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What Is the Driving Performance of Ambulatory Surgical Patients after General Anesthesia?

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Background: **Ambulatory surgical patients are advised to refrain from driving for 24 h postoperatively. However, currently there is no strong evidence to show that driving skills and alertness have resumed in patients by 24 h after general anesthesia. The purpose of this study was to determine whether impaired driver alertness had been restored to normal by 2 and 24 h after general anesthesia in patients who underwent ambulatory surgery.**

Methods: **Twenty patients who underwent left knee arthroscopic surgery were studied. Their driving simulation performance, electroencephalographically verified parameters of sleepiness, subjective assessment of sleepiness, fatigue, alertness, and pain were measured preoperatively and 2 and 24 h postoperatively. The same measurements were performed in a matched control group of 20 healthy individuals.**

Results: **Preoperatively, patients had significantly higher attention lapses and lower alertness levels *versus* normal controls. Significantly impaired driving skills and alertness, including longer reaction time, higher occurrence of attention lapses, and microsleep intrusions, were found 2 h postoperatively *versus* preoperatively. No significantly differences were found in any driving performance parameters or electroencephalographically verified parameters 24 h postoperatively *versus* preoperatively.**

Conclusions: **Patients showed lower alertness levels and impaired driving skills preoperatively and 2 h postoperatively. Based on driving simulation performance and subjective assessments, patients are safe to drive 24 h after general anesthesia.**

GENERAL anesthetic agents impair psychomotor function.[1–4] Some of these medications impair skills related to driving among volunteers for 8 h.[3,5] Despite inadequate studies of driving skills beyond 8 h after anesthesia, patients are advised to refrain from driving for 24 h after general anesthesia. Many of the general anesthetic agents that impair skills related to driving and contributed to our current recommendations about driving after general anesthesia are not used in ambulatory anesthesia.[6,7] Newer, shorter-acting agents provide faster recovery and earlier return to normal daily activity. Some general anesthetic agents have been shown to permit prompt return of driving skills among volunteers.[8] In a study of 12 volunteers, there was no significant difference in postanesthetic driving skills at 2, 3, and 4 h after anesthesia and the corresponding control sessions. However, healthy volunteers differ from patients, who may experience perioperative anxiety, sleep deprivation, and postoperative pain. In addition, many patients may receive preoperative sedative medication and postoperative analgesics or antiemetics. The omission of these medications from this study of volunteers highlights the need to study ambulatory surgical patients. Furthermore, postoperative sedation from the anesthetic agents may lead to decreased alertness and drowsiness, an important cause of vehicle crashes.[9] Driving impairment due to postanesthetic drowsiness has never been studied. We hypothesized that impaired driving skills and decreased alertness would resolve by 24 h after general anesthesia among certain ambulatory surgical patients.

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Materials and Methods

Subjects

This was a prospective, comparative, nonrandomized, clinical study. Hospital ethics board (Toronto Western Hospital, Toronto, Ontario, Canada) approval was obtained, and informed written consent was obtained from subjects. Two groups of nonpremedicated subjects were studied (fig. 1). The control group consisted of healthy (n = 20) individuals recruited *via* newspaper and hospital bulletin board advertisements. They were matched for the demographic characteristics of the experimental group. The experimental group consisted of patients with American Society of Anesthesiologists physical status I or II who were scheduled to undergo left knee arthroscopic surgery. Additional inclusion criteria included possession of a valid driver's license. Exclusion criteria included American Society of Anesthesiologists physical status III or IV, a history of gastroesophageal reflux, sleep disorders, obesity (body mass index > 35 kg/m^2) and chronic benzodiazepine and alcohol use, alcohol dependence, or recent use of medication with sleep altering qualities, and driving simulator sickness.

