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The deleterious impact of 24 hours shifts on medical reasoning is associated to their frequency among anesthesiology and critical care residents and physicians: a randomized crossover study

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Mathilde Ramier. The deleterious impact of 24 hours shifts on medical reasoning is associated to their frequency among anesthesiology and critical care residents and physicians: a randomized crossover study. Human health and pathology. 2021. dumas-03403810

HAL Id: dumas-03403810

<https://dumas.ccsd.cnrs.fr/dumas-03403810v1>

Submitted on 26 Oct 2021

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FACULTE DE MEDECINE ET DE PHARMACIE DE ROUEN

ANNEE 2020-2021

**THESE POUR LE DOCTORAT
EN MEDECINE**

(Diplôme d'État)

PAR

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Née le 1 NOVEMBRE 1991, à EVREUX (France)

PRESENTEE ET SOUTENUE PUBLIQUEMENT

LE 18 OCTOBRE 2021

Titre :

The deleterious impact of 24 hours shifts on medical reasoning is associated to their frequency among anesthesiology and critical care residents and physicians: a randomized crossover study

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Je promets et je jure d'être fidèle aux lois de l'honneur et de la probité dans l'exercice de la Médecine.

Je respecterai toutes les personnes, leur autonomie et leur volonté, sans discrimination.

J'interviendrai pour les protéger si elles sont vulnérables ou menacées dans leur intégrité ou leur dignité. Même sous la contrainte, je ne ferai pas usage de mes connaissances contre les lois de l'humanité.

J'informerai les patients des décisions envisagées, de leurs raisons et de leurs conséquences. Je ne tromperai jamais leur confiance.

Je donnerai mes soins à l'indigent et je n'exigerai pas un salaire au dessus de mon travail.

Admis dans l'intimité des personnes, je tairai les secrets qui me seront confiés et ma conduite ne servira pas à corrompre les mœurs.

Je ferai tout pour soulager les souffrances. Je ne prolongerai pas abusivement la vie ni ne provoquerai délibérément la mort.

Je préserverai l'indépendance nécessaire et je n'entreprendrai rien qui dépasse mes compétences. Je perfectionnerai mes connaissances pour assurer au mieux ma mission.

Que les hommes m'accordent leur estime si je suis fidèle à mes promesses. Que je sois couvert d'opprobre et méprisé si j'y manque.

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Table des abbreviations

- ISNIH : Inter Syndical National Union of Hospital Interns
- ANTS : non-technical skills for a population of anesthesiologists
- ICU : intensive care unit
- MCQ : multiple-choice questionnaire
- SCT : script concordance test
- KSS : Karolinska sleepiness scale

Introduction

"Primum non nocere". This dogma is taught to all medical students. However, it is hard to respect, for several reasons. One of them is that in France, doctors, especially hospital doctors, participate in the permanence of care. This has two aspects:

- the permanence of care, which consists in providing the fastest and most appropriate medical response possible, particularly in emergency situations, whether in or out of hospital.
- continuity of care, which consists of continuing the care of patients already hospitalized.

Some specialties are particularly affected by this need for continuity of care. In anesthesia and intensive care, it is most often organized in the form of a medical shift where the practitioner is required to work for a maximum of 24 hours in a row. At the end of these 24 hours, they must respect a safety rest, without hospital activity. This legal framework seems to be generally accepted today. It is part of a legitimate desire to ensure the quality of care.

Legal framework

Long working hours are a tradition in most specialties, including anesthesia and intensive care (1)(2). Required hours are often considered necessary for learning and developing professionalism. However, this model is increasingly being challenged. Over the past 20 years, there has been an increased awareness and understanding of the potential effects of fatigue on doctors and their consequences for patients, resulting in changes in legislation. Since 2015, the working time of the medical intern is regulated by:

- Articles R6153-2 of the public health code ;
- The decree n°2015-225 of February 26, 2015 ;

- The decree of June 30, 2015, on the methods for preparing and transmitting the duty rosters dedicated to the working time of residents and the decree of August 6, 2015, on the shift of interns.

A resident's work week must include ten half-days of work, including two half-days dedicated to academic training. The weekly working time must not exceed 48 hours, with since 2002, the integration of shift in hospital obligations and the obligation of a safety rest. Residents benefit from an 11-hours safety rest that must be taken immediately after each night shift. In 2020, a survey on the working time of interns was conducted by the National Union of Hospital Interns (ISNIH) (3). The anesthesia and intensive care interns who responded to this survey worked an average of five shifts per month. They reported an average of 62 hours of work per week and safety rest was respected in 97% of cases, making it the specialty that most respects the law. These official guidelines remain a reference, but their daily application depends on the organization and habits of each department and therefore remains an area for improvement.

History

As early as 1971, Friedman *et al*, highlighted the impact of resident fatigue on clinical tasks. They found twice as many errors in reading an electrocardiogram after a prolonged period of work, and residents were less able to recognize arrhythmias on the tracings. Long-term follow-up of this population of residents also showed that their mood was significantly affected by sleep loss, with an impact of fatigue on their social life (4). This pioneering study was to be followed by others corroborating these facts, particularly in surgery. In a large retrospective study, sleep deprivation led to an increase in the rate of complications during surgery (5). In simulated laparoscopic surgery, sleep deprivation was shown to increase the duration of surgery and the rate of error during surgical tasks (6–8). Studies on the impact of fatigue and sleep deprivation on anesthesiologists began in the late 1970s. They demonstrated that sleep

deprivation had a negative impact on decision-making skills in emergency situations (9). Cooper *et al*, reported that fatigue contributed to 6% of the critical incidents that resulted in 80% of anesthetic accidents in teaching hospitals (10–12).

Anesthesia and intensive care are a complex discipline that requires both technical and non-technical skills such as communication and stress management, which are essential in current practice and especially in crisis management.

Non-technical performance

Clinical performance in the management of critical events in simulated cases (bronchospasm, anaphylactic shock, esophageal intubation, ventricular tachycardia) appears to be significantly impaired by sleep deprivation in 48 French anesthesia residents (13). The residents in this study made more errors, the main ones being delay in identifying hypotension, lack of communication with the surgical team in the emergency, and pharmacological errors (wrong dose of adrenaline, administration of a drug to which the patient was allergic). Decision-making, organizational and communication performance were also impaired in a simulated scenario comparing pre and post-shift management of anaphylactic shock after administration of SUGAMMADEX during rapid sequence induction for peritonitis (14). This study used a score developed by Fletcher, validated to study non-technical skills for a population of anesthesiologists (ANTS). This score looks at four skills: task management, teamwork, situational awareness, and decision making (15). One study looked the possible adverse effects of sleep deprivation on "creative" thinking in physicians after a long period of wakefulness. It used three types of tests assessing flexibility, the ability to generate new ideas, change strategy or type of approach, and planning abilities. The results also show that sleep deprivation has a significant negative effect on flexibility, spontaneity, and creativity. A sleep-deprived participant will remain fixated on the strategies, they had previously used, therefore, it will be

more difficult to generate new ideas and to confront to make a decision in a more complex situation (16). Harrison *et al*, showed that sleep deprivation resulted in more rigid thinking, increased perseveration errors and marked difficulty in appreciating a new situation (17). Vigilance also appears to be affected by shift. The ability of anesthesia residents to detect significant changes in the four critical variables monitored on a scope (heart rate, blood pressure, saturation, and capnography) in the presence of simultaneous distraction, after a night of rest, and after 24 hours shift was significantly worse. These results support the intuitive proposition that a fatigued person is less likely than a rested person to detect significant changes (18).

Technical performance

In the literature, there are few studies about the impact of fatigue on technical procedures related to anesthesia and intensive care, such as orotracheal intubation, placement of central or peripheral venous catheters or chest tubes, and the various other procedures that may be required for a doctor. Smith-Coggins *et al*, in a study of emergency doctors found that the processing time in a simulated intubation task was significantly increased (31.6 sec vs 42.2 sec) (19). The risk of a blood exposure accident was also significantly increased after a 24-hour shift (20). Only one study in the literature which looked at the placement of an epidural catheter during the day and during a night shift did not find any significant difference in terms of complications (number of punctures, duration of placement), and this was true whether the epidural anesthesia was carried out by a novice intern, an intern who had already been trained, or a doctor. The other specialties, more specifically in surgical field, have studied the technical skills of their interns under conditions of fatigue, mostly during simulated scenarios, and show for many of them an increase in complications and the duration of the procedures, although this

was not always the case, notably during major risk surgery, such as thoracic, cardiac and neurosurgery (5,21–23).

Medical errors

According to the American Institute of Medicine, between 44,000 and 98,000 people die each year in hospitals as a result of medical errors (24). Notable events include, in 1984, the death of an 18-year-old woman in the operating room, an event related to a physician falling asleep after being on shift for more than 36 hours straight, causing an American public scandal and leading to the beginning of working time legislation in the United States (25). The "To err is human" report of 2001, which raised awareness of the importance of the human factor in medical errors (24). The authors highlighted those specialties such as anesthesia and intensive care, and emergency were those whose error rate could be the highest and with the most serious consequences.

Landrigan *et al*, in a notable randomized cohort study, found that 36% of serious medical errors in the intensive care units (ICU) occurred during 24 hours shifts, with six times as many diagnostic errors following this consecutive shift. There was a 20% increase in medical errors (errors in administering inappropriate pharmacological agents, labile blood products or filling solutions). Subsequently, changes in the working hours of the doctors led to a clear reduction in these errors. This study contributed to the modification of the working hours of doctors in the United States (26).

In a New Zealand self-report survey, 86% of anesthesiologists reported did a patient care error attributed to fatigue. In addition, fatigue was associated in this study with more frequent major pharmacological incidents (needle exchange, wrong drug, wrong dosage) (27,28). 83% of the anesthesia errors identified in an Australian study were of human origin, and in 3% of these, fatigue was judged to be the causal factor. These errors were mainly cases

of over or under dosing, prescription of the wrong drugs, and needle exchanges. Contributing factors were haste, distraction, inattention, failure to check equipment, or pressure to perform surgery. These incidents were more frequent during anesthesia induction and occurred more frequently between 7:00 p.m. and 3:00 a.m. and became significant after 10 consecutive hours of work (29).

Fatigue and driving: an example of an impaired complex task

Fatigue and sleep deprivation lead to a deterioration of cognitive and psychomotor skills as suggested by the previously studies. A decrease in cognitive function after about 18 hours without sleep is comparable to individual with a blood alcohol level of 0.5 g/L which is the limit for drunk driving in France (30). After a shift, the level of fatigue would correspond to that of a narcoleptic subject or one suffering from sleep apnea, especially since the disturbance occurs in the first part of the night, a period corresponding to deep sleep, which is considered as recuperative, with all the consequences admitted concerning this pathology on driving (31).

Using a driving simulator, Murray *et al*, studied the effect of sleep disruption on the ability of anesthesiologists to remain alert after a shift. Simulated driving appears to be a relevant method for assessing fatigue because in these tests, sustained alertness is required to details identical to those anesthesiologists are subjected to when monitoring general anesthesia and are additionally sensitive to the effects of fatigue. These tests involve passive concentration, require the subject to respond to stimuli, and are performed for a sufficiently long duration to show these requirements. After a night of sleep, subjects showed significant improvement in their vigilance scores, in contrast to what was observed after a shift, where interns' scores were impaired. Subjects' performance was more affected if their sleep was disrupted during the first third of the night (32)

These simulated data corroborate the results of the 2012 ISNIH intern time study, 11% of interns reported having a motor vehicle accident while coming off a shift (3). A cohort study of 2737 American interns showed an increased risk of motor vehicle accidents after a 24 hours shift. This study also showed that each shift completed increased the monthly risk of a commuting accident by 16% (33).

