ORIGINAL ARTICLE

EFFECTS OF FATIGUE AFTER SLEEP DEPRIVATION ON COGNITIVE FUNCTIONS IN ANAESTHESIA RESIDENTS

Dr. Neerja Puri M.D. *, Dr. Madan Lal Kapoor M.D. **, Dr. Ashutosh Talwar M.S. ***

ABSTRACT

Introduction: Maintaining vigilance during an anaesthetic is hampered by a variety of factors relating to the patient, working environment and anaesthetist himself. Since fatigue is a common issue in the medical environment, there have been many studies of the effects of sleep deprivation and fatigue on human performance and well being. A review of the literature does not permit us to come to any specific conclusion due to the many flaws/shortcomings in most of the studies, including poor definition of the degree of acute sleep deprivation, lack of assessment of accumulated chronic fatigue, the effects of diurnal variation in performance, motivation and incentives etc. A need was felt to study the effects of fatigue associate with sleep deprivation in anaesthetists.

Objectives: We undertook this study in the anaesthesia residents to assess the effects of sleep deprivation on the mental performing abilities.

Place of Study: Department of Anaesthesiology, Guru Gobind Singh Medical College & Hospital, Faridkot, Punjab (India).

Inclusion Criteria: Residents of anaesthesia department.

Exclusion Criteria: We excluded the variables known to affect the outcome. The residents who had used sedatives, alcohol or other similar CNS depressants; those with systemic illness/organic disorder or left handedness were excluded.

Material & Methods: In this study, fifty residents of anaesthesia were tested under two situations using a battery of cognitive function tests. Group I comprised of residents after their routine day duty (10 hrs, non sleep deprived). Group II was formed by the same residents after their night duty with less than 4 hours of sleep in the previous 24 hours (sleep deprived).

Results: The results lead us to the following

Conclusions: Fatigue following sleep deprivation adversely affects the psychomotor and cognitive functions of the anesthetist but not the short term.

Key Words : Anaesthetist; Performance ; Sleep deprivation; Resident ; Fatigue.

INTRODUCTION

The anaesthetist, like all other physicians is subjected daily to a multiple of stress factors affecting both his ability to provide medical care and his own health and well being. While specialists in other medical fields commonly receive positive public recognition for their professional success, an anaesthetist is more likely to receive only negative publicity from any adverse event during the surgery. The anaesthetists work with the knowledge that a mistake or error on their part may result in patient's death or injury.

Fatigue is a factor of life for all physicians involved in acute care medicine. It is most extensively

** Registrar Anaesthesia*
*** Associate Professor & Head of Dept*
**** Registrar Surgery*
Guru Gobind Singh Medical College & Hospital, Faridkot, Punjab. 151203

For Correspondence: *Dr. Neerja puri, M.D.(Anaesth) P.C.M.S-I*
88, Medical campus, Faridkot.(Punjab) 151203
Cell: 0091-98146-16427
E. Mail: neerjaashu@rediffmail.com

experienced during the internship and residency years, when they work under conditions that may result in sleep loss. The motto of the Indian society of Anaesthesiologists is "Eternal vigilance". Vigilance has been defined as "the detection of changes of a stimulus during long monitoring periods when the subject has little or no knowledge of the sequence of the changes".[1] The anaesthetist's task is complicated by the need to monitor more than one stimuli at a time. With the large number of stimuli presented to the senses of the anaesthetist, requiring his recognition of them (perception), decision-making (cognition) and action (motor activity), this bye word is indeed appropriate. Paget et al[2] in an extensive review concluded that sleep deprivation is an important factor affecting the quality of vigilance. They also point out that environmental factors such as pollution with trace anaesthetic gases and noise may have detrimental effects. Disastrous mishaps in anaesthesia are not so frequent in relation to the number of anaesthetics given. They are associated with failure to recognize and deal with problems arising from equipment, anaesthetic technique or the patient's physiology. A wrong decimal point, a forgotten drug interaction or incorrect labeling may lead to catastrophic results. Cooper etal[3]in a study of 70 serious incidents demonstrated that potentially dangerous incidents are actually common but are usually detected and corrected by vigilance of anaesthetist. More than half the critical incidents were caused by factors known to be potentiated by fatigue. The ability of physicians to compensate for the effects of fatigue for short periods of time has been suggested by some studies,[4,5] there has been no documentation of either the duration of effectiveness of such compensation. One of the difficulties involved in testing for compensation and recovery of fatigue is that the fatigued human subject does not "run down" like a battery or steadily produce less performance like an engine wearing out. Instead, performance becomes more inconsistent. The best performance remains the best but randomly variable period of poor performance becomes more frequent and more as fatigue increases.[6]