Performance

Driving skills were measured using the York Driving Simulator (York Computer Technologies, Kingston, On-

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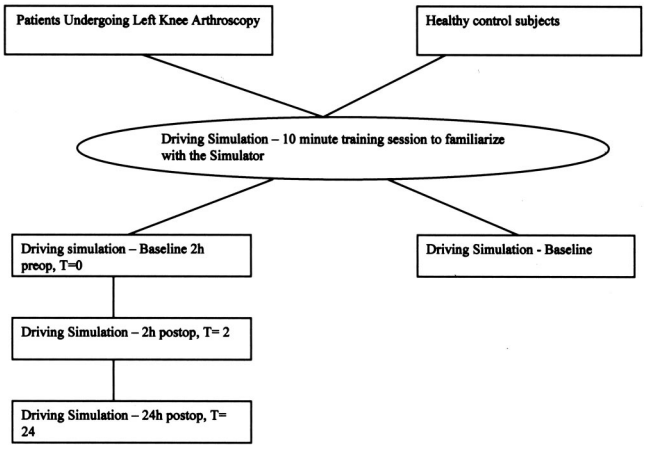

Fig. 1. The sequence of driving simulation testing.

tario, Canada). It consists of a personal computer, a 15-in monitor and peripheral steering wheel, an accelerator, and brake accessories. The simulator has been validated[10–12] as an effective research tool to measure psychomotor performance. The simulator presents a forward view from the driver's seat of a motorway road scene, with standard lane markings and sign signals appropriate to road environment. The driving scenario used in the study simulated monotonous highway driving designed to induce or exacerbate a soporific condition. The four-lane route has few turns, no stops or traffic lights, and posted speeds ranging from 70 to 100 km/h. Subjects drove for 30 min after instructions to stay in the right hand lane to avoid passing cars in the left lane. Patients were instructed to obey all lane markings and speed signs and to keep both hands on the steering wheel, while operating with the right foot only.

The simulator program samples a number of performance variables 10 times per second. These include reaction time for corrective steering maneuvers in response to "virtual wind gusts," mean velocity, and mean variability road position. The following performance outcome measurements were made. Road position (tracking) was measured as the percentage of deviation of the center of the vehicle from the center of the right hand lane. Tracking variability was expressed as the SD of tracking. Speed deviation, calculated as the difference in kilometers per hour of the speed of the vehicle from the posted speed limit, was expressed as the SD of speed deviation. Mean reaction time was expressed in milliseconds. Crashes were defined as off-road incidents where the vehicle departs from either the left or right lane markings of the highway or collides with a simulated vehicle passing in the left lane from behind. Off-road events were calculated as the number of times that the simulated vehicle had crashes. Electroencephalography (occipital placement [O2–A1]), bilateral electrooculography, and bilateral chin electromyography were continuously recorded during the simulated driving performance. This mini polysomnographic montage allowed us to identify the occurrence of sleep episodes during driving. Standards for polysomnography high- and low-frequency filter settings were used. Primary electroencephalography outcome measures included microsleep episodes, defined as 15–30 s of any sleep stage by electroencephalographic criteria, and attention lapses, defined as intrusion of α or θ electroencephalographic activity lasting more than 3 s but less than 15 s.

Procedure

On the day of surgery, the Stanford Sleepiness Scale, Fatigue Severity Scale,[13] Epworth Sleepiness Scale,[14] Alertness Scale ZOGIM-A,[15] and Visual Analog Alertness Scale were administered. Preoperative pain intensity was measured using a 10-point visual analog scale. After a 10-min driving simulator practice session, the subjects underwent a 30-min baseline simulated driving session. Subjects who voluntarily terminated the session, showed signs of simulator sickness, or showed susceptibility to simulator sickness were excluded from further participation. Driving simulator sickness was based on various behavioral manifestations (nausea, vomiting, headache, and so forth) as reported by the subject and assessed by a research assistant who was present throughout the course of the driving test. During the actual simulated driving session, individual electroencephalography was monitored for occurrence of microsleep episodes and attention lapses. Measured driving performance variables included mean lane accuracy, road position, mean speed, speed deviation, mean reaction time to virtual wind gusts, and off-road event "crashes."

