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SHORT COMMUNICATION

SHORT-TERM NEUROBEHAVIOURAL EFFECTS IN ANAESTHETISTS WITH LOW EXPOSURE TO NITROUS OXIDE

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The aim of this study was to assess whether a sample of 37 anaesthetists occupationally exposed only to N_2O showed any deterioration in vigilance and/or mood. The anaesthetists were examined with three neurobehavioural tests (Simple Reaction Time and Colour Word Vigilance to measure the vigilance and Mood Rating Scale to evaluate the level of stress and arousal) and underwent N_2O biological monitoring (to correlate the test results with the N_2O exposure) on the first and on the last day of the work week, before and after work in the operating room. No significant relationship was found between the biological monitoring and the test results. The only significant statistical difference was found between the beginning and the end of each workday in the arousal level, regardless of the result of the biological monitoring.

Key terms:
arousal, biological monitoring, mood, occupational exposure, stress, vigilance

Nitrous oxide is a colourless gas with a slightly sweet odour and taste. Used since the last century either alone or with halogenated agents, N_2O is the most important anaesthetic used in inhalation anaesthesia. There are many ways for N_2O to contaminate the operating room during inhalation anaesthesia, and put the staff in the operating room at risk of occupational exposure. For instance, it may leak out from the high pressure piping system (conveying N_2O to the anaesthetic circuit) or from the N_2O vaporiser/ventilator; the leakage may be caused by improper use of equipment by anaesthetists or by faulty installation, inadequate maintenance, or misuse of the scavenging system; excess gas may seep over the bag of the patient's mask; and

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a patient may exhale gas into the room. Leaks may occur in the anaesthetic breathing system when the face mask is used only for the start time, and/or when there is a problem with the patient's facial anatomy, and so on (1–3).

Literature confirms the findings of N_2O effects on blood (anaemia), pregnancy (miscarriage, stillbirth, and congenital abnormalities in newborns), liver (hepatic disorders), chromatids (genetic abnormalities), and on the central nervous system (neurobehavioural disorders such as vigilance impairment and mood effects) (4–8). The Diagnostic Statistical Manual of Mental Disorders (DSM IV) describes nitrous oxide as an agent with psychoactive effects in the chapter on disorders associated with substances not mentioned in other parts of the manual (9). Some studies indicate that a large portion of the anaesthetist's job involves complex vigilance and monitoring tasks (10–12).

In the course of intraoperative care for the patient, the anaesthetist usually performs a sequence of tasks to acquire information about the progress of anaesthesia. Data are obtained by consulting different sources, which include patients, many electronic and manual devices, and the operating staff (13, 14). The anaesthetist has to verify the validity of the information and formulate a hierarchy of data in terms of priority. Furthermore, the anaesthetist has to perform technical procedures, such as insertion of intravascular catheters or laryngoscopes, which require fine motor skills. In 1971, *Blum* (15) found that anaesthetists directed their attention away from patients 42% of the time and were idle (not performing any apparently active task) 40% of the time. These anaesthetists believed that this time, however, was productive because it was used to monitor, think, and analyse. *Boquet and co-workers* (16) filmed anaesthetists at work: they found that 60% of the visual activity was directed at the patient and at the surgical field. Only 10% was spent looking at the reservoir bag and less than 5% was directed at the monitors. Seventy-two percent of the time the anaesthetists were idle. However, it is worth noting that considerable technological improvements have brought along substantial changes in the activities of today's anaesthetists.

Several studies have demonstrated that human error can account for up to 70% of mishaps during anaesthesia (17, 18). In the study by *Mahoney and co-workers* (19), 75% of the intraoperative cardiac arrests observed appeared to be preventable. *Venables and co-workers* (8), who examined deaths occurring during anaesthesia, found that the anaesthetic was responsible for death in approximately 1/5 of the cases. In 1/3 the inadequate patient observation may have been the critical event. *Cooper and co-workers* (14) reported about critical incidents in two studies; 23% were due to monitoring or vigilance errors. Various factors may influence the anaesthetist's vigilance in the operating room and the exposure to waste nitrous oxide may be one of the most important.