Sleep loss has been ascribed to as a universal stressor.[7] Residents all over the world have to undergo this phase sometime or other. Various studies both in non-physicians and physicians have demonstrated that sleep deprivation affects the cognitive and psychomotor function adversely.[2,3,8,9] Unfortunately, not much attention has been paid to this aspect in India, in physicians in general and anaesthetists in particular. The present study is planned to indirectly assess the performance levels in anaesthesia residents secondary to sleep deprivation, by undertaking various psychomotor tests.

SUBJECTS AND METHODS

This study was carried out on fifty anaesthesia residents working in the department of anaesthesiology. Thirty of them were junior residents (M.D. students) and twenty were senior residents (doing residency after M.D). The sex distribution was 40 males and 10 females. The mean age was 27.55 + 3.31 years with a range of 24-39 years. A written informed consent was taken from all the residents. Prior approval from hospital ethics committee was taken for the study.

The residents were divided into two groups.

Group I (Non-sleep deprived)

It consisted of residents who had done 10 hours duty during the day with at least 6 hours of actual work but without sleep deprivation, which was defined as greater than 4 hours of uninterrupted sleep in the preceding 24 hours.

Group II (Sleep deprived)

It consisted of the same residents who had done 10 hours of night duty with at least 6 hours of actual work. These residents had been on duty during the day as part of their usual routine. The residents in this group were sleep deprived i.e. having less than 4 hours of uninterrupted sleep in the preceding 24 hours.

The residents acted as their own control.

Exclusion Criteria

The residents who fulfilled any of the following criteria were excluded from the study, since they are likely to affect the performance in an individual or combined basis.

a) Use of sedatives or other similar CNS depressants.

b) Consumption of alcohol within preceding 48 hours.
c) Systemic illness/organic disorder
d) History of head injury
e) Left handedness
f) Habitual sleeping hours < 6 hours/day.