All patients received a standard general anesthetic consisting of 2 mg midazolam, 2.5 mg/kg propofol, and 1.5 μg/kg fentanyl intravenously and maintenance of anesthesia was by nitrous oxide–oxygen 50:50 and 1 minimum alveolar concentration desflurane or sevoflurane by the laryngeal mask route. Additional fentanyl was given intravenously in 25-μg increments for systolic blood pressure or heart rate 20% above baseline. The termination of nitrous oxide and desflurane or sevoflurane was considered as t = 0 min. The patients were recovered in the postanesthesia care unit. Postoperative medications were administered on as-needed basis and consisted of 12.5–25 μg intravenous fentanyl at 5-min intervals for pain, 25 mg intravenous meperidine for postoperative shivering, and 1 mg intravenous granisetron for nausea and vomiting.

At 2 h postoperatively, the Stanford Sleepiness Scale, Fatigue Severity Scale, Epworth Sleepiness Scale, and Visual Analogue Alertness Scale were administered. Patients also repeated the 30-min driving simulation in the Sleep Research laboratory. All measures of driving performance and objective alertness (microsleep episodes and attention lapses) were obtained as before, after which patients were discharged home according to Post Anesthesia Discharge Score.[16] They were instructed to

Table 1. Characteristics of Normal Control Groups and Patients Who Underwent Surgery (Experimental Group)

Characteristics	Women			Men		
	Control Group (n = 8)	Experimental Group (n = 8)	*P* Value	Control Group (n = 12)	Experimental Group (n = 12)	*P* Value
Age, mean (SD), yr	38.2 (11.0)	47.0 (13.6)	NS	34.8 (12.4)	41.9 (11.5)	NS
BMI, mean (SD), kg/m^2	25.1 (5.7)	24.4 (4.0)	NS	26.4 (2.2)	27.9 (4.4)	NS
Epworth Sleepiness Scale score	6.8 (3.6)	7.2 (5.0)	NS	7.5 (2.4)	7.9 (4.8)	NS
Race, n (%)						
White	6 (75)	6 (83.3)	NS	10 (90)	9 (81.8)	NS
Nonwhite	2 (25)	2 (16.7)	NS	2 (10)	3 (18.2)	NS

Kruskal-Wallis and chi-square tests were used in all analyses.

BMI = body mass index; NS = not significant.

return to the Sleep Research laboratory at t = 24 h on the first postoperative day. Measures of subjective state of sleepiness, alertness, and fatigue were repeated, in addition to the objective measures of driving performance and objective alertness during the driving. Pain intensity was also recorded.

To control for the effects of circadian rhythm on performance, all postoperative 30-min drives took place between the hours of 10:00 AM and 3:00 PM. The control group was tested only once on the driving simulator during a 30-min test between 10:00 AM and 12:00 PM.

Statistical Analysis

Mean scores on the primary dependent variables were measured for each individual 30-min period of the driving simulation test. To confirm that the driving performance of our test sample did not differ significantly from that of untreated controls, a Student *t* test was used to compare the treated and untreated (normal control) groups. This single comparison was made for the preoperative period only. For comparisons of patients' driving performance over time, a repeated-measures analysis of variance was conducted. The three time points were the immediate presurgery period and 2 and 24 h after surgery. Tukey *post hoc* paired comparisons were used to further testing of statistically significant differences ($P < 0.05$). The Statistical Package for the Social Sciences software (SPSS 11.0 for Windows; SPSS Inc., Chicago, IL) was used.

Results

A total of 20 patients (12 men and 8 women) who underwent left knee arthroscopic surgery and 20 age- and body mass index–matched healthy controls (12 men and 8 women) completed the study. Demographic characteristics for these groups are shown in table 1. Although healthy controls were somewhat younger, there were no significant differences between the two groups in terms of demographics.

Driving performance parameters, objective and subjective sleepiness, and levels of fatigue and alertness in normal controls and patients before receiving an anesthetic are presented in table 2. There were no detectable effects of sex on the simulated driving measures and levels of sleepiness and fatigue as judged by the subjective scales. As compared with normal controls, the patients during preoperative period had a significantly higher number of attention lapses and lower alertness levels as evidenced by the alertness scale ZOGIM-A ($P = 0.008$ and $P = 0.02$, respectively). Subjective sleepiness (Epworth Sleepiness Scale score) was strikingly similar in both groups (within the normal range).