In one study, volunteers exposed to 91.5 mg/m^3 for up to four hours showed a decrease in audiovisual performance tests (20). In another report, similar exposure did not produce any changes in a battery of psychomotor tests, including an audiovisual task, but there was a nonsignificant trend toward changes in mood, such as tiredness (8). Some studies report that the operating staff often feel like the anaesthetised patients, experiencing drowsiness, irritability, depression, headache, nausea, and fatigue (21–23).

In 1976, *Bruce and Bach* (24) observed a significant decrease in the neurobehavioural performance and effects on mood in healthy volunteers exposed to 1,006.5

mg/m^3 of nitrous oxide. In 1980, *Cohen and co-workers* (25) showed that in dentists heavily exposed to N_2O, neurobehavioural symptoms (e.g., numbness, tingling and weakness) increased three to fourfold, twofold in lightly exposed assistants, and threefold in heavily exposed assistants. In 1978, *Smith and Shirley* (26) found that the acute exposure to anaesthetic trace gases in amounts commonly seen in an unscavenged operating room had no effects on the neurobehavioural performance of volunteers. In 1988, *Stollery and co-workers* (27) observed no deterioration in the mood or cognitive functions in the anaesthetists working in actively scavenged operating theatres. In 1992, *Saurel-Cubizolles and co-workers* (28) confirmed the hypothesis of causal relation between exposure to N_2O and neuropsychological symptoms, and showed a dose-response effect.

For several years, biological monitoring methods have been available to assess individual exposure of the operating staff to waste anaesthetics. Now it is possible to correlate the outcome of neuropsychological tests to the individually absorbed dose (29, 30). We designed this study in order to investigate the short-term effects (if any) of low-dose exposure to N_2O on anaesthetists' performances.

SUBJECTS AND METHODS

The subjects studied were 37 anaesthetists (20 men and 17 women) with mean age 42.7 years (SD=5.8) and mean occupational exposure to N_2O 13.9 years (SD=7.1). The investigation included three computerised neurobehavioural tests and N_2O biological monitoring. The three computerised tests – Simple Reaction Time (SRT), Colour Word Vigilance (CWV), and Mood Rating Scale (MRS) – were administered to assess the vigilance and mood of the anaesthetists. These tests are part of the Swedish Performance Evaluation System (SPES) created by the National Institute of Occupational Health of Solna, Sweden (21). The system consists of a number of semi-automated computerised performance tests with various scales to measure many functions, and, among these, mood and vigilance. Each subject received adequate instructions about the meaning of the tests and the use of the keys on the keyboard, before performing them. Simple Reaction Time is a sustained attention task measuring attention and response speed to an easily discriminated, but temporally uncertain visual signal. The task is to press a key on the keyboard as quickly as possible when a red square is presented on the display. A total of 96 stimuli are presented within six minutes at intervals varying between 2.5 and 5.0 seconds. The first minute serves for practice and the remaining five serve to assess performance.

Colour Word Vigilance is a more complex test than SRT. It is a task of the vigilance type because a response is required only to a minority of signals. The words *red*, *blue*, *yellow*, and *white* are presented on the screen and the text can be written in any of the colours. The task is to press a key as soon as the meaning of any of the four words happens to match the colour of the text displayed. The interval between consecutive stimuli is 2.2 seconds and the 16 possible combinations of words and colours are randomly distributed within each sequence of 16 stimuli.

Mood Rating Scale – created according to the Mood Adjective Check List (MACL) (31) – assesses various moods which are divided with two separate dimensions of stress and arousal. The anaesthetist answered twelve questions such as »Did you feel... in the last ten minutes?« and every question had a different adjective to describe a feeling. The anaesthetist had the possibility to choose between five different answers ranging from »not at all« to »very much«. The adjectives calm, relaxed, and restful defined low level of stress whereas tense, harried, and stressed denoted high level of stress. The adjectives passive, feeble, and ineffective defined low arousal, and energetic, active, and concentrated denoted high level of arousal.