Other extraneous variables

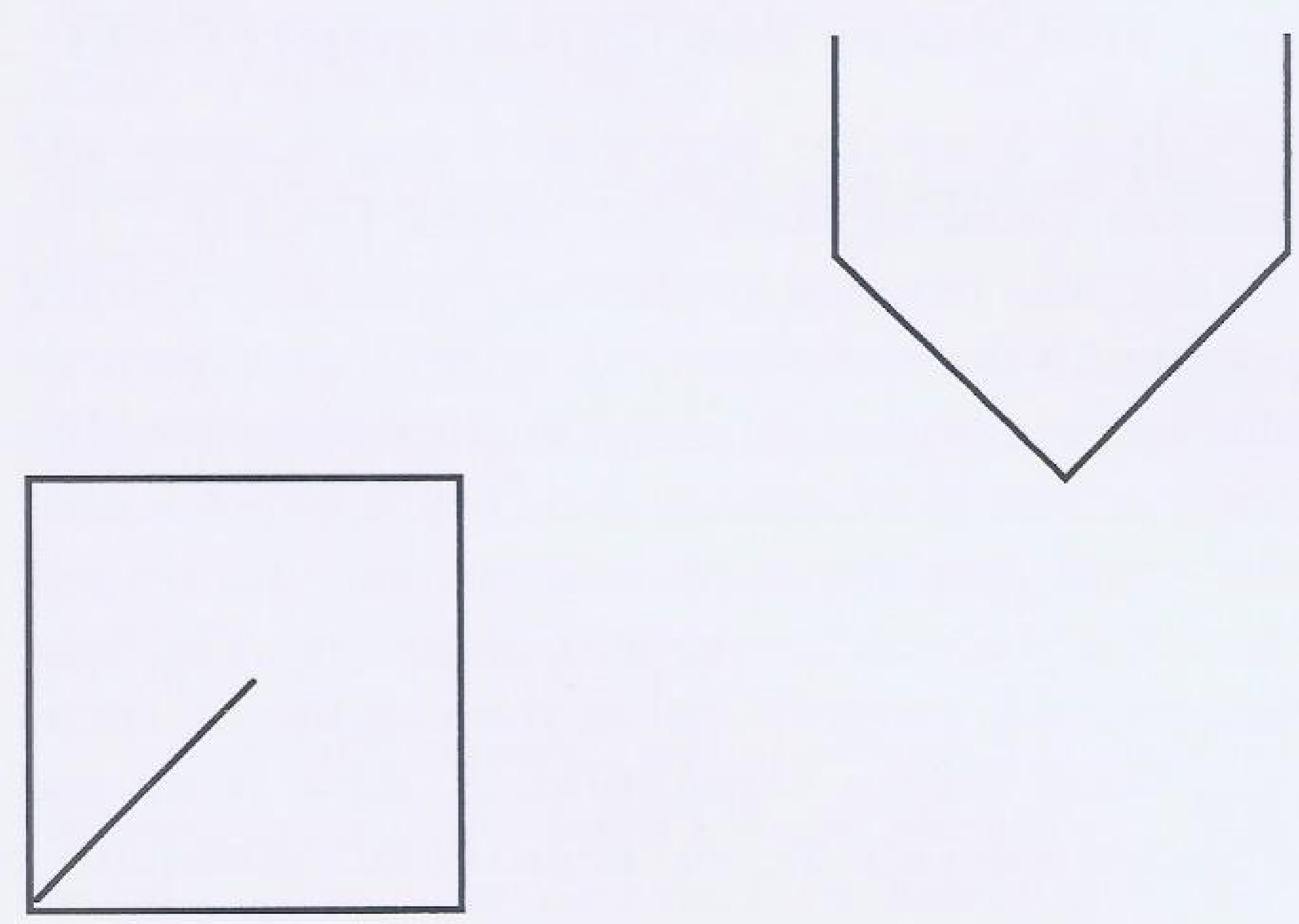
1) **Practice effect:** when a subject performs the same task at short intervals, he is likely to get used to it, and subsequent performance may show false results. This is called the 'practice effect'. In order to nullify this, the residents in each group were tested at least a week apart.
2) **Noise:** The tests were administered in a quiet room away from operating rooms to avoid the effect of noise on performance.
3) **Volatile agents:** The tests were conducted only if the resident had not used any inhalational technique during their duty hours.
4) **Visual acuity:** All the subjects were asked to retain their spectacles if needed.
5) **CNS stimulants:** Subjects were asked to refrain from nicotine or caffeine intake 2 hours before the test.
6) **Length of the test:** The total duration of the tests was approximately 45 minutes. The time limits for most tests were set by pilot studies to minimize the effect of time on the performance.
7) **Diurnal variation:** The tests were conducted between 1800 and 2000 hours in Group I and between 0600 and 0800 hrs in Group II. This avoided the circadian lull in mental activity which probably decreases the performance abnormality.
8) **Motivation:** All the residents volunteered to participate in this study. No incentives were offered.
9) **Familiarity with stressor:** None of the tests were in any way connected with the academic curriculum and none of the residents had done the tests before.
10) **Individual competence:** Since the same resident underwent the test in both groups, individual competence was kept constant.
11) **Interpretation:** All the tests had very specific answers and there was no scope for ambiguous answers.
12) **Adaptation:** Our study was designed to test the effect of acute sleep deprivation. None of the residents were on continuous on-call duties.

Two parameters i.e. short tem memory and mental efficiency representing psychomotor and cognitive functions were studied.

