Case Report

Neuro-cognitive Evaluation of a Fighter Pilot with Cardio-embolic Stroke Due to Patent Foramen Ovale: A Case Report

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A 38 year old, not obese, normotensive and smoker fighter pilot suffered from cardio-embolic stroke involving Lt MCA territory in Jul 2008 while on leave. Trans-oesophageal echocardiography showed presence of bi-directional shunting through patent foramen ovale. After initial management and stabilisation, percutaneous closure was done using 'Amplatzer PFO Occluder which is a double-disc device comprising of Nitinol mesh and polyester fabric. The device is reported to achieve a high Closure Rates with 96% of patients showing complete occlusion at three to six month follow-up.

At the time of stroke, he had logged total service flying experience of 1,964 hours and was serving at Air Force Academy with currency on a trainer aircraft (HJT-16 Kiran) with 450 hours of 'on type' experience. The other aircraft flown included Mig-21 (Type-77), Mig-21 (Type-75), Mig-21 Bison, HPT-32 and PZL TS-11 (Iskara). He recovered well. Subsequently, he was observed in ground medical category (A4) till Mar 2010 when he was upgraded to A3G2(T-24), Fit to fly Tpt/ Hptr only. Cardiologist opined that clinico-radiological profile placed him at low risk of event recurrence or a sudden incapacitating event. In Sep 2010, he was upgraded to A2G2(P), fit to fly Tpt/ Hptr. However, this was changed by the approving authority, to A3G2(T-4) and the pilot was advised an evaluation at IAM to decide his suitability for fighter flying as Weapon Systems Operator (WSO) in Su-30 MKI.

In November 2010, he was first evaluated for neurocognitive functions. The results are presented in Table-1. In Mar 2011, he was upgraded to A2G2(P), fit to fly Tpt/ Hptr with a waiver to fly Su-30 MKI as WSO. In Apr 2012, the pilot applied for an upgradation to front cockpit. Accordingly, in Jul 2012, he was permitted to fly in the front cockpit of Su-30 MKI as a co-pilot in Category A3G2(T24+T24). In Jul 2013, he was reviewed after a seizure free period of five years after stroke and was recommended to continue in A3G2(T-12) because Aviation Psychologist observed some improvement in his neurocognitive functions. During this period, he had accrued 95 hours of uneventful flying experience in the front cockpit of Su-30 MKI. He was finally reviewed in Nov 2013. At that time, he had no neurological deficit. However, Aviation Psychologist observed persistence of mild cognitive deficit (since its first identification in Nov 2010) in the form of visuo-motor analysis, synthesis and integration. On account of these, it was opined that the pilot could find it difficult to master novel and complex situations (Table-1).

Further and a more comprehensive neurocognitive evaluation with CogScreen AE was considered appropriate to get a clearer picture. It was followed by a neuro-cognitive evaluation at National Institute of Mental Health And Neuro Sciences (NIMHANS). Results of these are given in Tables-2 & 3 respectively.

The case was discussed with the most experienced test pilot at Bangalore. The method of test was explained to him. Ability of pilot to derive meaningful information from available visual cues in an abnormal flight situation and feature extraction (target acquisition) from background were specifically deliberated.

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Discussion

To decide if the pilot could safely and efficiently fly in the front cockpit of Su-30 MKI aircraft as pilot in command in the background of his neurocognitive status, following were considered-

1. **Is short form/ piecemeal administration of WAIS (Wechsler Adult Intelligence Scale) valid?**

   Evaluation through WAIS-III can be abbreviated through two methods. One is to reduce the number of items within individual subtests (eg, Satz-Mogel short form). The other is to reduce the number of subtests and transform results by referring to special tables [1,2] to obtain estimated results. However, for clinical usage, short form estimation of respective factor scores is not recommended [3,4].