Results of driving simulation performance and electroencephalographically verified sleepiness (episodes of microsleep and attention lapses) are presented in table 3. The repeated-measures procedure revealed significant within-group variation in road position, with *post hoc* tests demonstrating better lane accuracy achieved 24 h after surgery. Patients demonstrated poor lane accuracy both in the preoperative period and 2 h after surgery. Reaction time 2 h after surgery was significantly longer *versus* values obtained before surgery and 24 h after surgery ($P = 0.02$ and $P = 0.03$, respectively). All other driving performance variables (mean speed, speed devi-

Table 2. Driving Simulation Performance, Objective and Subjective Sleepiness, Fatigue, and Alertness in Normal Controls and Patients before Receiving General Anesthetic (n = 20)

Measure	Controls	Patients
Road position	28.5 ± 3.5	29.0 ± 5.8
Speed	89.5 ± 7.8	90.7 ± 10.7
Speed deviation	−0.4 ± 2.6	2.2 ± 10.5
Reaction time	1.040 ± 0.354	1.090 ± 0.283
"Crashes"	0.9 ± 1.2	0.8 ± 1.2
Attention lapses	0.15 ± 0.48	2.5 ± 1.7*
Microsleep	0.2 ± 0.61	0.15 ± 0.36
Stanford Sleepiness Scale score	2.2 ± 0.89	2.4 ± 0.88
Fatigue Severity Scale score	27.5 ± 9.3	26.4 ± 11.3
Alertness Scale ZOGIM-A score	37.0 ± 5.3	42.6 ± 5.4†
Visual Analog Alertness score	16.2 ± 10.5	10.1 ± 12.4
Epworth Sleepiness Scale score	7.3 ± 2.9	7.6 ± 4.7

Data are presented as mean ± SD. The Student *t* test was used for this analysis.

* $P < 0.01$. † $P < 0.05$.

Table 3. Driving Simulation Performance and Electroencephalographically Verified Parameters of Sleepiness before Surgery and 2 and 24 h after Surgery (n = 20)

Measure	Mean	SD	*P* Value *vs.* 2 h Postop*	*P* Value *vs.* 24 h*	F†	*P* Value*
Road position						
Preop (same day)	29.0	5.8	> 0.05	< 0.05	3.4	0.04
2 h postop	28.0	2.3		> 0.05		
24 h postop	25.2	6.2				
Speed						
Preop (same day)	90.7	10.7	> 0.05	> 0.05	0.10	NS
2 h postop	89.9	13.7		> 0.05		
24 h postop	90.7	6.9				
Speed deviation						
Preop (same day)	2.2	10.5	> 0.05	> 0.05	0.03	NS
2 h postop	1.9	13.2		> 0.05		
24 h postop	2.3	6.7				
Reaction time						
Preop (same day)	1.090	0.283	< 0.05	> 0.05	3.8	0.03
2 h postop	1.237	0.467		< 0.05		
24 h postop	0.981	0.299				
"Crashes"						
Preop (same day)	0.8	1.2	> 0.05	> 0.05	1.7	NS
2 h postop	1.6	3.7		> 0.05		
24 h postop	0.5	1.4				
Attention lapses						
Preop (same day)	2.5	1.7	< 0.05	< 0.05	24.3	0.0001
2 h postop	3.9	2.1		< 0.05		
24 h postop	1.1	1.0				
Microsleep						
Preop (same day)	0.15	0.36	< 0.05	> 0.05	6.2	0.01
2 h postop	0.75	1.16		< 0.05		
24 h postop	0.10	0.30				

* *P* values for Tukey *post hoc* analysis. † Overall test for differences.

NS = not significant; preop = immediate presurgical period (1–2 h before surgery) when patients were tested on the driving simulator; 2 h postop = patients were tested again on the driving simulator 2 h after surgery; 24 h postop = driving simulation test 24 h after surgery.

ation, and off-road events) failed to exhibit any statistically significant variation. There was a significant within-group variation for the occurrence of attention lapses and microsleep intrusions ($P = 0.001$ and $P = 0.01$, respectively). Specifically, these episodes were found to occur more often 2 h after surgery *versus* preoperatively and 24 h after surgery. A significantly higher number of attention lapses occurred before surgery *versus* 24 h after surgery.

