduces tolerance to a following+Gz exposure (Push-pull effect)
Vestibular Influence	Motion Sickness reduces+Gz tolerance
G-transition Effect	Push-pull effect or exposure to variable G levels

counter drugs/medication and health supplements for muscle building are also known to adversely affect the +Gz tolerance.[11]

As in our case, in-flight LOC most commonly occurs in student pilots.[12] However, Rayman reported that inflight LOC can occur in any aircrew regardless of age, type of aircraft, or flying experience.[12] Based on Rayman's study, a list of causes for inflight LOC for aircrew is brought out in Table 2. In addition, positive pressure breathing for G where available may also precipitate LOC among susceptible fighter aircrew.

The most common medical causes in a fighter aircrew could be either G-LOC, Syncope, or Seizure. Syncope is defined as, "Sudden, self-limited LOC and postural tone caused by transient global cerebral hypoperfusion, followed by a spontaneous, complete, and prompt recovery."[13] For all practical purposes, G-LOC may be considered as syncope in a sustained hypergravity environment. However, from the physiological point of view, the mechanism of LOC during G-LOC and Syncope may vary in an aircrew wearing an anti-G suit.[14] A meticulous history and clinical examination are vital to an accurate diagnosis of the etiology of LOC. However, in 40% of cases, the cause may remain unexplained.[13] G-LOC may be accurately diagnosed if it occurred during sustained exposure to high G levels (>2 s) with immediate and complete recovery within 30–40 s after the high G exposure ceased (list of symptoms and manifestations during G-LOC is shown in Table 3. The above should be confidently established through eyewitness account (in twin cockpit), G exposure levels and duration using Flight Data Recorder, before diagnosing G-LOC.

If factors reducing G tolerance are present Table 1, alone or in combination, G-LOC may occur at G levels as low as 2–3 G, and at a low onset rate of G.[15] G-LOC syndrome has been described by Whinnery in sufficient detail to allow one to distinguish from G-LOC and No G-LOC causes of transient inflight LOC which is been summarized in Table 3.[4] If manifestations of LOC do not match G-LOC, the aircrew should be evaluated as a case of syncope or seizure. In a solo fighter sortie, it is very difficult to establish the diagnosis due to a lack of eye-witness account and reliable history from the aircrew as the transient LOC is known to distort the memory as well. The severity and duration of LOC are not reliable for distinguishing syncope from Seizures.[16] Sheldon *et al*. proposed a point-based scoring system based on symptoms to diagnose syncope and seizures [Table 4]. This can diagnose seizures with overall accuracy, sensitivity, and

Table 2: Causes of inflight LOC among USAF aircrew from 1966 to 71.[12]

Causes for Inflight LOC
Rapid decompression
Hypoxia
Dysbarism
Seizure disorder
Improper anti-G straining maneuver
Vasovagal syncope
Coronary insufficiency
Over-pressurization of cockpit
Functional hypoglycemia
Migraine headache
Schizophrenia
−Gz

LOC: Loss of consciousness

Table 3: Symptoms and manifestations of G-LOC in the order of presentation may be used as guidance to establish the diagnosis of G-LOC.

Symptoms/Manifestations	Remarks
Grey-out/Peripheral light loss	Experienced after 2–5 s of exposure to high-G>2G may not be experienced during high rapid onset rate>1 G/s[4,10,15]
Black-out/Central light loss	Experienced after 2–5 s of exposure to high-G>2G may not be experienced during high rapid onset rate>1 G/s[4,10,15]
G-LOC	Experienced after 2–5 s of exposure to high-G >2G, LOC lasts for 9–10 s[4,10,15]
Dreamlets	Vivid dreams or random thoughts not related to immediate flying task or environment, experienced during recovery from G-LOC[4]
Myoclonic Jerks	Convulsive movements of limbs and neck may be observed during recovery from G-LOC[4]
Loss of memory/Retrograde amnesia	About 50% of aircrew may not be able to recall preceding events due to physiological amnesia[10]
Responds to the audio or visual alarms/RT calls, however, remains confused and disoriented	Loss of situational awareness/confusion and disorientation immediately after regaining consciousness is known as relative Incapacitation period which may last for 30 s or more[10]
No preceding symptoms like aura, presyncope (diaphoresis, nausea, palpitation, etc.)	These are experienced during seizure/syncope[16]
The Flight Data Recorder should be analyzed to assess the significant sustained G exposure which should coincide with the LOC	
Radio transmission communication may help in identifying confusion or disorientation after recovery from G-LOC	
Sudden, unexplained loss of altitude after pulling sustained G (>2 s) in the Flight data Recorder may indicate G-LOC, even if it is not reported by the aircrew	Aircraft may remain uncontrolled for a minute or longer (Total Incapacitation Period) due to G-LOC which may not be reported by the aircrew after recovery as loss of memory is reported among 50% of aircrew experiencing G-LOC[10]
Presence of factors reducing G-tolerance will result in visual symptoms and G-LOC at much lower G-levels than anticipated[15]	