To our knowledge, the impact of fatigue generated by shift has been studied on the different aspects we have mentioned. However, this impact has never been evaluated on the medical reasoning of anesthetists and critical care doctors in the specific context of shift.

Evaluation of medical reasoning

Clinical Reasoning and Script Theory

Non-technical skills play a fundamental role in the practice of anesthesia. They are cognitive and interpersonal skills that support technical excellence and maximize patient safety through medical reasoning. Doctors possess theoretical knowledge, skills (questioning, techniques) and clinical reasoning. Medical reasoning is the intellectual activity that selects and synthesizes information obtained from a specific clinical situation, integrates it with prior knowledge and experience, and uses it to make decisions about the diagnosis and management of the patient (34). Numerous studies in cognitive psychology have been conducted in recent decades to explore the foundations of the clinical reasoning process and various models have been described, including script theory (35). Scripts in medicine are the networks of knowledge developed by the clinician, specifically organized to be effective in a clinical task, which allows him to acquire automatisms concerning decision making. The pathways or "scripts" taken are updated and improved throughout the clinician's experience (36). The acquisition of good medical reasoning is therefore a primary objective of medical education, and its evaluation is not simple. Theoretical knowledge can be easily assessed by examinations such as the multiple-choice questionnaire (MCQ), whereas the assessment of clinical reasoning is less

straightforward. Based on cognitive script theory, a new tool for assessing clinical reasoning was created in the late 1990s: the Script Concordance Test (SCT)(37).

Principle of the SCT

The Script Concordance Test is one of the tools used to evaluate clinical reasoning. It measures the degree of organization of knowledge and verifies whether the knowledge is elaborated (i.e., organized to act effectively in the clinical context), rather than the mere presence of this knowledge. The problems with which health professionals are most often confronted in their daily practice are complex, the data of the problem are not all immediately available, the solution is not univocal and requires reflection mobilizing diverse knowledge. The SCT explores the clinical reasoning process implemented in a context of uncertainty in complex and ambiguous clinical situations, and therefore as close as possible to daily practice. It is a widespread tool and its use has been the subject of recommendations and guides to good practice for teachers in the health professions (38,39). Every SCT case can and should be a problem even for an experienced physician. The questions in a SCT are presented in vignettes that correspond to common situations encountered in clinical practice. Each vignette is deliberately short because this helps to create uncertainty ; data are deliberately ambiguous or information is missing. The candidate is presented with an initial hypothesis for diagnosis, investigation, or treatment. The candidate is asked to rate the impact of new information on this initial hypothesis by choosing one of the five steps of the Likert scale (is the initial hypothesis eliminated, less likely, unchanged, more likely, or certain) (38). The problems that healthcare professionals most often face in their daily practice are complex. The SCT explore the clinical reasoning process implemented in the context of uncertainty in complex, ambiguous clinical situations and therefore as close as possible to daily practice. This tool has already been used by the anesthesia and intensive care team of the Rouen University Hospital on several

occasions during studies (40–43). The SCT is an original test format since there is not just one correct answer to an item. An assessment is made of the degree of agreement between the student's responses and those of a reference panel of experimental physicians (anonymous and experts in the specialty). The experts' responses are used to build the scoring grid, which is the reference for determining the candidate's score, by a method of weighting the answer choices (points are assigned proportionally to the distribution of the experts' response to the question). The response of each member of the reference panel is thus taken into account ; the method allows for the variability usually found among experienced physicians when answering complex questions. Because of the difficulty in planning a clinical study of intern errors during on-call duty, SCT appear to be a useful tool for assessing clinical performance and offers the advantage of studying medical crisis management while excluding the risk of harm to patients. Considering the information regarding SCT, the purpose of the present study will be to examine the effect of sleep deprivation on medical reasoning using SCT, by evaluating anesthesia and intensive care doctors before and after shift in order to identify impairment in medical reasoning. Thus, the main objective of our study was to assess the impact of a shift on doctors' medical reasoning, measured by SCT.

Material and Methods

In accordance with French laws, the Ethics and Evaluation Committee for Non-Interventional Research approved this study (N°E2020-92) (44). All participants received information before any study procedures were undertaken, and practitioners were invited to participate as subjects in the study. All participants gave informed consent (by e-mail or telephone) and were informed that they could stop participating at any time, the tests were anonymous.

Population Selection

We included anesthesiology residents and physicians practicing in department of anesthesiology and critical care in 5 public hospitals of Normandy region (CHU Rouen, GHH Le Havre, CHG Dieppe, CHI Elbeuf, and CH Evreux) during the collection period. The exclusion criteria were refusal to participate or the presence of any element leading to a sleep disorder (young child, chronic sleep disorder or specific life event).

To participate in this study, it was necessary not to have any hospital work during a weekend of more than 48 hours. The anesthesiologists had to have left work on Friday evening the week before the test. The shifts were realized out on the different shift tables (Intensive care and anesthesia operating block of emergency, maternity).

The residents and seniors included were all from the same region. Therefore, the residents had received the same education. Learning objectives for anesthesiology residents are French National Guidelines for anesthesia teaching, given to all participating residents at the beginning of their 5-year anesthesiology program. The training program for all residents includes several types of learning with 10 days dedicated to specific topic lectures throughout the academic year. In addition, a weekly journal club and a weekly practice exchange group are

organized. The university department has supervised other works related to SCT's, which allowed all the residents and physicians to be already familiar with this assessment.

Study procedures

This prospective, cross-over, randomized study was conducted among anesthesiology residents and physicians. After inclusion, residents and physicians were randomized in two groups, depending of SCT set (A or B), allowing for a 1:1 cross-over randomization (groups A and B), stratified by resident and their different years of teaching or physician status (45). As a cross-over design, each group answered by email each to the two tests, one in a rest situation (after a 48-hours weekend without hospital work) and the other after a 24 hours-consecutives-shift (that had to be on a Monday, Tuesday or Wednesday, so as not to add to the fatigue accumulated by the work week to the evaluation). To avoid the bias of one test session being easier than the other, group A completed the first part of the assessment (Set A) after a weekend without work and the second part (Set B) after a 24h-shift; group B did the same in reverse order. It was asked to the anesthesiologists to respond at each test in the morning, before any others activities. The 2 tests were sent by email and accompanied by the Karolinska Sleepiness Scale (KSS) daytime alertness score to evaluate the daytime vigilance of the practitioners at the time of the test (46)(Appendix 1)(Appendix 2). This test was closely related to electroencephalogram and behavioral variables, indicating a high validity in measuring sleepiness.

Design of the Script Concordance Test

The SCT is a tool used to evaluate medical reasoning in conditions of uncertainty (39). The SCT format allows for incorporating the uncertainty that characterizes medical practice, and it is considered that the required cognitive tasks are closer to the reality of clinical reasoning

than in other kind of tests (37)(47). This methodology has been already use for anesthesiology residents (40–43). As previously described, SCTs confronted the responders with authentic uncertain clinical situations concerning anesthesiology and intensive care which were described in vignettes (40). The SCTs were written by one of the teachers (MR) and were reviewed and validated (and possibly modified, if needed) by two other teachers (TC and VC). The clinical situations were problematic even for experienced clinicians, either because there were not enough data, or the situations were ambiguous. There were several options for diagnosis, investigation, or treatment. The items (questions) were based on a panel of questions that an experienced clinician would consider relevant to this type of clinical setting. The item was consistent with the presentation of relevant options and new data (not described in the vignette). The task for the responder was to determine the effect these new data on the status of the option. The respondent’s task was to assess, using a 5-points Likert scale, the influence of this new element on the diagnostic hypothesis, the plan for investigation, or the treatment (Figure 1).

You support a 28 years-old man in the emergency room. He presents a closed fracture of the right leg.

If you think about...	And you discover...	Hypothesis become...
Perform a regional anesthesia (femoral and sciatic nerves blocks)	Persistent paresthesia in the peroneal nerve territory	-2 Contraindicated -1 Less useful 0 Neither more or less usefull +1 More useful +2 Essential
Perform a regional anesthesia (spinal anesthesia)	A congenital lung dyspalsia with chronic respiratory failure	-2 Contraindicated -1 Less useful 0 Neither more or less usefull +1 More useful +2 Essential
Perform a general anesthesia	A Cormack score at 4	-2 Contraindicated -1 Less useful 0 Neither more or less usefull +1 More useful +2 Essential

Figure 1 : Example of SCT.

The different points on the scale corresponded to positive values (the option was enhanced by the new data), neutral values (the data did not change the status of the option), or negative values (this option was ruled out by the data). The scoring system was based on the principle that any answer given by one expert had an intrinsic value, even if that answer did not coincide with those of other experts. In the present study, a group of 20 experienced anesthesiologists and intensive care physicians formed the expert panel and SCTs were designed as previously described (40,41,43). The principles of SCT are that for each item, the answer entitled the responder to a credit corresponding to the number of experts who had chosen it. All items had the same maximum credit, and raw scores were transformed proportionally to obtain a one-point credit for the answer that was chosen by most experts. Other choices received a partial credit. Thus, to calculate the scores, all results were divided by the number of individuals who had given answers chosen by the largest number of respondents. The total score for the test was the sum of all credits earned for each item. The total score was then transformed into a percentage score. An automatic correction software (freely accessible on the website of the University of Montreal) was used for scoring (48).

Study outcome

The primary end point was the performance of medical reasoning assessed by SCT before and after a 24hours-shift. The performance in SCT was expressed as degree of concordance with the panel of 20 experts (expressed out of 100 points).

The secondary measures were to research if the following items were associated with the performance of clinical reasoning after a 24h-shift:

- The variation of the KSS (Karolinska sleepiness scale) daytime alertness score.
- The number of 24h-shift during the previous 30 days.
- Vacations during the previous 30 days.

- The presence of more or less than 4 hours consecutive hours slept, without considering the hours of non-consecutive sleep that occurred before or after these hours.
- The management of a stressful event during the shift (suggested as examples: cardiac-arrest, death during emergency care, initial management of polytrauma, intubation of acute respiratory distress, code red for cesarean).
- The different resident years.
- The place where the shift took place (University hospital or peripheral hospitals).
- The type of shift (anesthesia or intensive care).

Finally, we measured the Cronbach's alpha coefficient, calculated after optimizing the test for the SCT (39), and the receiver operator characteristic curve generated with the number of 24h-shifts performed during the previous month in professionals with clinically significant alteration of medical reasoning after a 24h-shift and those without.

Data included information on the physicians and residents' personal characteristics.

Statistical analysis

With regard to previous publications on the evaluation of anesthesiologists by SCTs, we assumed that a difference of 6% between rest period and after-shift period would be clinically significant (43)(41). Based on these findings, assuming that the SD were similar, and using a power of 0.90 with a level of statistical significance at 0.05, it was estimated that at least 38 anesthesiologists should be analyzed before and after a 24h-shift. (i.e. a total of 38 anesthesiologists, because of the crossover design). Considering the likelihood of dropouts, we enrolled 90 anesthesiologists.

The values are presented as number and percentage values for qualitative variables, as mean and SDs for quantitative variables with a normal distribution, and as median and interquartile range for quantitative variables with a non-normal distribution. Residents and

physicians who did not respond to the two sets of tests were excluded from the final analysis. After performing a Shapiro-Wilk normality test, the quantitative variables were compared using a Wilcoxon test or a student t-test. The Pearson correlation test was used to assess the strength of the association between two quantitative variables. A multivariable analysis using a linear regression model, including demographic characteristics (age, sex, status (resident or physician)) and variables presenting a p-value<0.2 in the univariable analysis, was realized to identify the factors associated with the variation of medical reasoning after a 24h-shift. Receiver operating characteristic (ROC) curve analysis, including area under the ROC curve (AUC), was used to determine a number of shifts/month threshold able to discriminate professionals with and without clinically significant alteration of medical reasoning (defined as a SCT score reduction of at least 6%) after a 24h-shift. The significance threshold was set at 0.05. All statistics were analyzed using GraphPad PRISM software 9.1.2.