Results of the subjective assessments of sleepiness, fatigue, and alertness are shown in table 4. Scores on the Stanford Sleepiness Scale were the highest 2 h after the procedure. There was no significant difference in sleepiness scores before surgery and 2 h after surgery. The Visual Analog Alertness Scale showed significantly impaired alertness 2 h after surgery. There was no significant fluctuation between levels of alertness in the preoperative period and 24 h after surgery. Fatigue Severity and ZOGIM-A Scales did not reveal significant variations during each phase of the study protocol.

Although pain scores tended to be higher 2 and 24 h after surgery, there were no significant differences between the three conditions. Surprisingly, there was no association between Visual Analog Pain scores and mean speed, speed deviation, reaction time; off-road events; and electroencephalographically verified parameters of sleepiness before surgery and 2 and 24 h after surgery. Interestingly, there was a significant correlation between levels of pain and lane accuracy 2 h after surgery ($\rho = 0.53$, $P < 0.05$). No association between duration of anesthetic and driving performance was detected at any phase of the study. Highly significant correlations were found between occurrence of attention lapses and reaction time ($\rho = 0.83$, $P < 0.001$) and number of "crashes" and occurrence of microsleep episodes ($\rho = 0.66$, $P < 0.001$) at 2 h after surgery.

Discussion

In this study, the patients showed attention lapses, lower alertness levels, and poor lane accuracy preoperatively. Sleepiness, alertness, and driving performance were worst 2 h after surgery. Driving simulation performance and subjective assessments of sleepiness, fatigue, and alertness returned to normal levels by 24 h. There was no association between duration of an anesthetic and driving ability.

In the preoperative period, driving performance among patients was impaired to a greater extent than among controls. This may be related to the lapses in attention and lower alertness levels. Although patients

Table 4. Subjective Assessment of Sleepiness, Fatigue, Alertness, and Pain*

Measure	Mean	SD	*P* Value *vs.* 2 h Postop†	P Value *vs.* 24 h†	F‡	*P* Value†
Stanford Sleepiness Scale score						
Preop (same day)	2.4	0.8	> 0.05	> 0.05	3.4	0.04
2 h postop	3.0	1.0		< 0.05		
24 h postop	2.6	1.7				
Fatigue Severity Scale score						
Preop (same day)	26.4	11.3	> 0.05	> 0.05	0.13	NS
2 h postop	31.5	16.4		> 0.05		
24 h postop	27.3	12.6				
Alertness Scale ZOGIM-A score						
Preop (same day)	42.6	5.4	> 0.05	> 0.05	0.12	NS
2 h postop	39.4	7.2		> 0.05		
24 h postop	40.3	5.4				
Visual Analog Alertness score						
Preop (same day)	10.1	12.4	< 0.05	> 0.05	7.0	0.01
2 h postop	38.8	23.6		< 0.05		
24 h postop	15.7	14.6				
Visual Analog Pain score						
Preop (same day)	19.8	22.6	> 0.05	> 0.05	1.8	NS
2 h postop	43.2	24.9		> 0.05		
24 h postop	44.2	21.9				

* Experimental conditions were the same as described in table 3. † *P* values for Tukey *post hoc* analysis. ‡ Overall test for differences.
NS = not significant.

perceived their sleep to be normal, the actual duration of sleep and quality of sleep were not measured in this study. However, decreased sleep can affect driving ability. There is evidence that, among sleep-restricted drivers, subjective sleepiness and electroencephalographic patterns indicative of sleepiness were highly correlated.[17] However, performance decrement after prolonged wakefulness can be equivalent to or greater than what is currently acceptable for alcohol intoxication.[18,19] Furthermore, decreased sleep can affect awareness of driving limitations. Partially sleep-deprived male volunteers who were allowed 5 h of sleep were found to be less perceptive of their increased crash risk when compared with females.[20] More study is required of the potential link between preoperative sleeping patterns and preoperative driving performance. The duration and quality of sleep on the night before surgery may play a role in the lower alertness levels and reduced lane accuracy in the preoperative period. It seems that sleep deprivation also impairs cognitive function. Chronically sleep-deprived healthy adults were unaware of the increasing cognitive deficits resulting from sleep restriction.[21] A short duration of sleep or poor quality of sleep due to anxiety or pain can impact recommendations on whether a patient should drive to the hospital on the day of surgery.