I. Short term memory - Benton visual retention test.
II. Mental efficiency
   - Trail making task
   - Digit symbol test
   - HSOA Battery 23

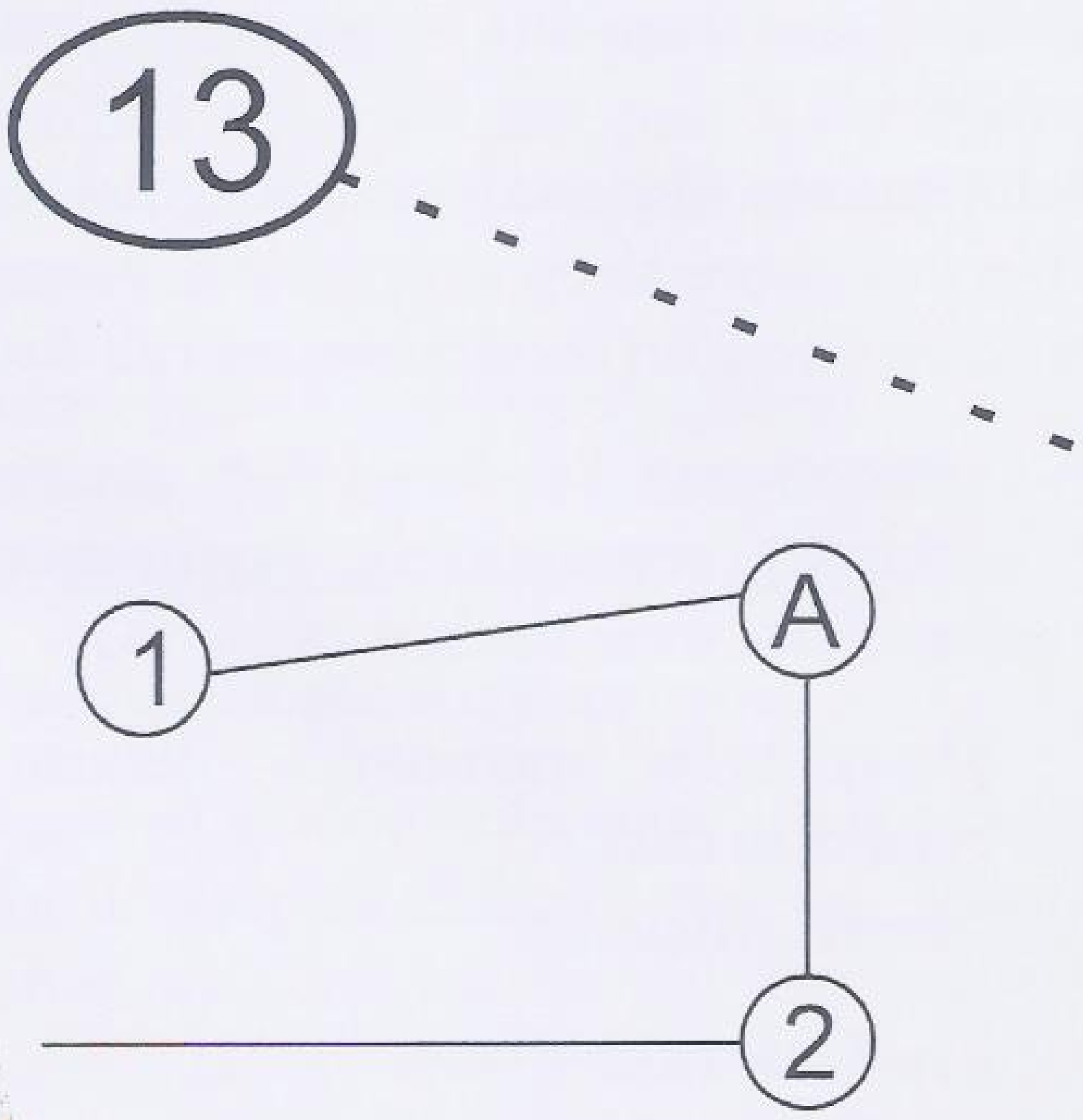
1) Benton Visual Retention Test (Benton 1963) Form 'D,49 (BVRT)

It tests the abstract organisation capability and delayed recall. It consists of a set of 10 designs. Each design was shown to the subject for 10 seconds. Then a gap of 10 seconds was given and the subject was asked to reproduce the design in a separate sheet or paper. The number of designs reproduced correctly were considered for scoring. E.g.