Results

Population characteristics

Ninety anesthesiology residents and physicians from four hospitals agreed to participate and were included, from March to July 2021. Then they were randomized in two groups (45 in each group). Five anesthesiologists randomized in Group A and one randomized in Group B were excluded from analysis after randomization (no or incomplete response). Finally, 40 participants in Group A and 44 in Group B were analyzed (Figure 2). Their characteristics are summarized in Table 1.

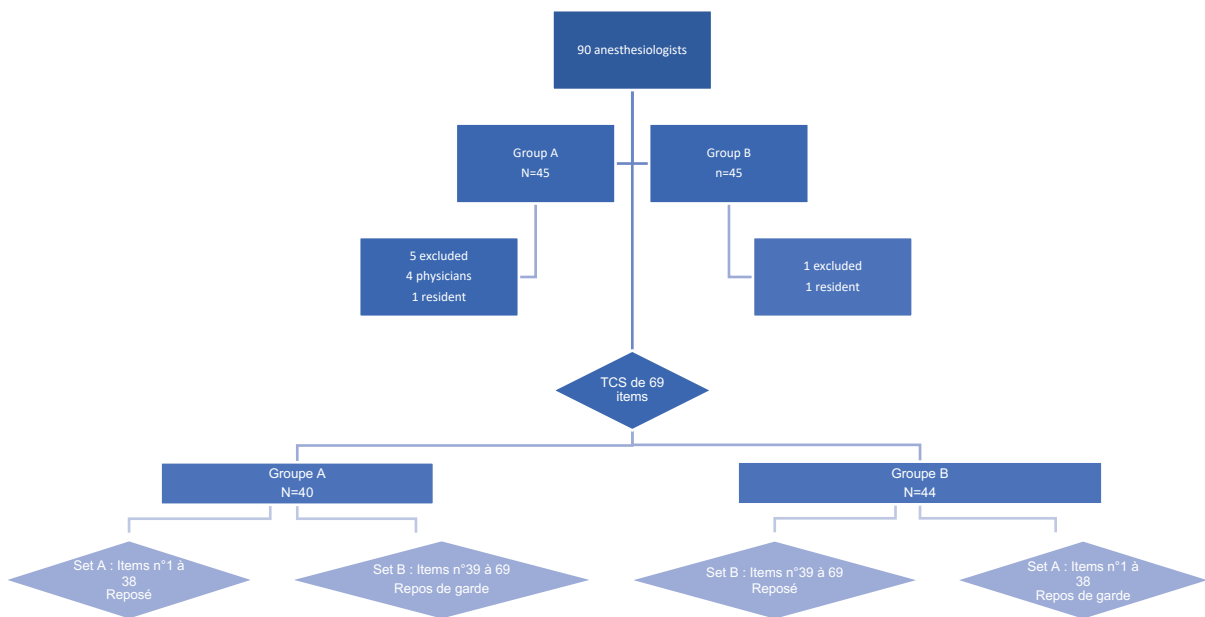


Figure 2 : Flow chart.

Table 1. Characteristics of the population analyzed.

Characteristic	Population (n=84)	Group A (n=40)	Group B (n=44)
Age (years)	30 ± 5	30 ± 6	30 ± 5
Sex			
Male	45 (53 %)	21 (53 %)	24 (54 %)
Female	39 (47 %)	19 (47 %)	20 (46 %)
Status			
Resident	58 (69 %)	29 (72 %)	29 (66 %)
Physician	26 (31 %)	11 (23 %)	15 (44 %)
Resident's year			
DESAR 1	8 (9%)	4 (13.8 %)	4 (13.8%)
DESAR 2	13 (15%)	7 (24.1 %)	6 (20.6%)
DESAR 3	16 (19%)	8 (27.6 %)	7 (24.1%)
DESAR 4	14 (17%)	7 (24.1 %)	7 (24.1%)
DESAR 5	7 (8%)	3 (10.3%)	4 (13.8%)
Number of 24h-shifts in the previous month	5 [4 ; 6]	5 [4 ; 6]	5 [4 ; 6]
KSS score			
Before shift	3 [3 ; 4]	3 [3 ; 4]	3 [3 ; 4]
After shift	6 [6 ; 7]	7 [6 ; 7]	6 [6 ; 7]
Number of hours consecutively slept during 24h-shift			
<4 hours	49 (59 %)	25 (62 %)	24 (55 %)
>4 hours	35 (41 %)	15 (38 %)	20 (45 %)
Vacations during the previous month			
Yes	28 (34%)	17 (42 %)	11 (25 %)
No	56 (66%)	23 (58 %)	33 (75 %)

Values are presented as number and percentage (n, %) for qualitative variables, and as mean ± SD or median [interquartile range] for quantitative variables.

Concerning the residents, they performed on average 5 shifts per month, including 1 on weekends for most of them. 50% of them did their shift in intensive care and the other 50% in anesthesia. Concerning the physicians, 88% of the population was composed of seniors working at the Rouen University Hospital, 73% of them had less than 5 years of experience, and they worked an average of 5 shifts per month, including 1 on weekends for most of them. 38% of them did their shift in intensive care and the 62% others in anesthesia.

SCTs optimization

For evaluation, SCTs including 31 scenarios for a total of 93 items were submitted to a panel of 20 experts. According to the recommendations of Lubarsky *et al.*, we optimized SCT by performing a post-hoc analysis (39). Items with high variability, low variability, or binomial responses were excluded. We obtained a final version with 28 scenarios and 69 items. The final assessment consisted of 69 SCTs divided in two tests (38 SCTs and 31 SCTs) and Cronbach's alpha coefficient (index of consistency and reliability) was 0.64. The test is considered to be adequate when Cronbach's alpha coefficient reaches a value of 0.64. (49)

Impact of a 24h-shift on medical reasoning

SCTs performance (expressed as degree of agreement with the expert panel) was lower after a 24h-shift than after a weekend without work (68 ± 8 vs. 65 ± 9 , respectively; $p=0.008$). We found no significant variation in medical reasoning (expressed as variation in SCTs performance between the rest period and the post-shift period) between residents and physicians (-4 ± 11 vs. -2 ± 10 , respectively; $p=0.40$). Overall, the difference in SCT score between before and after was greater for year 1 and 2 residents and, inversely, was lesser (not statically significant) for year 3 and 4 residents and even for year 5 residents. All results are presented in Table 2.

Table 2. Residents' SCT performance.

	SCT performance before vs after	P value
DESAR 1-2 (n=21)	65 vs 60 [0.2 ; 9.6 %]	0.04
DESAR 3-4 (n=30)	66 vs 62 [- 0.8 ; 9.6 %]	0.1
DESAR 5 (n=7)	71 vs 70 [- 8.5 ; 10.2 %]	0.8

Values are presented as mean; IC 95%.

Impact of the previous month's activities on medical reasoning variation

We found a negative correlation between the number of 24h-shifts performed during the previous month and the variation of medical reasoning after a 24h-shift (Figure 3).

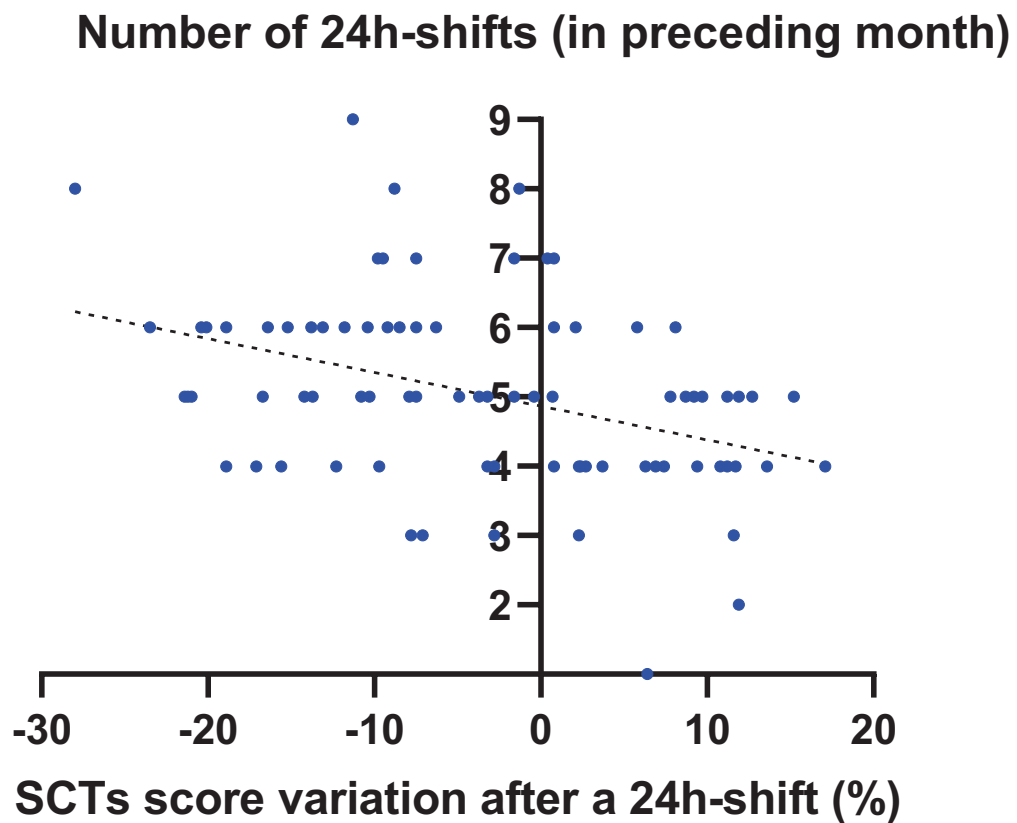


Figure 3. Correlation between medical reasoning variation (script concordance tests (SCTs) scores variation between a rest period vs. after a 24h-shift) and the number of 24h-shifts during the month preceding the evaluation. Result is presented as Pearson correlation coefficient with 95% confidence interval.

Professionals who had at least one week of vacations in the month preceding the 24h-shift didn't decrease the performance of medical reasoning after this 24h-shift unlike those who had no vacations (0.4 ± 8 vs. -5 ± 11 , respectively; $p=0.02$; Figure 4).