G-LOC: G-induced loss of consciousness, LOC: Loss of consciousness

Table 4: Point scores for the diagnosis of seizures, in the absence of knowledge of the numbers and historic duration of losses of consciousness and lightheaded spells.[16]

Criteria	Points
Waking with cut tongue	2
Abnormal behavior noted	1
Loss of consciousness with emotional stress	1
Postictal confusion	1
Head turning to one side during loss of consciousness	1
Prodromal déjà vu or jamais vu	1
Any presyncope	−2
Loss of consciousness with prolonged sitting and standing	−2
Diaphoresis before a spell	−2

Classified as Seizure if score ≥1 and Syncope if score ≤1 with overall accuracy, sensitivity and specificity of 94%.

specificity of 94%.[16] However, this scoring system may fail to distinguish between seizures and convulsive syncope.

Many underlying cardiovascular and neurological causes of syncope or seizures may be triggered by the hyper gravity as well as other stresses of flying. Considering the risk associated, at least basic investigations must be carried out to rule out the most common cardiovascular and neurological causes of transient LOC as suggested in Table 5.

Where available, HPHC should be used as a tool to investigate G-LOC consequent to suspected low G tolerance. However, the aircrew should be exposed to it only after the basic evaluation (as suggested in Table 5) and preparation to handle Seizure episodes during the HPHC run. Even if any structural lesion in the brain/heart does not manifest with Seizure/Syncope during the HPHC run, it should not be concluded that no causal relationship of Seizure/Syncope exists with the lesion as it may not happen under every exposure to hyper gravity. Further, it would be unethical to provoke seizure/syncope in such cases just to establish the diagnosis. In our first case, as the Flight Cadet was sent for evaluation of G-tolerance, it was imperative to evaluate him in the HPHC to establish the diagnosis of Low G Tolerance even if an FCD lesion was diagnosed. Necessary Seizure precautions and the presence of a Medical Specialist were ensured in this case during the HPHC run. His G-tolerance was within the normal limits for Indian fighter aircrew.[1,17] However, he was disqualified because of the seizure potential due to the FCD.

Table 5: Minimum basic investigations suggested to rule out the most common causes of transient loss of consciousness at the boarding centres.

Investigations	Remarks
Complete blood count, serum electrolytes, calcium, and urinalysis	To rule out anemia, infection, and electrolyte imbalances[13]
Fasting and post-prandial blood sugar with HbA1C	To rule out impaired glucose metabolism (IFG, IGT, and diabetes) and functional hypoglycemia[8,13,16]
24-h ambulatory blood pressure	To rule out hypertension[8,13,16]
Resting electrocardiogram	To rule out any ischemic heart disease and rhythm disturbances[8,13,16]
Tread mill test	To rule out cardiovascular causes like coronary insufficiency[8,13,16]
2D- echo	To rule out structural heart issues[16]
24-h Holter monitoring	To rule out any cardiovascular rhythm disturbances[16]
Head up tilt test	To establish the diagnosis of vasovagal syncope[13,16]
CT scan/MRI of brain	To rule out any structural lesion of brain, especially in unprovoked solitary transient LOC[13,16]
EEG	To rule out Epileptogenic foci/Seizure[8,16]

EEG: Electroencephalogram, TMT: Tread mill test, LOC: In-flight loss of consciousness MRI: Magnetic resonance imaging, CT: Computed tomography

The individual ability to tolerate G stress depends on the complex admixture of psycho-physiologic variables.[3,4,18,19] In the author's experience, many pilots, even Flight Surgeons have this wrong notion that everyone can be trained to perform in a high G environment. The second case highlights that there are individuals who will not be able to tolerate high G stress even with a good physique and unremarkable clinical status. Such individuals should not be pushed into the high-risk world of fighter flying especially the high-performance fighters. As per one estimate, approximately 10% of aircrew may not be able to meet the high-G requirements of current generation high performance fighter aircraft.[20] This emphasizes the need for G-tolerance standards for a fighter aircrew during the selection.

The third case highlights the significance of proper high G training using the HPHC before the commencement of high-G fighter flying in an aircrew. This aircrew was practicing prolonged Valsalva during straining which reduced G tolerance resulting in G-LOC.[8,10] It must be recognized that the very method used to increase G tolerance and prevent blackout or loss of consciousness may very well become a cause of in-flight loss of consciousness if not performed properly. Rayman reported five cases and Whinnery and Gondek reported seven cases of inflight LOC due to improper AGSM.[8,12] Therefore, proper instruction and training in the performance of AGSM are vital links to assure maximum aircrew safety in current generation fighter flying. He had to undergo intensive ground training to understand the physiology of high-G and unlearn the "AGSM" he was practicing. The ground training included videotape replay of his own centrifuge-induced LOC and blackout episodes, videotape of aircrew performing correct AGSM, instruction, observation, supervised performance of the AGSM, repeat centrifuge testing to confirm the effectiveness, and ensure aircrew self-confidence in performing AGSM while flying MiG-29 in Dynamic Flight Simulator up to 9G. The aircrew was diagnosed as a case of G-LOC due to improper AGSM and has now resumed his Operational Syllabus Training after the correction of AGSM performance in the DFS. This re-emphasizes the need for utilizing the centrifuge early in aircrew training and in assuring that all instructor pilots are competent in the performance and instruction of AGSM for maximum G-protection. There is no substitute for high G training in the HPHC in this regard.