2. **Are the scores indicative of an impaired cognitive ability?**

   (a) **WAIS-III**- T Score in Block Design Subtest was 50. It corresponds to that of 50th percentile of normal population. Mean and SD in T Scores are 50 and 10, respectively. In Object Assembly Subtest, the Scaled Value was 7. Mean and SD in Scaled Values are 10 and 3, respectively. Therefore, the scaled Value of 7 represents a Score less than mean by 1 SD. It corresponds to 16th percentile of normal population. On the other hand, T Score in Matrix Reasoning was 69. It is 1.69 SD higher than the mean and corresponds to 95th percentile of the normal population. For standardisation of Scores, reference is made to [5] and Fig-1.

   (b) **CogScreen AE Evaluation -** T Scores for accuracy varied from 34 to 71 (5th to 97.5th percentile), that for speed varied from 31 to 71 (2.5th to 97.5 th percentile) and for thruput varied from 31 to 54 (2.5th to 65th percentile). Process Scores (again normalised in terms of T Scores) varied, from 34 to 59.Base Rate Analysis, which determines the number of scores falling at or below 5th percentile compared to a selected normative comparison group (not age specific) [6], yielded the following results-

	No. of scores at or below 5th percentile	**Percentile**	**T Score**
Speed	4	10	37
Accuracy	1	45	48
Thruput	3	7.5	35
Process	1	37.5	47

   (c) **Logistic Regression Probability Value (LRPV)** was 0.7437 which was indicative of brain injury due to stroke. However, LRPV indicates only the association with brain injury. It is not an index of severity of brain injury/ dysfunction [6].

   (d) **Neuro-cognitive evaluation at NIMHANS**- A comprehensive evaluation indicated that performance of the pilot on executive functions (verbal & spatial memory, planning, concept formation and set shifting), speed of processing, response inhibition was in superior range (above 60-96th percentile). However, his verbal learning and memory were found in low average range (30th percentile) which could be suggestive of difficulty in that domain. A conventional approach is to apply 5th percentile cut off score. This means considering scores falling below the 5th percentile as indicating impairment. The use of 5th percentile cut off score results in correct identification of 80% of patients with confirmed neurologic disorders. By definition, only 5% of normal would be misclassified as impaired [6]. Following the above approach, the scores are not classified as 'impaired'.

3. **Applicability of normative data provided with the above tests to the pilot in question**

The WAIS-III is based on a standardisation sample of 2,450 people, aged 16 to 89 years. Data gathered according to 1995 US Census data were used to stratify the sample according to age, gender, race/ ethnicity, education level, and geographic region. The sample was divided into 13 age groups, with 100 to 200 in each age group. Ethnicity has an impact on test scores [7,8]. In the United States, Caucasians scored highest, African Americans lowest, and Hispanics intermediate. On most factors, failure to correct for ethnicity results in African Americans being three times likelier than whites to be misclassified as impaired. Employing scores which are corrected for age alone, as has been standard practice, normal individuals who are ethnic minorities (are not well represented in the normative sample) have substantially increased probabilities of being incorrectly classified as cognitively impaired.

On the other hand, comparison of CogScreen Scores between US and Russian pilots has revealed more similarities than differences and percentage of variance accounted for by nationality has been small (10-21%) [6]. In view of the above, an evaluation on CogScreen was considered relevant (even in the absence of normative data from Indian pilots).

At the same time, the cognitive test battery at NIMHANS employs normative data which is derived from a sample of same ethnicity.

4. **Concordance of the results obtained through different tests/ batteries**

Certain findings in the results of WAIS-III are not in agreement with each other. In Object Assembly Subtest, examinee is presented, in order of increasing complexity, with puzzle pieces that must be put together to depict a common object. It measures visual-spatial skills and visual-constructional ability. In Block Design Subtest, examinee is asked to replicate models or pictures of two-color designs with blocks. The Object Assembly and Block Design Subtests correlate more highly with each other than with any of the other Wechsler Subtest which most likely reflects the fact that they both require patient to construct an object or design from discrete parts. It appears to be sensitive to damage in the left- and right- parietal and occipital lobes although it may also be sensitive to frontal lobe damage [9]. Thus, a difference in the performance between Block Design and Object Assembly test is unexplained.