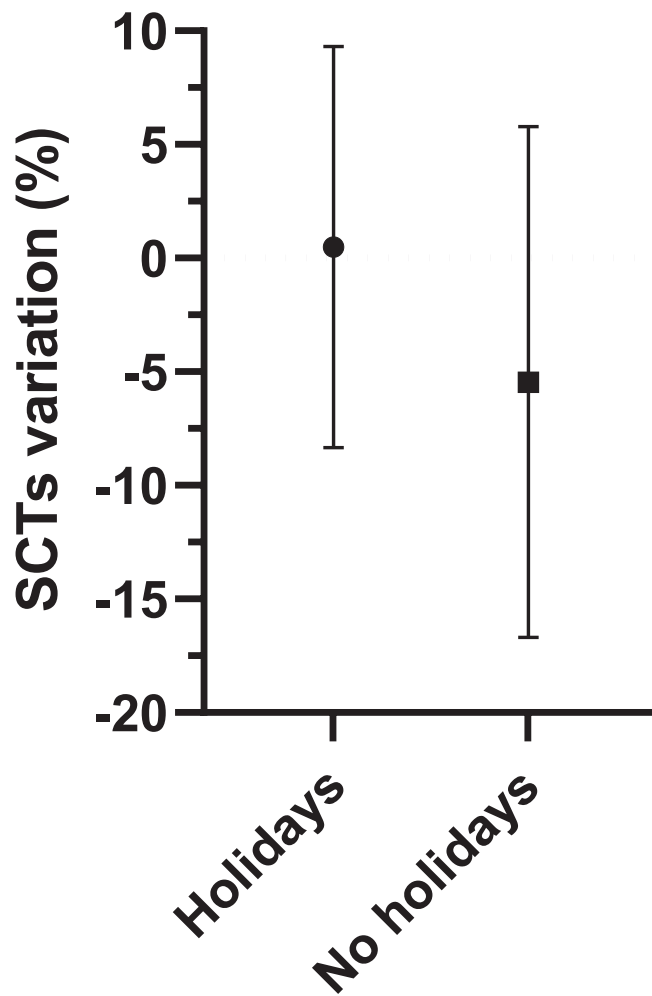


Figure 4. Medical reasoning variation (script concordance tests (SCTs) scores variation between a rest period vs. after a 24h-shift) among professionals having holidays (at least one week) in the preceding month vs. those who had no holidays. Data are presented as mean \pm SD. *, $p < 0.05$.

In multivariable analysis, the number of 24h-shifts performed during the previous month was the only factor associated with a decrease of medical reasoning after a 24h-shift (Table 3).

Table 3. Multiple linear regression model to predict the variation of medical reasoning after a 24h-shift.

Variable	Variation of medical reasoning (%)		
	Beta	95% Confidence Interval	<i>P</i> value
Sex (female)	-2.03	-6.49;2.42	0.37
Age (years)	-0.20	-0.74;0.35	0.47
Status (physician)	4.03	-2.27;10.33	0.21
Holidays during the previous month (yes)	4.06	-0.71;8.83	0.09
Number of 24h-shift during the previous month	-2.92	-4.5;-1.26	0.0008

Concerning the number of 24h-shifts performed during the previous month, the AUC for discriminating professionals with clinically significant alteration of medical reasoning after a 24h-shift (reduction of SCTs score ≥ 6 %) to professionals without medical reasoning alteration after a 24h-shift was 0.72 [0.61-0.83] ($p=0.0007$; Figure 5). With a number of shifts ≥ 5 /month, the sensitivity was 82.1 [67.3-91.0]% and the specificity was 51.1 [37.0-65.0]% (Figure 5).

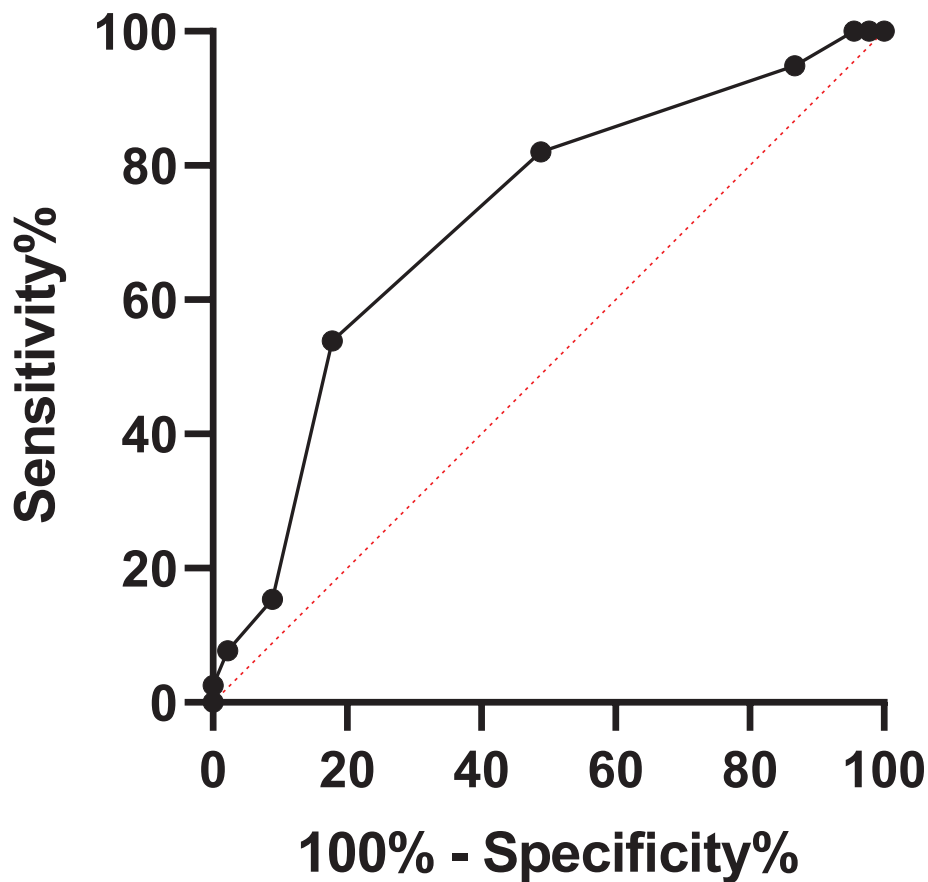


Figure 5. Receiver operator characteristic curve generated with the number of 24h-shifts performed during the previous month in professionals with clinically significant alteration of medical reasoning after a 24h-shift and those without. The receiver operator characteristic (ROC) curve is the plot of the true positive rate (sensitivity) vs the false positive rate (100 – specificity) for different positivity thresholds (different cutoff levels of shifts/month). The calculated value of the area under the ROC curve (AUC) was 0.72 (superior to the random value of 0.5), indicating that the number of 24h-shifts performed during the previous month discriminated professionals with and without alteration of medical reasoning after a 24h-shift

Impact of shift associated factors with medical reasoning variation

We found no significant medical reasoning variation between professionals who slept 4 hours or less and those who slept more than 4 hours consecutively during the shift (-4 ± 11 vs. -

2±11; p=0.42). There was no difference of medical reasoning variation between professionals who experienced a stressful event during the shift and those who did not (-5±10 vs. -3±11; p=0.30). There was no correlation between evolution of fatigue level (measured by the variation of KSS before and after the 24h-shift) and medical reasoning variation ($r=-0.02$ [-0,23;0,20] ; p=0.86).

Discussion

Clinical reasoning' performance of anesthesiologist, measured by the SCT, was significantly poorer after 24h-shift than after rest period. This performance is also affected negatively by the number of shifts in the month preceding the assessment or positively by previous holidays. The 24h-shift affected year 1 to 2 residents more than others residents or physicians. The fatigue or sleeping more or less than 4 consecutive hours during the 24-shift have no impact on the performance of clinical reasoning.

To our best knowledge, we report for the first time that a 24h-shift is associated with a decrease of medical reasoning' performance evaluated by SCTs among anesthesiologists. Arzalier-Daret *et al.* used a 2 validated simulated scenario in 48 residents in anesthesia, showing that sleep deprivation after a night shift significantly decreased global performance in managing simulated events (13). In addition, sleep deprivation increased the time required to identify and correct events, as well as pharmacological errors (wrong drug dosage, administration of a drug to which the patient was allergic). Although no difference in clinical performance was reported by Howards *et al.*, they showed that sleep deprivation impaired psychomotor performance and increased sleepiness in 12 residents in anesthesia (6). For Neuschwander *et al.*, sleep deprivation after a night shift was associated with impaired non-technical skills of 20 anesthesia residents in a simulated anesthesia intraoperative crisis scenario (4). This reduced mobilization of nontechnical skills was associated with impaired team working, increased sleepiness, and decreased confidence in anesthesia skills. Maltese *et al.* assessed the impact of a night shift on 4 different cognitive performances of 51 intensivists from 3 ICUs (24 seniors and 27 residents). They showed significant alteration of cognitive abilities, regardless of experience or duration of sleep, compared with their own performance after a night of rest. These results are consistent with our findings, because the clinical competence is a multi-dimensional, complex construct, representing the ability of a professional to use clinical judgment skills and reasoning in

addition to knowledge to solve complex problems in a specific context (50). The SCT is based on the script theory, which postulates that in specific situations clinicians mobilize prestored sets of knowledge (their scripts) that are used to understand the situation and act according to specific goals and it was a pertinent tool to assess the clinical reasoning (51).

Surprising the performance of clinical reasoning is decreased by 24h-shift but independently of the number of consecutive hours of sleep or fatigue experienced, in contrast to the works done in the simulation framework. Sleep deprivation was defined as the lack of at least a four-hours period of consecutive sleep during the previous 24 hours. 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 studies of non-physicians (52)(53). Based on the physiology of sleep, four-hours period of consecutive sleep corresponds both to half of a normal night's sleep and as the addition of the two sleep cycles that normally allow each person to access deep sleep, considered to be restorative sleep (54). In the literature, there is no consensus regarding this definition in sleep studies, but was often used as evidenced by these meta-analysis (55)(56).

Shift results in acute sleep deprivation, not infrequently approaching 24 hours without sleep. Two comprehensive qualitative reviews of the effect of sleep loss in resident physicians, both reported a decline in performance after 24 hours without sleep, but more precisely, studies have shown that alertness is higher, and errors are lower if continuous wakefulness is limited to 16 hours (57)(58). Persico *et al.* tested four cognitive abilities (processing speed, working memory capacity, perceptual reasoning, and cognitive flexibility) in a population of 40 emergentists (19 physicians and 21 residents) (59). Their cognitive abilities of emergency physicians were significantly altered after a 24-hours shift,

whereas they were not significantly different from the rested condition after a 14-hour night shift. These studies suggest that performance is not necessarily related to sleep time during shift, as we have shown, but that there may be a threshold at which performance appears to be impaired.

Our study suggests that the alteration of medical reasoning is not only related to the difficulty of the shift itself but seems to be more related to the accumulation of them. The number of shifts performed in a month appears to significantly alter the medical reasoning. There was indeed a linear correlation between the number of shift and the alteration of medical reasoning in our study. There appears to be a threshold beyond which the number of shifts appears to impair medical reasoning, estimated at 4 shifts a month. We did not find similar studies in the literature that identified a threshold of shifts per month above which medical reasoning was impaired. Moreover, practitioners who had at least a week of vacations in the previous month had a medical reasoning that remained stable, unlike those who did not. Taken together, these results suggest that the impairment of clinical reasoning may be related to chronic fatigue, rather than acute fatigue generated by a shift sleep deprivation. Good quality studies have shown that a reduction in the time worked by residents reduce errors in the ICU. However, these studies focused on the number of hours per week and not on the number of shifts per month, and were carried out in the USA, where the number of hours worked by residents are much more to than in France (26)(57). In France, a recent study concerning the working time of anesthesia residents estimated the weekly working time at 62 hours. 70% of the residents exceeded the French recommendations for weekly working hours (48 hours) (3). The absence of impairment of medical reasoning in our study in physicians is probably associated with the decrease in working time in the month before the test. We also found this threshold of 4 shifts/month to be a significant factor in burnout, among anesthesiologist but this data remains controversial (60)(61).

The lack of correlation that we found between the self-evaluation of tiredness and performance suggests that anesthesiologists were not able to accurately evaluate their tiredness and attention capacity. This result is in agreement with those of previous studies. Ernst *et al.* reported a lack of correlation between subjective and objective evaluation of concentration performance in physicians undertaking shifts duties (62). Moreover, Maltese *et al.* showed no significant correlation between self-report and evaluation of cognitive performance in intensivists undertaking night shifts (63). Several factors could contribute to this result. First, cognitive impairment by itself could alter the ability to self-evaluate tiredness and attention capacity. Second, auto-evaluation does not directly relate to performance but to subjective feelings. Finally, on the Karolinska sleepiness scale, the threshold of 6 allowed to define as tired the students, other study define 7 as threshold, which was more discriminating (64).