2) PGI Memory Scale, Part VIII (PGI MS)

This scale consists of 10 sub tests to measure various aspects of memory. In the present study, one sub test (part VIII) verbal retention for dissimilar pairs was used. This sub test measures short term memory for new learning. It consists of five dissimilar



unrelated pairs of words. They are presented to the subject once in succession. Then, one of the words of the pair is presented to the subject as a stimulus and he is supposed to recall the associated word of the pair. Three trials are conducted in random. If the subject fails to tell the correct pair, the answer is mentioned to him and another stimulus is then provided to him. The total range of the score could be 0 to 15 i.e. no learning to complete learning. As an example, one of the pairs is KID and BITTER.

Tests for Mental Efficiency

1) Trail Making Task (Reitan 1958)51 (TMT)

It is a test for hemisphere coordination and assesses visual vigilance and mental flexibility. The subject was required to connect randomly marked points on a sheet of paper with a continuous line in an alternating alphabetical and numerical sequence. The test is similar to a Connect- the-Dots puzzle but does not result in a perceptible figure. A total of one minute was allowed as the maximum time. The score was inversely proportional to the number of errors committed during completion. A pilot study had indicated that 1 minute wil1 he an optimal duration.

2) Digit Symbol Test (DST)

It is a part of Weschler Adult Intel1igence Scale. 52 In this test, all the digits from 0 to 9 are given one symbol each. These digits are then randomly written in a continuous fashion. The subject had to write the appropriate symbol below each digit within one minute.

The subject was instructed to complete the test in the same sequence. The time limit was set by pilot studies, e.g.

3	6	5	4	7	2
J	O	U	L	□	⊥

Scoring is based on the difference between correct and incorrect answers. This test assesses the ability to shift from one type of work to the other.

3) HSOA Battery - 23 (HSOA)

This test consists of pairs of jumbled alphabetical letters. They are either identical or different from each other in their content or order. The subject had to identify whether the pairs are identical or not. There were a total of 80 pairs and the maximum time was kept as 5 minutes. The time limit was set after previous pilot studies. Scoring was done by the number of correct answers. This test helps to assess the ability to concentrate.

e.g. axewcyqf
nrnnohhop
azewcyqf
nmnohhop

Before each test, the nature of the test and its time constraints were explained to the subject. A few relatively complex tests had samples in the beginning. The tests were administered by a single person to all residents. The tests were first administered to Group I and subsequently to Group II residents. No other person was present in the testing room.

The order of the test administered was kept constant for all residents in both the groups. First the tests for short term memory were administered followed by tests for mental efficiency. There was no specific reason for choosing this particular order and the results were unlikely to be biased due to the comparison of the 'within-group' type.

RESULTS

Fifty residents of anaesthesiology department were assessed during this study. Table-I shows the distribution of age, sex, level of residency and anaesthesia experience of the residents.

Table-I: Age, sex and anaesthesia experience of residents

	Number	Age (Years)		Experience (Years)	
		Mean	SD	Mean	SD
Total residents	50	27.55	3.31	2.80	2.21
Males	40	26.43	4.68	2.51	2.23
Females	10	26.91	2.80	3.65	2.12
Junior Residents	30	24.92	5.19	1.53	1.26
Senior Residents	20	30.64	2.67	5.14	1.59

The table shows that the mean anaesthesia experience was 5.14 years for senior residents and 1.53 years for junior residents, which routinely corresponds to their age difference. The mean age of males and females is comparable.

The subjects had slept for an average of 6.4 hours/24 hours in Group I with an uninterrupted sleep of 5.7 hours. The cut off point for exclusion was 4 hours as already mentioned. In group II, subjects had slept for 2.5 hrs on an average with uninterrupted sleep for only 1.8 hours in 24 hours.

Table-II: Sleep duration in 24 hrs

	Group I Mean (Hrs)		Group II Mean (Hrs)	
	Total	Uninterrupted	Total	Uninterrupted
Total residents (N=50)	6.48 ±0.59)	5.73 ±0.65	2.57 ±1.20	1.87 ±0.75
Males	6.45	5.65	2.79	1.77
Females	6.63	5.90	2.12	1.92
Junior residents	6.46	5.88	2.53	1.81
Senior residents	6.52	5.46	2.61	2.05

Thus, the average sleep in group I and group II (both total and uninterrupted) was similar irrespective of sex or level of residency.