Employing confirmatory factor analysis, [10] have shown that, in the visuospatial domain, processing-and-storage WM tasks and storage-oriented STM tasks equally implicate executive functioning and are not clearly distinguishable.

Moreover, the results from WAIS-III and NIMHANS were also not in agreement with each other. At NIMHANS, an adequate performance was observed in Visuo-Spatial Construction, Visuo-Perceptual Organisation & Visuo-Motor Coordination.

5. **Performance of the pilot in cognitive abilities which are shown to have maximum covariance with flying ability**

Taylor's Aviation Factor Score of his performance in CogScreen AE, represented as T Scores, were 37.64 for deductive reasoning, 61.94 for motor coordination under speed, 52.57 for visual learning and recall, 47.39 for visual/ psychomotor tracking accuracy.

6. **Concordance of the results of WAIS-III with the site of the lesion and clinical status**

In cases of stroke involving left MCA territory, the usual cognitive defect is apraxia (mostly, global, ideomotor apraxia). No such

deficit was present in the pilot. As brought out above, Object Assembly and Block Design Subtests are susceptible to damage in the left- and right- parietal and occipital lobes.

7. **Evaluation by a senior Test Pilot and examination of the Executive Report on flying**

After due deliberation, it was inferred that such an ability was possessed by the pilot as evident from the executive report.

Summary

When the performance of the pilot in WAIS-III is viewed with that in the neuro-cognitive test battery from NIMHANS, it is obvious that the performance of the pilot in certain laboratory based tasks requiring working memory is below average (but not impaired). Performance in other tasks (including ones with the involvement of working memory) was above average. The psychologist who administered/ witnessed the tests informed that the pilot was slow in understanding the task. However, he could do the task normally when he understood it.In the absence of any clinical deficit and a satisfactory (above average) overall performance in most of the tests of neuro-cognitive function, the (average/ below average) performance in visual learning and memory was not attributed to stroke. It is neither considered an impaired response. It was regarded to be a trait feature with which the pilot was selected, completed his training and logged 2,250 hours of Total Service Flying experience.

It was also conceived that, in such a highly trained pilot, average or a little less than average performance in one odd domain will be well compensated with experience and other abilities. Remark like 'the pilot may find it difficult to master the novel and complex situations' was considered too global considering the circumstances from which it is derived. No flight safety related issue was visualised and the case was considered Fit to be upgraded to A2G2(P) which is unrestricted flying on type.