Finally, our work corroborates the fact that young residents, who have a medical reasoning under construction, have a more important alteration of their medical reasoning. This is in agreement with the work of Enser *et al.* shown that another element than fatigue, the noise, impacted more the medical reasoning (evaluated by the SCT) in the young residents population (DESAR 1 and 2) (41).

Limitations

Despite interesting results, our study has several limitations. First, the Cronbach coefficient alpha in our SCT evaluation was slightly low. The limited number of SCT after optimization probably explains this low coefficient. Nevertheless, this coefficient value remains adequate according to the guidelines concerning the SCT, supporting the validity of our study (49). Second, our SCTs were sent by e-mail to the participants, in contrast to the Ducos *et al.* where the subjects answered the SCT during a one-hour test (one minute per item) and under

supervision (65). Our methodology therefore allowed the respondents to access various sources of information, even though they were asked not to use any help, representing a potential bias. Thirdly, our population is small and from one region, which had received the same educating programs, composed of volunteers which exposes to a selection bias. Our population included only French anesthesiologists, considering the difference of organization and rhythm of work between countries, it would be uncertain to generalize our results to other countries or other specialties. Fourth, in our study, we examined the impact of fatigue on professionals' daytime vigilance using only the KSS score. Nevertheless, a more comprehensive and global approach to the participants' fatigue would have been relevant to know the percentage of chronically fatigued individuals in our population, to try to highlight a correlation between medical reasoning variation and chronic fatigue felt by the professionals. We also considered an objective assessment of sleep quality via wrist actimetry (Fitbit®, The Fitbit Company, San Francisco, CA) allowing a continuous and prolonged assessment of sleep : duration, sleep efficiency (sleep time compared to theoretical sleep time in percentage), sleep fragmentation index (66). However, given the small number of watches available and the size of our sample, these data could not have been collected in our sample. Fifth, a more comprehensive assessment of shift activity (volume of activity, shift in operating room or in ICU, etc.) would have helped us to better interpret our results. However, considering our small sample size, a specific questionnaire for each type of shift chart probably would not have allowed any discrimination. A specific questionnaire differentiating each criterion according to the shift typology may better identify the elements associated with the loss of medical reasoning (e.g., number of admissions or calls from ICU nurses for ICU shifts, number of caesarean and epidurals for maternity shifts).

Conclusion

Our study suggests that a 24h-shift impairs the medical reasoning of anesthesiologists, and that this impairment is proportional to the number of shifts performed during the previous month. This observation reinforces the fact that the frequency of 24h-shifts should be limited to prevent the occurrence of medical errors.

Appendix

Appendix 1 : Questions

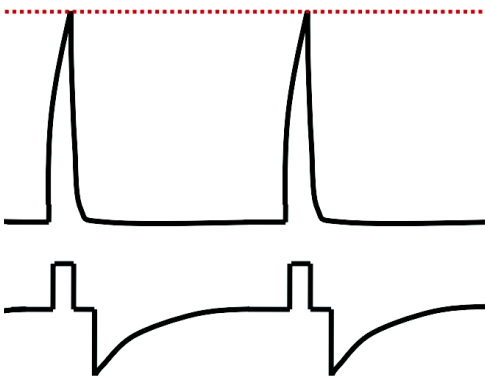
Cas clinique :

Réanimateur chirurgical au CHU, on vous propose d'accueillir une patiente de 60 ans à la suite d'une chute de QUAD casquée à 60 km/h. Le bilan initial sur place retrouve une patiente agitée, présentant un score de Glasgow à 12, des pupilles isocores et réactives. Elle présente un épistaxis, une plaie oculaire et une déformation du visage. Son auscultation cardio-pulmonaire est symétrique, sans bruit surajouté. Il existe un doute sur une paraplégie.

Si vous pensez	Et qu'alors vous trouvez	Cette nouvelle donnée rend l'hypothèse diagnostique
<u>Item N°1</u> Retirer le casque de la patiente	Suspectez une lésion rachidienne.	-2 -1 0 +1 +2
<u>Item N°2</u> Faire une titration morphinique	Une agitation incoercible et un score de Glasgow à 12.	-2 -1 0 +1 +2

Cas clinique :

Au bloc opératoire vous constatez brutalement qu'un patient présente une désaturation importante imposant d'augmenter la FiO2 jusque 100% (FiO2 initiale à 40%), vous permettant d'obtenir une SpO2 à seulement 90%.

Si vous pensez	Et qu'alors vous trouvez	Cette nouvelle donnée rend l'hypothèse diagnostique
<u>Item N°3</u> Une intubation sélective	Une auscultation symétrique lors de l'intubation initiale.	-2 -1 0 +1 +2
<u>Item N°4</u> Un pneumothorax	<u>Vous constatez ces courbes de pressions sur le respirateur, 1 heure après l'incision :</u> 	-2 -1 0 +1 +2



Cas clinique

Vous prenez en charge en SSPI une patiente de 60 ans ayant pour antécédent une fibrillation atriale, emboligène, anti coagulée par FLUINDIONE et ralentie par BISOPROLOL. Elle vient d'être prise en charge au bloc pour une hépatectomie droite dans le cadre d'un carcinome hépatocellulaire. La fibrillation atriale est rapide (FC à 160 BPM), et mal tolérée hémodynamiquement.

Si vous pensez	Et qu'alors vous trouvez	Cette nouvelle donnée rend l'hypothèse diagnostique
<u>Item N°5</u> Reprendre le BISOPROLOL	De la NORADRENALINE e a été nécessaire en per opératoire.	-2 -1 0 +1 +2
<u>Item N° 6</u> Tenter de réduire la fibrillation atriale par un choc électrique externe	Elle a bénéficié de 1 litres de remplissage peropératoire.	-2 -1 0 +1 +2

Cas clinique :

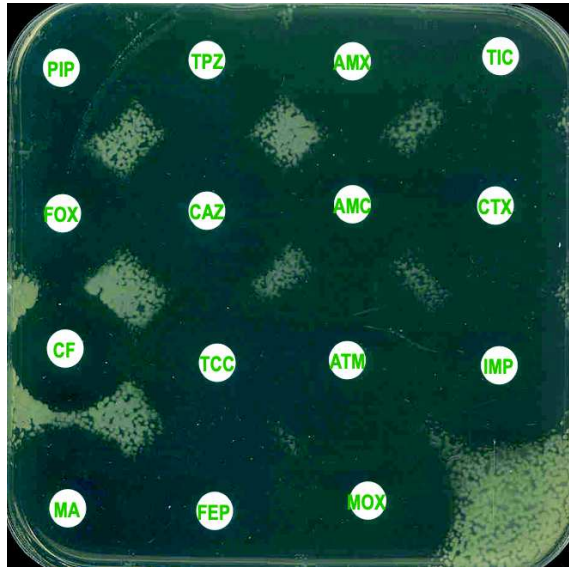
Vous êtes de garde en réanimation neurochirurgicale et vous êtes appelé par l'infirmière pour modification pupillaire chez une patiente de 69 ans, prise en charge dans le cadre d'une hémorragie méningée Fisher 4, WFNS4, dérivée depuis quelques heures, en attente d'artériembolisation.

Si vous pensez	Et qu'alors vous trouvez	Cette nouvelle donnée rend l'hypothèse diagnostique
<u>Item N°7</u> Réaliser du MANNITOL	<u>Voici les pupilles de la patiente :</u> 	-2 -1 0 +1 +2
<u>Item N°8</u> Réaliser une nouvelle imagerie cérébrale	<u>Voici les pupilles de la patiente :</u> 	-2 -1 0 +1 +2

Cas clinique :

A la suite de plusieurs pics fébriles chez à patient à J10 de prise en charge d'un enclouage fémorale dans les suites d'une chute vous décidez en accord avec l'équipe d'orthopédie de débiter une antibiothérapie

probabiliste et de reprendre au bloc le malade compte tenu d'un écoulement purulent au niveau de la cicatrice.

Si vous pensez	Et qu'alors vous trouvez	Cette nouvelle donnée rend l'hypothèse diagnostique
Item N°9 Débuter de la VANCOMYCINE	Une colonisation à <i>Enterococcus faecium</i> connue.	-2 -1 0 +1 +2
Item N°10 Débuter de la VANCOMYCINE	La présence de plusieurs paires d'hémocultures positives depuis 48 heures à bacille gram négatif.	-2 -1 0 +1 +2
Item N°11 Traiter par PIPERACILLINE-TAZOBACTAM	Voici l'antibiogramme de l' <i>Escherichia coli</i> identifié dans les prélèvements : 	-2 -1 0 +1 +2

Cas clinique :

Vous voyez en salle de naissance une patiente de 36 ans, elle a déjà eu 2 enfants dont un né par césarienne, à la suite de pré-éclampsie. Elle pèse 90Kg (80kg avant la grossesse). La péridurale a été jugée envisageable lors de la consultation d'anesthésie.

Si vous pensez	Et qu'alors vous trouvez	Cette nouvelle donnée rend l'hypothèse diagnostique
Item N° 12 Poser la péridurale	La température est à 38,5°C lors de son entrée en salle de naissance.	-2 -1 0 +1 +2

Cas clinique :

Vous êtes appelé en salle de naissance une heure après la pose d'une péridurale pour une patiente hypotendue à 75/55 mm Hg, tachycarde à 144 BPM. La saturation est à 93% sous 5 litres d'oxygène aux lunettes. Sur le plan obstétrical, le travail est en cours, la dilatation du col est alors estimée à 5 doigts.

Si vous pensez	Et qu'alors vous trouvez	Cette nouvelle donnée rend l'hypothèse diagnostique
<u>Item N° 13</u> Une rachianesthésie totale	La patiente ne présente pas de déficit moteur.	-2 -1 0 +1 +2
<u>Item N° 14</u> Un hématome rétro placentaire	La patiente ne présente pas de métrorragie.	-2 -1 0 +1 +2
<u>Item N° 15</u> Une embolie amniotique	Sur le bilan d'hémostase délocalisé, un TP à 24%, un fibrinogène à 1,5 g/l.	-2 -1 0 +1 +2
<u>Item N° 16</u> Une intoxication aux anesthésiques locaux	La patiente présente des céphalées.	-2 -1 0 +1 +2
<u>Item N° 17</u> Une intoxication aux anesthésiques locaux	La patiente devient confuse.	-2 -1 0 +1 +2

Cas clinique :

Vous voyez en consultation programmée Mr X, 67 ans, hypertendu, hypercholestérolémie, tabagique à 40 PA sous KARDEGIC dans les suites d'un infarctus du myocarde il y a 4 ans (1 stent sur l'artère coronaire circumflexe), fraction d'éjection du ventricule gauche (FEVG) sur la dernière échographie en 2018 à 55% pour une lobectomie lobaire supérieur droite. Vous envisagez de réaliser une péridurale thoracique pour l'analgésie.

Si vous pensez	Et qu'alors vous trouvez	Cette nouvelle donnée rend l'hypothèse diagnostique
<u>Item N°18</u> Demander une échographie trans-thoracique	Un examen clinique normal.	-2 -1 0 +1 +2
<u>Item N°19</u> Réaliser un ECG	Le patient présente une dyspnée d'effort.	-2 -1 0 +1 +2
<u>Item N°20</u> Demander un bilan d'hémostase	Un examen clinique normale.	- 2 -1 0 +1 +2

Cas clinique :

Vous prenez en charge un patient de 83 ans pour talcage pleural, il présente de très nombreux antécédents dont une cardiopathie ischémique à fraction d'éjection du ventricule gauche (FEVG) altérée à 30%. Lors de l'induction, vous réalisez l'induction, puis le patient présente une hypotension puis un arrêt cardiaque.