Biological monitoring served to compare the vigilance and mood test results with the anaesthetists' occupational exposure to N_2O. It consisted of the measurement of urinary N_2O in samples collected at the end of the shift. To avoid possible environmental contamination of the biological samples, the urine samples were collected in a room just outside the operating room. The N_2O biological concentrations were analysed with the head space method, using an HP G1800 gas chromatograph connected to a quadripolar mass selective detector.

The anaesthetists' mood and performance were examined on four different occasions: on the first and the last day of the work week and at the beginning (7:30 a.m.) and the end (12:00 a.m.) of the work shift in the operating room. The biological monitoring of exposure to N_2O was performed at the end of each workday.

The data were analysed by means of EPI Info® statistical software (32). The probability of 0.05 was used as the level of significance for statistical tests. Two-tailed tests were used. Differences between the results of each anaesthetist obtained at the beginning and the end of the shift were tested by means of Wilcoxon test. The differences in the exposure to N_2O between the anaesthetist whose performance deteriorated and those whose did not were analysed by means of Mann-Whitney test.

RESULTS

Table 1 shows the results of the SRT, CWV, and MRS tests. The SRT values measured on the first day of the work week at the beginning of the shift show a significant increase at the end of the shift, whereas the CWV values show a significant decrease for the same period.

Positive arousal scores show a statistically significant decrease both on the first day and the last day of the work week; negative arousal shows a statistically significant increase for the same period.

Negative stress scores show a statistically significant increase both on the first day and the last day of the work week; positive stress score differences are never significant.

To investigate the presence of any effect on the SRT test possibly due to N_2O exposure, mean biological exposure values of anaesthetists whose reaction times had increased during the first day of the shift work were averaged and compared to those of the anaesthetists whose values had shown no change or had shown some improvement. The results in Table 2 show that the difference is not statistically significant.

The N_2O biological monitoring data revealed the N_2O urinary means of 8.3 μg/L (SD=8.0) and 9.7 μg/L (SD=11.6) on the respective first and the last day of the

Table 1 *Mean results of neurobehavioural test for the assessment of vigilance and/or mood of anaesthetists (SD in brackets)*

	First day of the work week		Last day of the work week	
Tests	**Beginning**	**End**	**Beginning**	**End**
Simple Reaction Time (ms)	295 (44)	318 (59)*	305 (50)	318 (75)
Colour Word Vigilance (ms)	591 (35)	580 (40)*	585 (42)	589 (52)
Mood Rating Scale (score)				
positive arousal	9.5 (2.1)	7.6 (2.4)*	9.4 (2.0)	7.5 (2.2)*
negative arousal	3.5 (2.9)	5.3 (3.2)*	3.5 (2.8)	5.2 (2.9)*
positive stress	9.9 (2.8)	9.6 (1.6)	9.5 (2.0)	9.3 (2.3)
negative stress	2.6 (2.4)	4.7 (2.1)*	3.2 (2.3)	4.7 (2.3)*

* Statistically significant difference, at $P<0.05$

Table 2 *Mean biological exposure values in anaesthetists with increased Simple Reaction Times on the first day of work, compared to those of the anaesthetists with unchanged or improved values (SD in brackets)*

Subjects	**N**	**N_2O in urine µg/L**
Anaesthetists with unchanged or improved reaction times	9	6.9 (5.1)
Anaesthetists with prolonged reaction times	28	12.6 (11.7)
Total	37	

week, indicating thus low occupational exposure to N_2O (N_2O TLV-TWA of 91.5 mg/m^3 corresponding to the N_2O urinary values of 27 μg/L) (4, 31).