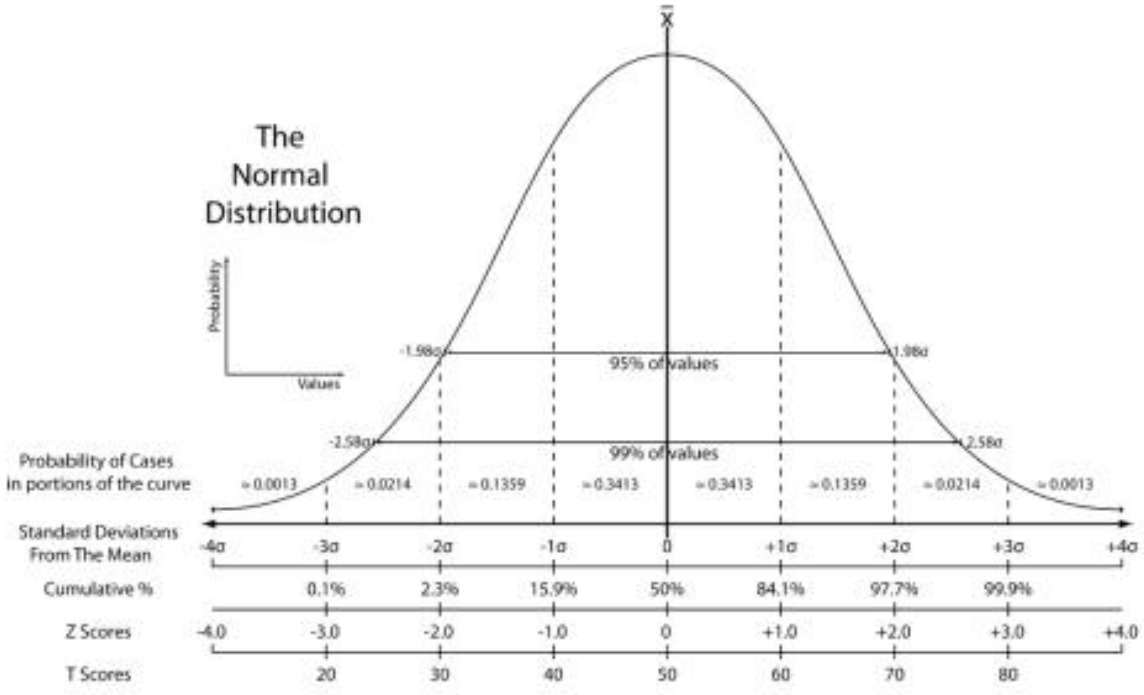

Fig -1 Normalised Scores

Table-1 Initial (preliminary) neurocognitive evaluation at IAM

Advanced Progressive Matrices	20/36	Above 90th percentile
Koh's Block Design	8/25	Below Average
Alexander's Pass Along	12/20	Low Average
Picture Construction Test	11/15	Average
Wechsler's Memory Scale	140	Above Average
General Information	5/6	
Orientation	5/5	
Visual Memory	11/14	
Mental Control	9/9	
Verbal Memory	15/21	
Digit Span	15/15	
Paired Association Memory	20/21	
Complex Verbal Memory		Average
Complex Visual Memory		Low Average

30 Nov 2010

1. Performance on advanced progressive matrices indicated high average level of abstract reasoning.

2. However, scores on block design and picture construction test were interpreted to be indicative of below average capacity for visuo-motor analysis, synthesis and integration for abstract designs and average level for meaningful pictures.

3. Visuo-spatial planning was observed to be at low average level.

4. Scores on Wechsler's memory scale indicated above average level of overall memory functions. Numerical memory was at above average level.

5. Visual learning and delayed recall were intact. Both simple and complex verbal memory functions were observed to be at average level.

6. Verbal learning and delayed recall were considered poor. Simple visual memory was at average level. Complex visual memory was at low average level.

22 Oct 2013

1. Three sub-tests of Wechsler's Abbreviated Intelligence Scale were administered. These were matrix reasoning, block design and object assembly.

2. In matrix reasoning, he had above average performance (Score 32/35 T Score 69). Scores of performance in block design (Score 39/71, T Score 50) and object assembly (Score 21/52, Scaled Score 7) were considered to suggestive of below average level of visuo-motor analysis, synthesis and integration while solving problems dealing with meaningful pictures.

3. The psychologist further elucidated that he could not complete complex tasks even outside an extended time limit on both the above tests. In block design, he could finish designs 1-8 within the time limit.

4. However, his performance was inconsistent in the more complex designs from 9-13. When spatial orientation was required, he failed to complete the tasks even in 10 minutes even though it should have been completed In 3 minutes. In the object assembly test, there are

five simple objects to assemble within the time limit. He could do only the first one and failed to assemble four other objects within the time limit. On the objects 3 & 4, he had less than half the junctures in place even after 10 minutes. On object 5, he had no junctures in place even after 10 min.

5. Thus, it was concluded that there continued to be evidence of mild deficit observed in visuo-motor analysis, synthesis and integration suggesting fronto-temporal involvement in line with the MRI findings. It was also concluded that he might find novel and complex situations difficult to master. These information processing deficits were considered likely to affect his flying performance.