Si vous pensez	Et qu'alors vous trouvez	Cette nouvelle donnée rend l'hypothèse diagnostique
<u>Item N°21</u> Un choc anaphylactique	Induction réalisée avec HYPNOMIDATE, ROCURONIUM et de REMIFENTANIL.	-2 -1 0 +1 +2
<u>Item N°22</u> Effet hémodynamique de l'induction	Induction réalisée avec HYPNOMIDATE, ROCURONIUM et de REMIFENTANIL.	-2 -1 0 +1 +2

Cas clinique :

De garde au SAMU, vous prenez en charge un patient de 48 ans, dans les suites d'un arrêt cardio-respiratoire en fibrillation ventriculaire sur un terrain de foot ou le patient jouait un match. Cet arrêt cardiaque a eu lieu devant témoins, il a été massé toute suite et vous arrivez sur place après 12 min d'arrêt, il a déjà reçu 3 chocs par un défibrillateur disponible sur place. Vous administrez de l'ADRÉNALINE, 1 mg.

Si vous pensez	Et qu'alors vous trouvez	Cette nouvelle donnée rend l'hypothèse diagnostique
<u>Item N°23</u> Administrez de l'AMIODARONE	Le patient est à 12 min de réanimation cardio-pulmonaire.	-2 -1 0 +1 +2
<u>Item N°24</u> Envisager la mise en place d'une ECMO veino-artérielle de sauvetage	Le patient ne présente aucune comorbidité.	-2 -1 0 +1 +2
<u>Item N°25</u> Envisager la mise en place d'une ECMO veino-artérielle de sauvetage	Le patient est maintenant en asystolie.	-2 -1 0 +1 +2

Cas clinique :

Réanimateur chirurgical au CHU, on vous propose d'accueillir une patiente de 60 ans à la suite d'une chute de QUAD casquée à 60 km/h. Le bilan initial sur place retrouve une patiente agitée, présentant un score de Glasgow à 12, des pupilles isocores et réactives. Elle présente un épistaxis, une plaie oculaire et

une déformation du visage. Son auscultation cardio-pulmonaire est symétrique, sans bruit surajouté. Son abdomen est douloureux. Il existe un doute sur une paraplégie.

Si vous pensez	Et qu'alors vous trouvez	Cette nouvelle donnée rend l'hypothèse diagnostique
<u>Item N°26</u> Intuber la patiente	Un score de Glasgow maintenant à 9.	-2 -1 0 +1 +2
<u>Item N°27</u> Utiliser de la KETAMINE comme hypnotique	Elle présente un traumatisme crânien grave.	-2 -1 0 +1 +2
<u>Item N°28</u> Utiliser du THIOPENTAL comme hypnotique	Elle présente un traumatisme crânien grave.	-2 -1 0 +1 +2

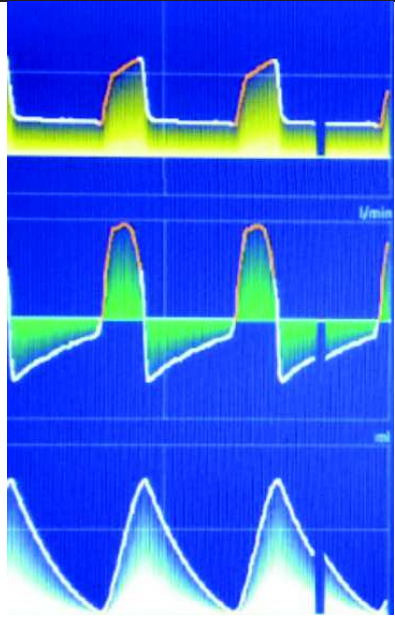

Cas clinique :

Vous prenez en charge un patient de 69 ans dans les suites d'une pneumopathie hypoxémiante à SARS COV2. Il présente une PO2 à 6 K.PA, une saturation à 90%, intubé, ventilé en ventilation assistée contrôlée en FiO2 60%.

Si vous pensez	Et qu'alors vous trouvez	Cette nouvelle donnée rend l'hypothèse diagnostique
<u>Item N°29</u> Majorer la PEEP	La pression de plateau est à 28.	-2 -1 0 +1 +2
<u>Item N°30</u> Introduire des curares	Le patient est adapté au respirateur.	-2 -1 0 +1 +2
<u>Item N°31</u> Réaliser une séance de Décubitus Ventral	Le rapport P /F est à 120, sans curares.	- 2 -1 0 +1 +2

Chez ce même patient pour affiner la ventilation :

Si vous pensez	Et qu'alors vous trouvez	Cette nouvelle donnée rend l'hypothèse diagnostique
<u>Item N°32</u> Augmenter la fréquence respiratoire	<u>Voici les courbes sur le respirateur :</u>	-2 -1 0 +1 +2

		
<p><u>Item N°33</u> Diminuer la PEEP</p>	<p>Voici les courbes sur le respirateur :</p> 	<p>-2 -1 0 +1 +2</p>

Cas clinique :

Vous voyez en consultation Léon, accompagné de ses deux parents, il est âgé de 2 ans et 6 mois. Vous le voyez dans le cadre d'une amygdalectomie programmée. Il a déjà été opéré d'une hernie inguinale droite alors qu'il avait 3 mois, chirurgie et anesthésie sans complication, les parents ne se rappellent plus des modalités de l'anesthésie.

Si vous pensez	Et qu'alors vous trouvez	Cette nouvelle donnée rend l'hypothèse diagnostique
<u>Item N°34</u>	Léon n'a pas de SAOS, ni co morbidité majeure.	-2 -1 0 +1 +2

Réaliser cette chirurgie en ambulatoire		
<u>Item N°35</u> Hospitaliser Léon en USC en post opératoire	Léon a 2 ans et 6 mois, sans co morbidité majeure.	-2 -1 0 +1 +2
<u>Item N°36</u> Réaliser un bilan d'hémostase pré opératoire	<u>Vous trouvez ce bleu sur l'enfant :</u> 	-2 -1 0 +1 +2

Cas clinique :

Vous êtes amené à prendre en charge en ambulatoire à 9 heures du matin une patiente de 55 ans, dans le cadre d'une fibroscopie digestive haute. Il s'agit d'un examen de contrôle, la patiente en a déjà eu à plusieurs reprises, dans le cadre d'une néoplasie gastrique traitée par gastrectomie partielle, il y a deux ans. Une rechute est suspectée, diagnostiquée sur des douleurs dorsales invalidantes et traitées par Morphinique ainsi qu'une carcinose péritonéale probable. Elle dit avoir été « shootée » les autres fois.

Si vous pensez	Et qu'alors vous trouvez	Cette nouvelle donnée rend l'hypothèse diagnostique
<u>Item N°37</u> Utiliser de la KETAMINE sans intubation orotrachéale	La patiente est à jeun depuis minuit.	-2 -1 0 +1 +2
<u>Item N°38</u> Utiliser du PROPOFOL sans intubation orotrachéale	La patiente est à jeun depuis minuit.	-2 -1 0 +1 +2

Cas clinique :

*Vous êtes de garde en réanimation neurochirurgicale et vous êtes appelé par l'infirmière pour une pression intracrânienne (PIC) élevée chez une patiente de 69 ans, prise en charge dans le cadre d'une hémorragie méningée Fisher 4, WFNS 5, dérivée depuis quelques heures, en attente d'artériomolisation. La PIC est à 25 depuis 30 min, indépendamment de toute stimulation. ACSOS : agressions cérébrales d'origine systémique
DTC : dopplers transcraniens*

Si vous pensez	Et qu'alors vous trouvez	Cette nouvelle donnée rend l'hypothèse diagnostique
<u>Item N°1</u> Majorer les sédations	Des DTC normaux et autres ACSOS contrôlés.	-2 -1 0 +1 +2
<u>Item N°2</u> Réaliser une nouvelle imagerie cérébrale	Des DTC normaux et autres ACSOS contrôlés.	-2 -1 0 +1 +2

Cas clinique :

Vous voyez en salle de naissance une patiente de 36 ans, elle a déjà 2 enfants dont un né par césarienne, à la suite de pré-éclampsie. Elle pèse 90Kg (80kg avant la grossesse). L'anesthésie péridurale (APD) a été jugée envisageable lors de la consultation d'anesthésie.

Si vous pensez	Et qu'alors vous trouvez	Cette nouvelle donnée rend l'hypothèse diagnostique
<u>Item N° 3</u> Réaliser une APD	Qu'elle a un antécédent de chirurgie lombaire basse.	-2 -1 0 +1 +2
<u>Item N° 4</u> Réaliser une APD	Une thrombopénie à 90 000/mm ³ lors du bilan du 6 ^e mois, avec un antécédent de pré-éclampsie.	-2 -1 0 +1 +2
<u>Item N° 5</u> Réaliser une APD	Un syndrome inflammatoire biologique (CRP à 80 mg/L et Leucocytes à 12 000/mm ³).	-2 -1 0 +1 +2

Cas clinique :

Vous devez poser une voie veineuse centrale à un patient polytraumatisé, sédaté et nécessitant un support vasopresseur par NORADRENALINE.

Si vous pensez	Et qu'alors vous trouvez	Cette nouvelle donnée rend l'hypothèse diagnostique
<u>Item N°6</u> Poser un cathéter fémoral droit	La patiente ne présente pas de fracture des membres inférieurs.	-2 -1 0 +1 +2

Cas clinique :

De garde en réanimation médicale vous constatez à la contre visite une franche majoration de l'oxygénodépendance d'une patiente sur la journée (FiO2 80% versus 40% à la visite matinale). Elle est fébrile en plateau à 39°C. Cette patiente est hospitalisée depuis 4 jours à la suite d'une exacerbation de BPCO. Elle a dû être intubée au bout de 48h après non-compliance à la ventilation non invasive.

Si vous pensez	Et qu'alors vous trouvez	Cette nouvelle donnée rend l'hypothèse diagnostique
<u>Item N°7</u> Débuter de l'AMOXICILLINE- ACIDE CLAVULANIQUE	Elle était colonisée à <i>Pseudomonas Aeruginosa</i> lors de sa précédente hospitalisation.	-2 -1 0 +1 +2

Cas clinique :

Vous prenez en charge un patient de 35 ans dans les suites d'un hématome extradural après chute de vélo non casqué. Le patient a été intubé en séquence rapide par le SAMU. Vous le prenez en charge au bloc opératoire. 5 min après l'incision, il présente une hypotension et une tachycardie. PA= 60/30 mmhg FC=135/min BPM.

Si vous pensez	Et qu'alors vous trouvez	Cette nouvelle donnée rend l'hypothèse diagnostique
<u>Item N°8</u> Un choc anaphylactique	Une antibioprophylaxie par Céfazoline réalisée 15 min avant l'incision.	-2 -1 0 +1 +2
<u>Item N°9</u> Un engagement cérébral	Une diurèse de 1800 ml dans la sonde urinaire.	-2 -1 0 +1 +2
<u>Item N°10</u> Effet hémodynamique du SEVORANE	Une MAC à 1,5 de Sevorane.	-2 -1 0 +1 +2

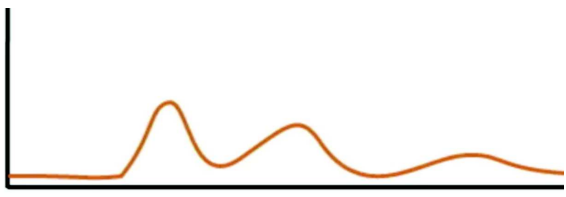
Cas clinique :

Réanimateur chirurgical au CHU, on vous propose d'accueillir une patiente de 60 ans à la suite d'une chute de QUAD casquée à 60 km/h. Le bilan initial sur place retrouve une patiente agitée, présentant un score de Glasgow à 12, des pupilles isocores et réactives. Elle présente un épistaxis, une plaie oculaire et une déformation du visage. Son auscultation cardio-pulmonaire est symétrique, sans bruit surajouté, son abdomen est douloureux. Il existe un doute sur une paraplégie.