Table III - Test scores (all residents)

Test	Group I Mean (SD)	Group II Mean (SD)	Difference Mean (SD)	p value
Benton's visual retention test	7.60 (1.91)	7.15(2.31)	0.45 (2.29)	> 0.05
TMT	9.74 (2.07)	7.91(2.48)	1.83 (2.57)	< 0.001
DST	40.15 (5.63)	37.13 (6.75)	3.08 (5.34)	< 0.001

Table IV - Comparison of difference in test scores with regard to sex & experience

Test	Males Mean (SD)	Females Mean (SD)	Junior Residents Mean (SD)	Senior Residents Mean (SD)	P value
TMT	1.58 (2.51)	3.20 (3.55)	1.83 (2.28)	1.75 (3.11	> 0.05
DST	3.90 (6.23)	2.70 (3.56)	2.43 (6.29)	3.89 (3.54)	> 0.05

There was a significant decline ($p < 0.001$) in scores on Trail making task after sleep deprivation when all the subjects were taken as a whole. But there was no significant difference among the residents irrespective of sex or level of residency.

All the residents had a statistically significant decline in their scores on DST after sleep deprivation. However, once again there was no significant difference in performance among the residents.

DISCUSSION

The safe conduct of anaesthesia depends on the appropriate application by the skilled anaesthetist of knowledge concerning the physiology of patients during and after anaesthesia, the characteristics of anaesthetic and adjuvant drugs, and the means of monitoring the patient and the life support equipment throughout the peri-operative period. Traditionally, it has been assumed that an adequately trained anaesthetist will automatically perform appropriately. Deviations from optimal outcomes were understood to be due to imperfections in the art and science of anaesthesia, leading to a heavy emphasis on the scientific and technical part of anaesthesia training and care. More rarely, adverse outcomes were ascribed to negligence or incompetence on the part of the anesthetist.

"Performance" itself is an intuitively meaningful concept that is difficult to define precisely. There are no gold standards for the clinical decisions and actions of anaesthetists. They depend heavily on the context of specific situations. There are several performance shaping factors that are potentially of sufficient magnitude to be of concern. the most significant of them are aging, illness, drug abuse, attitudes, fatigue and sleep deprivation. Factors with less significance are level of illumination, environmental temperature, background noise and the presence or absence of music. In this study, we have attempted to exclude the factors, which have been proved to affect mental performance. Fatigue and sleep deprivation have been implicated in many industrial and transportation accidents. The most well known examples are the explosion of the space shuttle challenger and the nuclear disasters at three mile island and Chernobyl, all of which involved personnel suffering from both acute and chronic fatigue.[29] Fatigue is the mechanism whereby slowdown or cessation of function is initiated, allowing for regeneration and prevention of overuse of individual tissues or organs within the overall physiologic framework of the body. This protective mechanism warns that the body's physiologic equilibrium is somewhere breaking down. It is not an indication of breakdown but an index of stress on the adaptive mechanism.

Sleep deprivation was defined as the lack of, at least a four hour period of uninterrupted sleep during the previous 24 hours.[10] This specific definition of sleep deprivation has not been fully tested in physician subjects, but four hours of uninterrupted sleep seems to be the minimum requirement for a beneficial effect on cognitive performance in the studies of non physicians.[10,11,12]

Studies have demonstrated that small but repeated deficits in sleep will accumulate, forming a 'sleep debt' that can only be repaid by recovery sleep.[13,14] The most obvious result of sleep deprivation is an increased tendency to fall asleep or to remain asleep and an increased rapidity of sleep onset. The literature reveals a consensus that a performance decrement is likely to occur after 18 to 24 hours without sleep and that a more severe decrement will occur after about 30 to 36 hours without sleep.[15,16] The decrement will be more severe at the times of circadian lull.[17]

With few exceptions, behavioural and psychomotor performances show decrements with sleep deprivation. The results emerge from the performance on a variety of tasks, such as perpetual-motor, visual vigilance, auditory, memory and work tasks.[18]

Investigators have concluded that sleep deprivation affects information processing, resulting in longer periods to resolve. Performance upon being "awakened" from sleep appears to be inferior to that of normal waking conditions, and the effects of sleep deprivation become more pronounced when assessed by sustained or continuous work tasks, as compared with brief behaviour samples.