The importance of HPHC as a high-G training tool is well established and undisputed. However, this case study also highlights the importance of HPHC as a diagnostic tool. In the absence of HPHC, it would have been almost impossible to diagnose the issues related to these cases confidently resulting in unnecessary medical evaluation or permanent grounding of aircrew without establishing the cause.

CONCLUSION

This paper discusses various medical causes for in-flight loss of consciousness among fighter aircrew with special emphasis to diagnose in-flight G-LOC. Three interesting cases are discussed to highlight the approach to an in-flight LOC- one case due to secondary cause and two cases due to low-G tolerance. This paper also highlights that "Low-G tolerance" as an entity exists where no possible causes may be attributed. An interesting case of inflight G-LOC due to the improper performance of AGSM has been discussed, emphasizing the importance of the HPHC both as a training device and as a diagnostic tool.

Declaration of patient consent

Patient's consent not required as patients identity is not disclosed or compromised.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Kumar A, Nataraja MS, Sharma V. Analysis of G-induced loss of consciousness (G-LOC) and almost loss of consciousness (A-LOC) incidences in high-performance human centrifuge at Institute of Aerospace Medicine Indian Air Force. Indian J Aerosp Med 2019;63:53-60.
2. Malik H, Gupta JK, Kapur R. G-induced loss of consciousness (G-LOC) in the Indian Air Force. Indian J Aerosp Med 1992;36:1-5.
3. Gillingham KK, Fosdick JP. High-G training for fighter aircrew. Aviat Space Environ Med 1988;59:12-5.
4. Whinnery JE. The G-LOC Syndrome. Washington, DC: BUMED; 1990.
5. Kabat J, Krol P. Focal cortical dysplasia-review. Pol J Radiol 2012;77:35-43.
6. Blümcke I, Thom M, Aronica E, Armstrong DD, Vinters HV, Palmini A. The clinicopathologic spectrum of focal cortical dysplasias: A consensus classification proposed by an ad hoc task force of the ILAE diagnostic methods commission. Epilepsia 2011;52:158-74.
7. Kim DW, Lee SK, Chu K, Park KI, Lee SY, Lee CH, *et al*. Predictors of surgical outcome and pathologic considerations in focal cortical dysplasia. Neurology 2009;72:211-6.
8. Whinnery JE, Gondek MR. Medical evaluation of G-sensitive aircrewmen. Aviat Space Environ Med 1978;49:1009-13.
9. Whinnery JE. On the Theory of Acceleration Tolerance. Report No NADC-88088-60.
10. Green DC. Long duration acceleration. In: Gradwell DP, Rainford DJ, editors. Ernsting's Aviation and Space Medicine. 5th ed. Florida: CRC Press; 2016. p. 131-56.
11. Sather TE. The safety and effectiveness of supplement use in aviation. Sport J 2013; 16, p 1-14. https://thesportjournal.org/article/the-safety-and-effectiveness-of-supplement-use-in-aviation/
12. Rayman RB. In-flight loss of consciousness. Aerospace Med 1973;44:679-81.
13. Sodhi SS, Cooper DH, Faddis MN. Syncope. In: Crees Z, Fritz C, Huedebert A, Noe J, Rengarajan A, Wang X, *et al*., editors. The Washington Manual of Medical Therapeutics. 36th ed. Philadelphia, PA: Wolters-Kluwer; 2020. p. 641-56.
14. Self DA, White CD, Shaffstall RI, Mtinangi BL, Croft JS, Hainsworth R. Differences between syncope resulting from rapid onset acceleration and orthostatic stress. Aviat Space Environ Med 1996;67:547-54.
15. Position Paper in Response to NTSB Recommendations A-99-1 and A-99-2. Aerospace Medical Association Safety Committee; 1999.
16. Sheldon R, Rose S, Ritchie D, Connolly SJ, Koshman ML, Lee MA, *et al*. Diagnosis of syncope and seizures. JACC 2002;40:142-8.
17. Kumar A, Nataraja MS. Describing the continuum from ALOC to G-LOC. Indian J Aerosp Med 2020;64:32-6.
18. Sarnoff CA, Mebane JC. Episodic psychogenic G-force intolerance. J Aviat Med 1958;29:287-290.
19. Wachs TJ, Perry CJ. Psychogenic G-force intolerance revisited. Aviat Space Environ Med 1978;49:76-7.
20. Gillingham KK. G-tolerance standards for aircrew training and selection. Aviat Space Environ Med 1987;58:1024-6.

How to cite this article: Kumar A. In-flight loss of consciousness in a fighter aircrew – G-LOC or No G-LOC conundrum. Indian J Aerosp Med 2022;66:84-9.