Si vous pensez	Et qu'alors vous trouvez	Cette nouvelle donnée rend l'hypothèse diagnostique
<u>Item N°11</u> Introduire de la NORADRENALINE	Elle est instable et a déjà reçu 1 litres de NaCl 0,9% et présente un Hemocue à 9 g/dl.	-2 -1 0 +1 +2
<u>Item N°12</u> Passer 500 ml d'HEA	Elle est instable et a déjà reçu 1 litres de NaCl 0,9% et présente un Hemocue à 9 g/dl.	-2 -1 0 +1 +2

Cas clinique :

Réanimateur en réanimation chirurgicale, vous prenez en charge un patient de 18 ans en urgence, il présente un pneumothorax complet traumatique à la suite de la chute d'un toit parmi le bilan lésionnel.

Si vous pensez	Et qu'alors vous trouvez	Cette nouvelle donnée rend l'hypothèse diagnostique
<u>Item N°13</u> Exsuffler le pneumothorax	Vous trouvez cette capnographie alors qu'elle était normale durant tout le début de l'intervention 	-2 -1 0 +1 +2

Cas clinique :

Au bloc opératoire, vous êtes amené à prendre en charge un patient de 70 kg pour hématome du psoas dans les suites d'un surdosage en AVK (INR à 6) chez un patient traité au long cours par AVK dans le cadre d'une fibrillation atriale non emboligène et au cours de la chirurgie, le patient présente un état de choc, le saignement per opératoire est estimé à 1,5 litres.

Si vous pensez	Et qu'alors vous trouvez	Cette nouvelle donnée rend l'hypothèse diagnostique
<u>Item N°14</u> Transfuser 2 CGR uniquement, sans PFC	Hémocue à 8g/dl et drainage d'1,5 litres de sang en lien avec l'hématome.	-2 -1 0 +1 +2
<u>Item N°15</u> Administrer de l'ACIDE-TRANEXAMIQUE	La patiente n'en a pas reçu en préopératoire.	-2 -1 0 +1 +2
<u>Item N°16</u> Administrer des complexes prothrombiniques (PPSB)	Il a reçu en préopératoire 500 UI de PPSB en pré-opératoire.	-2 -1 0 +1 +2
<u>Item N°17</u> Administrer des concentrés plaquettaires	Plaquettes initiales à 80 000/mm ³ .	-2 -1 0 +1 +2

Cas clinique :

Vous voyez Mr X, 67 ans, sans antécédent médico-chirurgicaux ni traitement, en consultation programmée pour une chirurgie de prothèse de genou.

Si vous pensez	Et qu'alors vous trouvez	Cette nouvelle donnée rend l'hypothèse diagnostique
<u>Item N°18</u> Réaliser un bilan d'hémostase	Le patient souhaite une rachianesthésie.	- 2 -1 0 +1 +2

Cas clinique :

Vous prenez en charge une patiente de 65 ans dans les suites d'une colectomie gauche programmée. Cette chirurgie a été réalisée il y a 9 jours. Elle se présente aux urgences dans un tableau de péritonite. Vous organisez une reprise chirurgicale.

Si vous pensez	Et qu'alors vous trouvez	Cette nouvelle donnée rend l'hypothèse diagnostique
<u>Item N°19</u> Débuter des antibiotiques avant le bloc	Elle présente un état de choc.	-2 -1 0 +1 +2
<u>Item N°20</u> Débuter des antifongiques avant le bloc	Elle présente un état de choc.	-2 -1 0 +1 +2

Cas clinique :

Vous décidez de réaliser une anesthésie en séquence rapide chez une patiente de 25 ans dans le cadre d'une péritonite appendiculaire. La patiente refuse la sonde nasogastrique en pré opératoire. Elle reçoit de la CIMETIDINE. Lors de l'induction la patiente présente une régurgitation de liquide gastrique.

Si vous pensez	Et qu'alors vous trouvez	Cette nouvelle donnée rend l'hypothèse diagnostique
<u>Item N°21</u> Aspirer dans la sonde d'intubation avant de ventiler la patiente	La SpO2 est à 90%.	-2 -1 0 +1 +2
<u>Item N° 22</u> Réaliser une radiographie de thorax en SSPI	La SpO2 est à 90% en FIO2 50% au cours de l'intervention.	-2 -1 0 +1 +2

<u>Item N° 23</u> Extuber la patiente en SSPI	La SpO2 est à 90% en FiO2 50% en SSPI.	-2 -1 0 +1 +2
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Cas clinique :

Vous posez une péridurale sans difficultés, chez une patiente de 39 ans, G4P1, naissance précédente à la suite d'une césarienne pour stagnation, vous êtes appelé par la sage-femme pour une analgésie difficile brutale deux heures après la pose.

Si vous pensez	Et qu'alors vous trouvez	Cette nouvelle donnée rend l'hypothèse diagnostique
<u>Item N°24</u> Un cathéter de péridural non en place	Elle était initialement soulagée.	-2 -1 0 +1 +2
<u>Item N°25</u> Une dose insuffisante	La patiente présente un niveau sensitif chaud/froid au niveau L1.	-2 -1 0 +1 +2

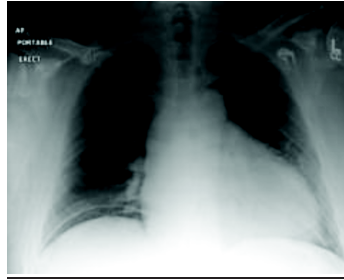
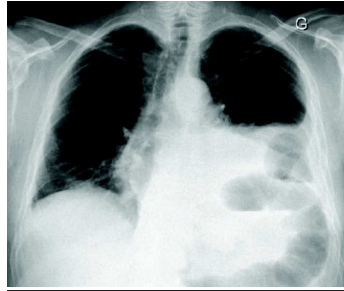
Cas clinique :

Vous voyez Mr X, 67 ans, sans antécédent médico-chirurgicaux ni traitement, en consultation programmée pour une chirurgie de prothèse de genoux. Il présente plusieurs critères d'intubation difficile (score de Mallampati, ouverture de bouche, mobilité mandibulaire restreinte).

Si vous pensez	Et qu'alors vous trouvez	Cette nouvelle donnée rend l'hypothèse diagnostique
<u>Item N°26</u> Utiliser un vidéolaryngoscope	Une ouverture de bouche à 2 cm.	-2 -1 0 +1 +2
<u>Item N°27</u> Utiliser un vidéolaryngoscope	Le patient présente également des critères de ventilation au masque difficile.	-2 -1 0 +1 +2
<u>Item N°28</u> Réaliser une rachianesthésie	Le patient veut catégoriquement être endormi pour le geste.	- 2 -1 0 +1 +2

Cas clinique :

Vous prenez en charge un patient de 19 ans, dans les suites d'un accident de la voie publique en scooter, il présente une fracture du fémur ouverte et traumatisme thoracique. Il est conscient et agité. Les constantes sont les suivantes PA = 110/80 mm Hg FC= 140 BPM FR 33/min SpO2 (AA)= 88% sous 4 litres d'oxygène à son arrivée en réanimation chirurgicale soit 4 heures après l'accident.

Si vous pensez	Et qu'alors vous trouvez	Cette nouvelle donnée rend l'hypothèse diagnostique
<u>Item N°29</u> Embolie graisseuse	Des pétéchies sur le torse du patient de façon diffuse	-2 -1 0 +1 +2
<u>Item N°30</u> Un hémopéricarde	Voici la radiographie de thorax du patient : 	-2 -1 0 +1 +2
<u>Item N°31</u> Un hémothorax	Voici la radiographie de thorax du patient : 	-2 -1 0 +1 +2

Appendix 2 : KSS score

1	Extrêmement éveillé
2	Très éveillé
3	Éveillé ou Normal
4	Assez éveillé
5	Ni éveillé ni fatigué
6	Quelques signes de fatigue
7	Somnolent mais ne luttant pas contre le sommeil
8	Somnolent luttant contre le sommeil, effort notable pour rester éveillé
9	Très somnolent avec de gros efforts pour ne pas s'endormir

References

1. Baldwin Jr DC, Daugherty SR, Tsai R, Scotti Jr MJ. A national survey of residents' self-reported work hours: thinking beyond specialty. *Academic Medicine*. 2003;78(11):1154-63.
2. Conditions_travail_etudiants_internes_assistants_-_rapport_final.pdf
3. Enquête - Temps de travail des internes. ISNI. 2020
4. Friedman RC, Bigger JT, Kornfeld DS. The Intern and Sleep Loss. *New England Journal of Medicine* 22 juill 1971
5. Rothschild JM. Risks of Complications by Attending Physicians After Performing Nighttime Procedures. *JAMA* 14 oct 2009
6. Grantcharov TP, Bardram L, Peter F-J, Rosenberg J. Laparoscopic performance after one night on call in a surgical department: prospective study. *Bmj*. 2001;323(7323):1222-3.
7. Eastridge BJ, Hamilton EC, O'Keefe GE, Rege RV, Valentine RJ, Jones DJ, et al. Effect of sleep deprivation on the performance of simulated laparoscopic surgical skill. *The American Journal of Surgery*. Août 2003
8. Taffinder NJ, McManus IC, Gul Y, Russell RCG, Darzi A. Effect of sleep deprivation on surgeons' dexterity on laparoscopy simulator. *The Lancet*
9. Williamson JA, Webb RK, Pryor GL. Anaesthesia safety and the « critical incident » technique. *Aust Clin Rev*. juin 1985;(17):57-61.
10. Cooper JB. Preventable anesthesia mishaps: a study of human factors. *Quality and Safety in Health Care*. 1 sept 2002
11. Cooper JB, Newbower RS, Kitz RJ. An analysis of major errors and equipment failures in anesthesia management: considerations for prevention and detection. *Anesthesiology*. janv 1984;60(1):34-42.
12. Cooper JB, Newbower RS, Long CD, McPeck B. Preventable anesthesia mishaps: a study of human factors. *Anesthesiology*. déc 1978;49(6):399-406.
13. Arzalier-Daret S, Buléon C, Bocca M-L, Denise P, Gérard J-L, Hanouz J-L. Effect of sleep deprivation after a night shift duty on simulated crisis management by residents in anaesthesia. A randomised crossover study. *Anaesthesia Critical Care & Pain Medicine* sept 2017
14. Neuschwander A, Job A, Younes A, Mignon A, Delgoulet C, Cabon P, et al. Impact of sleep deprivation on anaesthesia residents' non-technical skills: a pilot simulation-based prospective randomized trial. *British Journal of Anaesthesia*. juill 2017
15. Fletcher G, Flin R, McGeorge P, Glavin R, Maran N, Patey R. Anaesthetists' Non-Technical Skills (ANTS): evaluation of a behavioural marker system. *Br J Anaesth*. mai 2003;90(5):580-8.