Many ambulatory surgery patients meet discharge criteria within 2–3 h after general anesthesia.[22] We have demonstrated that patients are significantly sleepier and less alert 2 h after anesthesia. This was reflected in driving performance parameters, and subjective assessments of sleep and fatigue and visual analogue alertness scores. These findings at 2 h after anesthesia support current recommendations for patients to be discharged with a responsible adult as an escort. This observation is in contrast to our previous study where healthy volunteers showed no significant driving impairment 2 h after anesthesia.[8] These volunteers did not have surgery or postoperative analgesics. However, in the current study, the use of opioids, benzodiazepines, and postoperative antiemetics could have contributed to the psychomotor impairment seen 2 h after anesthesia. Unlike the case with subjective alertness, no association could be found between driving performance impairment and visual analog pain scores at 2 h. There is, however, strong evidence[23] that unrelieved pain may decrease psychomotor cognitive performance. Driving performance and subjective assessment parameters were not significantly impaired at 24 h. This finding supports current recommendations to refrain from driving for 24 h after ambulatory anesthesia and surgery. However, actual on-road testing is required to determine safety under real-world conditions.

This study has several limitations. Subjective alertness/sleepiness scores used in our study are limited by their lack of sensitivity. There may be a discrepancy between self-perceived sleepiness and the underlying true physiologic sleepiness in a given individual.[24]

The effects of circadian rhythm can affect driving performance. Even a few hours' shift in testing driving performance can be significant, especially if that testing occurs in a known circadian low such as the 1:00–4:00 PM block.

Impairment of driving performance is defined as failure to exercise the expected degree of prudence or control to ensure safe operation of the vehicle under the traffic conditions pertaining at the time and is often

expressed as traffic violation and traffic crashes.[25] The driving simulator offers the nearest possible laboratory condition to everyday driving. The advantages include experimental control and subject safety. However, the relatively small size of the monitor display, along with the computer-generated stimuli, makes it impossible to reproduce the variety of conditions observed in real traffic. The current simulator can evaluate only a restricted range of behavioral demands likely to be encountered on road. It is difficult to obtain on-road validation of the driving simulator because of ethical and practical constraints.

Driving performance can be reduced without resulting in significant violations or crashes. Minor traffic violations and failure to heed warning signals can also occur when driving is impaired. In addition, impairment of some driving parameters will be of greater significance to driving safety than others. Reaction time, lane deviation, and number of times over the speed limit are important factors for determining safety. However, there has been no statistically significant difference with respect to these driving performance variables between 2, 3, and 4 h after anesthesia among volunteers and their corresponding control groups.[8] It is not clear whether drivers in the postanesthetic period exhibit poor judgment or increased risk-taking behavior while driving. These factors are harder to measure on a driving simulator.

The results of this study cannot be generalized to all the ambulatory surgical population. Our study tested a relatively younger and healthy population. Modern ambulatory surgery involves patients of various age groups and coexisting diseases. A greater impairment might be seen in older age groups. The anesthetic technique, the duration of surgery, and drugs used postoperatively may have varying effects on driving performance after anesthesia.

We conclude that patients showed lower alertness levels and impaired driving performance preoperatively, which may suggest that patients should be advised about driving to the hospital preoperatively. Sleepiness, alertness and driving performance were worst at 2 h after surgery. Based on driving simulation performance and subjective assessments of sleepiness, fatigue, and alertness, patients can resume driving at 24 h after general anesthesia. To determine whether patients are truly safe to drive after general anesthesia would involve studying their judgment and risk-taking behavior in the postoperative period. Further studies should also assess impairment of driving skills in the context of the various anesthetic drugs, anesthetic techniques, and anesthetic duration.

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