Table-2 Detailed neurocognitive evaluation employing CogScreen AE at IAM

Speed Scores

Variable	Description	Score	Percentile	T Score
ASCRTC	Auditory Sequence Comp	0.82	47.50	50
DATDRTC	Visual Monitoring Dual	0.47	92.50	65
DATIRTC	Visual Monitoring Alone	0.23	97.50	71
DATSCRTC	Div Attn Seq Comp	2.06	50.00	50
DTTAABS	Tracking Alone	10.20	72.50	56
DTTDABS	Tracking Dual	21.66	87.50	62
DTTPARTC	Previous Number Alone	0.44	47.50	50
DTTPDRTC	Previous Number Dual	0.61	57.50	52
MANRTC	Manikin	2.13	20.00	42
MATHRTC	Math	27.90	17.50	41
MTSRTC	Matching to Sample	1.91	5.00	34
PFCRTC	Pathfinder Combined	1.22	32.50	46
PFLRTC	Pathfinder Letter	0.80	17.50	41
PFNRTC	Pathfinder Number	1.16	2.50	31
SATACRTC	Arrow Color	0.68	2.50	31
SATADRTC	Arrow Direction	0.63	10.00	37
SATDIRTC	Discovery	1.32	5.00	34
SATINRTC	Instruction	0.91	7.50	36
VSCRTC	Visual Sequence Comp	2.43	17.50	41

Table-2 Detailed neurocognitive evaluation employing CogScreen AE at IAM (continued)

Accuracy Scores

Variable	Description	Score	Percentile*	T Score*
ASCACC	Auditory Sequence Comp	90.00	40.00	48
BDSACC	Backward Digit Span	100.00	97.50	71
DATSCACC	Div Attn Seq Comp	88.00	42.50	48
DTTPAACC	Previous Number Alone	94.29	52.50	51
DTTPDACC	Previous Number Dual	100.00	97.50	71
MANACC	Manikin	100.00	97.50	71
MATHACC	Math	100.00	97.50	71
MTSACC	Matching to Sample	95.00	50.00	50
PFCACC	Pathfinder Combined	100.000	97.50	71
PFLACC	Pathfinder Letter	95.83	10.00	37
PFNACC	Pathfinder Number	100.00	97.50	71
SATACACC	Arrow Color	100.00	97.50	71
SATADACC	Arrow Direction	100.00	97.50	71
SATDIACC	Discovery	48.44	5.00	34
SATINACC	Instructional	100.00	97.50	71
SDCACC	Symbol Digit Coding	100.00	97.50	71
SDCDRACC	Symbol Digit Delayed Recall	100.00	97.50	71
SDCIRACC	Symbol Digit Immediate Recall	100.00	97.50	71
VSCACC	Visual Sequence Comp	100.00	97.50	71

Baseline Database- Major US Carriers - Age Group 2, 35-39

Thruput Scores

Variable	Description	Score	Percentile	T Score
ASCPUT	Auditory Sequence Comp	66.18	40.00	48
DATSPUT	Div Attn Seq Comp	25.63	47.50	50
DTTPAPUT	Previous Number Alone	129.45	52.50	51
DTTPDPUT	Previous Number Dual	98.68	65.00	54
MANPUT	Manikin	28.21	27.50	45
MATHPUT	Math	2.15	32.50	46
MTSPUT	Matching to Sample	29.81	7.50	36
PFCPUT	Pathfinder Combined	49.22	35.00	46
PFLPUT	Pathfinder Letter	71.91	15.00	40
PFNPUT	Pathfinder Number	51.77	2.50	31
SATACPUT	Arrow Color	87.98	2.50	31
SATADPUT	Arrow Direction	94.94	12.50	38
SATDIPUT	Discovery	21.95	5.00	34
SATINPUT	Instructional	65.79	7.50	36
SDCPUT	Symbol Digit Coding	27.61	12.50	38
VSCPUT	Visual Digit Comp	24.74	20.00	42

Table-2 Detailed neurocognitive evaluation employing CogScreen AE at IAM (continued)