Ford and Wentz[19] evaluated 27 interns on four occasions during their internship year. 4 of them had at least one episode of major depression during the year by standard criteria and an additional 11 claimed to have experienced a clinical depression. Anger, dysphoria and fatigue increased as the year progressed and were found to be negatively correlated with the amount of sleep obtained in the preceding week. Sharp et al[20] also found that interns moods as assessed by the profile of mood states were significantly worse after 6 months of residency due to increase in anger, tension, confusion, depression and fatigue due to sleep loss.

Other studies [21-25] used the profile mood states or other self reported data to assess resident affect or motivation after one night's sleep loss, with residents reporting a greater decrease in thinking efficiency, a greater mood disturbance, more depression and fatigue, more anxiety and less motivation than the control group.

The function of psychological tests is to 'measure difference between individuals or between the reactions of the same individual on different occasions'. One of the first problems that stimulated the development of psychological tests was the identification of the feeble minded. A strong impetus to the early development of tests was likewise provided by problems arising in education. Due to the difficulties in trying to measure actual clinical performances, many studies of sleep deprivation in residents have relied on neuro-psychological tests as a proxy measure. As many as 20 of them have been used till date. The majority of these tests were less than 3 minutes in duration. Orton et al[26] applied the choice reaction time, vigilance reaction time, Haptic sorting task and profile of mood states on 20 house officers after call duty of 31 hours and found a decrease in performance on selective tests. Hart et al who had assessed surgery residents could not find much difference in performance as far as cognitive functions were concerned. Even deaconson et al[25] could not find much difference in grammatical reasoning, trail making and PASAT but differences in mood states was noted. Incidentally, he had also studied residents in surgery. The explanation given was that chronic sleep deprivation led to a sort of adaptation, which helped them to cope up with the stress.

From the above studies, the only clear trend that is evident is that, in short duration tests, manual dexterity, reaction times and recall tasks did not seem to deteriorate in most studies after one night's sleep loss. Six years after the first study on medicine interns, Beatty et al[27] assessed 6 anaesthesia residents for effects of sleep deprivation. Sleep deprivation was defined as less than 2 hours of sleep in 24 hours. They used a 50 minute monitoring task of multichannel numeric display of life processes on a large overhead screen, similar to what could be used in the surgical environment. There were a digital read out and values, including heart rate, systolic blood pressure, respiratory rate, tidal volume and arterial concentration of oxygen and carbon dioxide. There were two sets of testing on separate mornings between 7 and 8 a.m. They also used Neisser letter search and Bradley grammatical reasoning tests. They concluded that sleep deprivation effects were minimal on vigilance but reasoning ability was significantly affected.

Two recent surveys have shown that many anaesthetists report fatigue as an element of professional life that led to errors in patient care. In a study conducted by Gravenstein et al[28], the majority of respondents (61%) agreed with the statement that they had made an error in anaesthesia administration that they attributed to fatigue.

Sleep is a period of diminished responsiveness to external stimuli, which regularly alternates with periods of wakefulness. Normal circadian rhythms are biphasic and reveal a lull in the level of alertness and performance (the circadian lull) at two times in 24 hour period (early morning 0200 to 0600 ; day time 1400 to 1800).[30] In addition to prolonged work or sleep deprivation, symptoms of fatigue can be related to the disruption of the circadian clock as a result of having a sleep wake cycle that is out of phase with one's natural rhythm. In this study, we administered the tests after 6 am or 6 pm to avoid the effect of 'circadian lull.'

Most adults sleep at least 7 to 8 hours per night. Infants and old people have more interruptions. Adults with habitual sleep duration of less than 4 hours or greater than 9 hours have decreased longevity. [31]Sleep tendency, sleepiness and rapid eye movement and sleep propensity, and all peaks approximately 3 hours before awakening. There are certain times called "wake maintenance zones" when it is very difficult to fall asleep even in subjects who are sleep deprived.