16. Horne JA. Sleep loss and « divergent » thinking ability. *Sleep*. déc 1988;11(6):528-36.
17. Harrison Y, Horne JA. One night of sleep loss impairs innovative thinking and flexible decision making. *Organ Behav Hum Decis Process*. mai 1999;78(2):128-45.
18. Denisco RA, Drummond JN, Gravenstein JS. The effect of fatigue on the performance of a simulated anesthetic monitoring task. *Journal of Clinical Monitoring*. janv 1987
19. Smith-Coggins R, Rosekind MR, Buccino KR, Dinges DF, Moser RP. Rotating shiftwork schedules: can we enhance physician adaptation to night shifts? *Acad Emerg Med*. oct 1997;4(10):951-61.
20. Ayas NT, Barger LK, Cade BE, Hashimoto DM, Rosner B, Cronin JW, et al. Extended work duration and the risk of self-reported percutaneous injuries in interns. *JAMA*. 6 sept 2006;296(9):1055-62.
21. Ellman PI, Kron IL, Alvis JS, Tache-Leon C, Maxey TS, Reece TB, et al. Acute sleep deprivation in the thoracic surgical resident does not affect operative outcomes. *Ann Thorac Surg*. juill 2005;80(1):60-4; discussion 64-65.
22. Ellman PI, Law MG, Tache-Leon C, Reece TB, Maxey TS, Peeler BB, et al. Sleep deprivation does not affect operative results in cardiac surgery. *Ann Thorac Surg*. sept 2004;78(3):906-11; discussion 906-911.
23. Micko A, Knopp K, Knosp E, Wolfsberger S. Microsurgical Performance After Sleep Interruption: A NeuroTouch Simulator Study. *World Neurosurgery*. oct 2017
24. Institute of Medicine (US) Committee on Quality of Health Care in America. *To Err is Human: Building a Safer Health System*. Kohn LT, Corrigan JM, Donaldson MS, éditeurs. Washington (DC) : National Academies Press (US) ; 2000
25. Asch DA, Parker RM. The Libby Zion Case. *New England Journal of Medicine*. 24 mars 1988
26. Landrigan CP, Rothschild JM, Cronin JW, Kaushal R, Burdick E, Katz JT, et al. Effect of Reducing Interns' Work Hours on Serious Medical Errors in Intensive Care Units. *New England Journal of Medicine*. 28 oct 2004
27. Gander PH, Merry A, Millar MM, Weller J. Hours of work and fatigue-related error: a survey of New Zealand anaesthetists. *Anaesth Intensive Care*. avr 2000;28(2):178-83.
28. Gander P, Millar M, Webster C, Merry A. Sleep Loss and Performance of Anaesthesia Trainees and Specialists. *Chronobiology International*. janv 2008
29. Morris GP, Morris RW. Anaesthesia and Fatigue: An Analysis of the First 10 Years of the Australian Incident Monitoring Study 1987–1997. *Anaesth Intensive Care*. 1 juin 2000 [cité 11 mars 2021] ;28(3):300-4.
30. Williamson AM. Moderate sleep deprivation produces impairments in cognitive and

motor performance equivalent to legally prescribed levels of alcohol intoxication. *Occupational and Environmental Medicine*. 1 oct 2000 ; 57(10):649-55.

31. Howard SK, Gaba DM, Smith BE, Weinger MB, Herndon C, Keshavacharya S, et al. Simulation Study of Rested Versus Sleep-deprived Anesthesiologists: *Anesthesiology*. juin 2003

32. Murray D, Dodds C. The effect of sleep disruption on performance of anaesthetists – A pilot study*. *Anaesthesia*. 2003 [cité 25 déc 2018];58(6):520-5.

33. Barger LK, Cade BE, Ayas NT, Cronin JW, Rosner B, Speizer FE, et al. Extended Work Shifts and the Risk of Motor Vehicle Crashes Among Interns: *Obstetrical & Gynecological Survey*. juin 2005

34. Charlin B, Bordage G, Van Der Vleuten C. L'évaluation du raisonnement clinique. *Pédagogie Médicale*. févr 2003

35. Monteiro SM, Norman G. Diagnostic reasoning: where we've been, where we're going. *Teach Learn Med*. 2013;25 Suppl 1:S26-32.

36. Lubarsky S, Dory V, Audétat M-C, Custers E, Charlin B. Using script theory to cultivate illness script formation and clinical reasoning in health professions education. *Can Med Educ J*. 2015;6(2):e61-70.

37. Charlin B, Brailovsky C, Leduc C, Blouin D. The Diagnosis Script Questionnaire: A New Tool to Assess a Specific Dimension of Clinical Competence. *Adv Health Sci Educ Theory Pract*. 1998;3(1):51-8.

38. Fournier JP, Demeester A, Charlin B. Script Concordance Tests: Guidelines for Construction. *BMC Medical Informatics and Decision Making*. déc 2008

39. Lubarsky S, Dory V, Duggan P, Gagnon R, Charlin B. Script concordance testing: From theory to practice: AMEE Guide No. 75. *Medical Teacher*. mars 2013

40. Clavier T, Ramen J, Dureuil B, Veber B, Hanouz J-L, Dupont H, et al. Use of the Smartphone App WhatsApp as an E-Learning Method for Medical Residents: Multicenter Controlled Randomized Trial. *JMIR Mhealth Uhealth*. 9 avr 2019

41. Enser M, Moriceau J, Abily J, Damm C, Occhiali E, Besnier E, et al. Background noise lowers the performance of anaesthesiology residents' clinical reasoning when measured by script concordance: A randomised crossover volunteer study. *Eur J Anaesthesiol*. 2017;34(7):464-70.

42. Compère V, Moriceau J, Gouin A, Guitard P-G, Damm C, Provost D, et al. Residents in tutored practice exchange groups have better medical reasoning as measured by the script concordance test: A pilot study. *Anaesth Crit Care Pain Med*. févr 2015;34(1):17-21.

43. Compère V, Abily J, Moriceau J, Gouin A, Veber B, Dupont H, et al. Residents in tutored practice exchange groups have better medical reasoning as measured by script concordance test: a controlled, nonrandomized study. *Journal of Clinical Anesthesia*. août 2016

[cité 21 mars 2018];32:236-41.

44. Toulouse E, Lafont B, Granier S, Mcurk G, Bazin J-E. French legal approach to patient consent in clinical research. *Anaesth Crit Care Pain Med.* déc 2020;39(6):883-5.
45. Create a blocked randomisation list | Sealed Envelope.
46. Kaida K, Takahashi M, Akerstedt T, Nakata A, Otsuka Y, Haratani T, et al. Validation of the Karolinska sleepiness scale against performance and EEG variables. *Clin Neurophysiol.* juill 2006;117(7):1574-81.
47. Charlin B, van der Vleuten C. Standardized assessment of reasoning in contexts of uncertainty: the script concordance approach. *Eval Health Prof.* sept 2004;27(3):304-19.
48. OBTENIR LES SCORES DE VOS TCS PAR VOIE INFORMATIQUE
49. Taber KS. The Use of Cronbach's Alpha When Developing and Reporting Research Instruments in Science Education. *Res Sci Educ.* 1 déc 2018
50. Rencic J, Schuwirth LWT, Gruppen LD, Durning SJ. A situated cognition model for clinical reasoning performance assessment: a narrative review. *Diagnosis (Berl).* 27 août 2020;7(3):227-40.
51. Charlin B, Roy L, Brailovsky C, Goulet F, van der Vleuten C. The Script Concordance test: a tool to assess the reflective clinician. *Teach Learn Med.* 2000;12(4):189-95.
52. Opstad PK, Ekanger R, Nummestad M, Raabe N. Performance, mood, and clinical symptoms in men exposed to prolonged, severe physical work and sleep deprivation. *Aviat Space Environ Med.* sept 1978;49(9):1065-73.
53. Haslam DR. Sleep loss, recovery sleep, and military performance. *Ergonomics.* févr 1982;25(2):163-78.
54. Sommeil · Inserm, La science pour la santé
55. Philibert I. Sleep Loss and Performance in Residents and Nonphysicians: A Meta-Analytic Examination. *Sleep.* nov 2005
56. Samkoff JS, Jacques CH. A review of studies concerning effects of sleep deprivation and fatigue on residents' performance: *Academic Medicine.* nov 1991
57. Lockley SW, Cronin JW, Evans EE, Cade BE, Lee CJ, Landrigan CP, et al. Effect of reducing interns' weekly work hours on sleep and attentional failures. *New England Journal of Medicine.* 2004;351(18):1829-37.
58. Gottlieb DJ, Parenti CM, Peterson CA, Lofgren RP. Effect of a change in house staff work schedule on resource utilization and patient care. *Arch Intern Med.* oct 1991;151(10):2065-70.
59. Persico N, Maltese F, Ferrigno C, Bablon A, Marmillot C, Papazian L, et al. Influence of Shift Duration on Cognitive Performance of Emergency Physicians: A Prospective Cross-

Sectional Study. *Ann Emerg Med.* août 2018;72(2):171-80.

60. Berger B. Étude REPAR: Réévaluation de l'Épuisement Professionnel en Anesthésie-Réanimation en France par auto-questionnaire. :79
61. Doppia M-A, Estryn-Béhar M, Fry C, Guetarni K, Lieutaud T, comité de pilotage de l'enquête SESMAT. [Burnout in French doctors: a comparative study among anaesthesiologists and other specialists in French hospitals (SESMAT study)]. *Ann Fr Anesth Reanim.* nov 2011;30(11):782-94.
62. Ernst F, Rauchenzauner M, Zoller H, Griesmacher A, Hammerer-Lercher A, Carpenter R, et al. Effects of 24 h working on-call on psychoneuroendocrine and oculomotor function: a randomized cross-over trial. *Psychoneuroendocrinology.* sept 2014;47:221-31.
63. Maltese F, Adda M, Bablon A, Hraeich S, Guervilly C, Lehingue S, et al. Night shift decreases cognitive performance of ICU physicians. *Intensive Care Med.* mars 2016;42(3):393-400.
64. Akerstedt T, Gillberg M. Subjective and objective sleepiness in the active individual. *Int J Neurosci.* mai 1990;52(1-2):29-37.
65. Ducos G, Lejus C, Sztark F, Nathan N, Fourcade O, Tack I, et al. The Script Concordance Test in anesthesiology: Validation of a new tool for assessing clinical reasoning. *Anaesthesia Critical Care & Pain Medicine.* févr 2015 ; 34(1):11-5.
66. de Zambotti M, Goldstone A, Claudatos S, Colrain IM, Baker FC. A validation study of Fitbit Charge 2™ compared with polysomnography in adults. *Chronobiol Int.* avr 2018;35(4):465-76.

The deleterious impact of 24 hours shifts on medical reasoning is associated to their frequency among anesthesiology and critical care residents and physicians: a randomized crossover study

Abstract

Background : Shift is common for anesthesia and critical care doctors, but its impact on medical reasoning remains uncertain.

Objective : The present study attempted to evaluate the impact of shift on the clinical reasoning performance of anesthesiology and intensive care doctors (residents and seniors). Changes in medical reasoning were measured by script concordance tests (SCT).

Methods : This multicentric, prospective, randomized, cross-over study was conducted in 5 public hospitals of Normandy region. Two groups of anesthesia and critical care doctors were formed, and each was assessed using SCT. Performance was assessed using a 69-items SCT. Group A completed the first part of the assessment (38 SCT) after a weekend without work and the second part (31 SCT) after a 24-hours shift. Group B did the same in reverse order. The primary outcome was medical reasoning's performance as measured by SCT after a weekend without work and after a 24-hours shift.

Results: In this study, 84 doctors (26 physicians and 58 residents) were randomized. Performance was lower after 24-hours shift than after a rest period (68 [SD 8] vs 64 [SD 9], $p = 0.0082$).

Conclusion : Our study suggests that medical reasoning' performance of anesthesiologists, measured by the SCT, was significantly poorer after 24h-shift than after rest period. This observation confirms the hypothesis that many shifts should be avoided to prevent the occurrence of medical errors. The impact of shift and the fatigue it generates should be studied further.