Process Scores

Variable	Description	Score	Percentile	T Score
DATDPRE	Indicator Dual Premature Resp	1.00	80.00	58
DATIPRE	Indicator Alone Premature Resp	3.00	45.00	48
DTTAHIT	Boundary Hits– Single Task	2.00	22.50	42
DTTDHIT	Boundary Hits– Dual Task	0.00	97.50	71
PFCCOOR	Combined Coordination	1.17	82.50	59
PFLCOOR	Letter Coordination	1.42	47.50	50
PFNCOOR	Number Coordination	0.67	97.50	71
SATDIFAI	Discovery– Fail to Maintain Set	4.00	7.50	36
SATDIPER	Discovery– Perseverative Errors	2.00	60.00	53
SATDIRUL	Discovery– Rule Shifts	2.00	5.00	34

Baseline Database- Major US Carriers - Age Group 2, 35-39

Base Rate Analysis

Determines the number of scores falling at or below the 5th percentile and 15th percentile compared to a selected normative comparison group.

	Number of Scores at or below 5th percentile	Percentile	T Score
Speed	4	10	37
Accuracy	1	45	48
Thruput	3	7.5	35
Process	1	37.5	47

Table-2 Detailed Neurocognitive Evaluation employing CogScreen AE at IAM (continued)

	Number of Scores at or below 5th percentile	Percentile	T Score
Speed	6	15	40
Accuracy	2	57.5	52
Thruput	8	10	37
Process	2	40	48

Taylor Aviation Factor scores

Factor	Description	Z-	T-
Attribute Identification	Deductive reasoning	1.24	37.64
Motor Coordination	Motor coordination under speed and working memory	1.19	61.94
Visual Association Memory	Visual learning and recall	0.26	52.57
Speed/ Working Memory	Visual scanning, perceptual speed,	0.27	47.30
Tracking	Visual/psychomotor tracking accuracy	0.94	59.39

Table-3 Detailed neurocognitive evaluation at NIMHANS

Successfully completed all the tests

Attention- His attention could be aroused and sustained clinically. His span of attention, as tested on spatial Span Test, falls in the superior range. In Colour Trail Test, his performance was adequate in Trail 1 & 2, suggesting capacity of focussed attention. On sustained attention task (Digit Vigilance), his score was 81st percentile.

Motor Speed and Mental Speed- His motor speed capacity, as tested on Finger Tapping Test, was adequate on both hands. His mental speed, as assessed by Digit Symbol Substitution Test, was in the superior range (95th percentile), suggesting a good information processing and mental speed.

Executive Functions- His Category Fluency was assessed using animal name test. Performance was found to be 90th percentile. His Verbal Memory (Verbal N Back Test), Spatial Working Memory (Spatial Span Test), Planning (Tower of London), Concept Formation and Set-shifting Ability, Response Inhibition was found to be in superior range (75th – 95th percentile).

Table-3 Detailed Neurocognitive Evaluation at NIMHANS (continued)

Learning and Memory Functions- Verbal Learning and Memory (both acquisition and recall of information), assessed on Ray's Auditory Learning Test (RAVLT), was found to be in the superior range. He learnt 15 out of 15 verbal items and could recall all the 15 items in trials 3, 4 and 5 as well as on immediate recall and on delayed recall (after 20 minutes). On recognition of verbal items, he recalled all correctly. There was no false alarms. However, his visual memory, as assessed on Complex Figure Test, immediate (after 3 minutes) and delayed (after 30 minutes) was found to be in low average range (30^{th} percentile). It suggested difficulty in this domain.

Visuo-Spatial Construction, Visuo-Perceptual Organisation & Visuo-Motor Coordination- Assessed on CFT-COPY, Bender Gestalt Test (BGT) as well as on 'Copying Three Dimensional Figure (Cube, House), his performance was adequate.

Parietal focal signs- There was no evidence of agnosia for tactile, finger objects, naming colours of objects. No apraxia, buccofacial, ideational or ideomotor. No left/ right disorientation, routine finding difficulty, body schema disturbances.

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Acknowledgements

We wish Dr Keshav Kumar J, Additional Professor and Consultant, Department of Clinical Psychology, NIMHANS for his valuable help in evaluating the case.

Disclaimer

The opinions expressed in this article are those of the author and do not reflect the official views of Indian Air Force or the Indian Society of Aerospace Medicine