Our study was designed to assess indirectly the effects of sleep deprivation on the mental performing ability of the anaesthetists. Although the choice of residents was random, senior residents were included in the study to assess whether their performance was different, in any way from the junior residents.

Since a single test may not be accurate reflection of difference in the mental performance of residents after sleep deprivation, we chose a battery of tests for this study. Thus, the chances of finding a difference are increased, reducing the possibility of false positive or false negative results. At the same time, too many tests themselves might lead to fatigue and affect the results. Hence the total duration of testing was restricted maximum of 45 minutes.

The following are the details of the tests performed :

1. **Tests for short term memory**

Short term memory is extremely important in anaesthetic practice. The anaesthetist has to keep in mind the various parameters of the patients (both pre-op and intra-op) simultaneously. In addition, the signals from the monitors and the surgeon have to be kept in mind.

2. **Benton Visual Retention Test (BVRT)**

Although this test has not been used in sleep deprivation studies done so far, it has been applied widely in psychological studies pertaining to effect of anaesthesia or head trauma on cognitive functions. Our study does not show any significant decrease in performance of residents. Similarly, the comparison among the junior & senior residents and male & female residents showed no difference. Two other studies by Hart etal[32] and ' Bartle etal' which tested immediate recall by different methods did not show any decline in performance after sleep deprivation.

Any anaesthetic procedure involves considerable interaction of multiple sensory inputs which have to be simultaneously analyzed and decision has to be taken whether any action is required or not, and if so, the appropriate response has to be given. These processes need complex cortical responses like abstract organization, ability to switch over from one task to another, analysis and hemisphere coordination etc.

Five tasks were selected to assess these modalities. They were Trail Making task, digital symbol test, letter comparison, visual organization test and standard progressive matrices.

3. Trail making task (TMT)

The present study showed a significant decrease in performance among the residents of Group II ($p < 0.001$). One of the reasons may be that we were able to exclude many of the extraneous variables which probably had affected the results of previous studies. At the same time, our study also shows that the performance of the residents was not significantly different when compared among themselves either in terms of experience or sex This strengthens our point that the result was not due to the influence of either age or sex. TMT has been used earlier in a few studies. A couple of them showed a decline in performance in this test after sleep deprivation but the results were affected by other variables. Harrah et al had tested both medicine and surgery interns and concluded that surgery staff were more resistant to effects of sleep deprivation. Hence the deprivation becomes difficult. Hawkins et al[33] had demonstrated that the quality of meals, snacks and alcohol in the previous 48 hours also affected the results. In the presence of these factors, it is difficult to conclude that this task was not influenced by the other variables.

In contrast, Bartle and Deaconson, in two separate studies could not find any decline in performance after sleep deprivation.[34,35] The former had noted differences only in the mood states and dexterity. The latter had tested residents who were on call every other night thus leading to possibility of adaptation and hence better performance. In addition they had also offered cash incentives which might have influenced the performance.

Asken et al in their review on the sleep deprivation in residents suggested that "at a minimum, a medical education experience should be able to demonstrate that it can live up to the dictum- 'above all do no harm'." Physicians have both a professional and moral obligation to ensure that factors under their control do not jeopardize the well being of their patients. Fatigue is one stress factor that is uniquely amenable to control, either voluntarily or by legislation, by the limitation of hours of work and provision of adequate number of physicians. In addition to high litigation costs and the hospital costs of complications, the more important price to be paid by error in medical practice is the psychological stress associated with a disaster, devastating the practice of a responsible physician.

In our study, there was no significant difference among the residents with regard to the sleep durations. There was no statistically significant difference in performance after sleep deprivation in the tests for short term memory. Of the tests for mental efficiency, the TMT, DST, HSOA-23 showed a significant decline in the scores after sleep deprivation. When the residents were compared in terms of sex difference (males vs. females) or experience (junior residents vs. senior residents), there was no significant difference in performance.

CONCLUSION

The results lead us to the following conclusions: Fatigue following sleep deprivation adversely affects the psychomotor and cognitive functions of the anaesthetist but not the short term memory. Mental efficiency is impaired to a greater extent following sleep deprivation.

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