DISCUSSION AND CONCLUSION

The study did not comprise a separate control group (that is, of nonexposed subjects), but it rather compared data on the anaesthetists before and after work in the operating room. Furthermore, we are aware that performance and mood may deteriorate by the end of a workday. The results of the SRT test show that for each examination the reaction times were longer at the end of the work shift. They also show a particular trend of the reaction times:

$$FB < FE > LB < LE,$$

where F is the first and L the last day of the work week whereas B is the beginning (7:30 a.m.) and E the end (12:00 a.m.) of the work shift in the operating room.

In the CWV test, the reaction time for the correct answers is longest at the beginning of the first day, decreases at the end of the same day, and increases progressively on the last day, but without reaching the value of the first day at the beginning of the shift.

It is evident that the reaction times in these two tests (SRT and CWV) have an opposite trend; on the first day of the work week at the beginning of the work shift they are the best in the SRT and the worst in the CWV. These contrasting results are hard to understand as both SRT and CWV tests assess vigilance. CWV is a more complex task and practice may improve the performance results.

Our data on mood show that the neurobehavioural function compromised in the anaesthetists is the arousal; significant differences in the arousal were found between the end and the beginning of each workday, that is, the anaesthetists were more active at the beginning of the working day.

As underlined by *Weinger and Englund* (23), it would be interesting to study how and how many human factors and common workplace stressors (ergonomic, organisational, career development, role and task factors, work environment, shift work) affect the vigilance, the monitoring performance, and the mood of the anaesthetists.

There was no significant dose-effect relationship between the N_2O biological monitoring and the computerised test results. Our sample of anaesthetists showed very low exposure to N_2O in the operating room. On the first and the last day of the work week the respective average N_2O urinary concentration was 8.4 and 9.8 μg/L, with values lower than the biological N_2O value of 27 μg/L that corresponds to a N_2O TLV-TWA of 91.5 mg/m^3 (4, 31). These biological monitoring data are indeed far from the values of 146,400–219,600 mg/m^3 that are apt to affect neurobehaviour (20). Thus, our results corroborate the findings of *Smith and Shirley* (26) and *Stollery and co-workers* (27); short-term exposure to anaesthetic trace gases (N_2O in our study) commonly seen in the scavenged operating rooms has no effect on neurobehavioural performance (mood and vigilance in our study).

However, the anaesthetists with significant lengthening of Simple Reaction Times were found an average urinary concentration of 12.6 μg/L N_2O, which was twice as high as in the anaesthetists who had unchanged or improved reaction times (6.9 μg/L). These data are interesting from the biological point of view, because they suggest possible evidence of impairment, confirming the results of *Saurel-Cubizolles and co-workers* (28) as to the causal relation between exposure to N_2O and neuropsychological symptoms.

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Sažetak

KRATKOTRAJNI UČINCI IZLOŽENOSTI NISKIM KONCENTRACIJAMA DIDUŠIKOVA OKSIDA U ANESTEZIOLOGA

Cilj je ovoga ispitivanja bio utvrditi do kakvih promjena budnosti i raspoloženja dolazi u 37 anesteziologa profesionalno izloženih didušikovu oksidu. Promjene u budnosti ispitane su s pomoću zadatka jednostavnog vremena reagiranja i zadatka pozornosti, a promjene u raspoloženju s pomoću skale procjene različitih raspoloženja. Mjerenja su izvršena na početku i na kraju prvog i zadnjeg radnog dana u tjednu, a mjerenja didušikova oksida u urinu izvršena su samo na kraju radnog vremena prvoga i posljednjeg radnog dana u tjednu. Nije utvrđena povezanost između rezultata biološkog monitoringa i psihologijskog ispitivanja. Konzistentne statistički značajne razlike utvrđene su jedino u subjektivnim procjenama budnosti na početku i na kraju radnog dana.

Ključne riječi:
biološki monitoring, profesionalna izloženost, pobuđenje, pozornost, raspoloženje, stres

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