What Are the Effects of Sleep Deprivation and Fatigue in Surgical Practice?

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Sleep deprivation and fatigue have long been linked with accidents in high-risk industries and serious errors in the medical profession, but their effects on surgical performance are less well understood. This article outlines the important functions that human sleep serves and describes the neurobehavioral effects of wakefulness extension and mental fatigue that are relevant to surgical performance, including attentional failure, risk taking, and decision-making bias. Methods used to explore the effects of sleep deprivation and fatigue on surgical performance, from laboratory studies to outcomes data, are discussed; the findings are summarized; and important deficiencies in the literature are highlighted. Future strategies to mitigate performance decline, such as novel assessment tools and countermeasures with proven efficacy, are presented, and their deployment is discussed in the context of key ethical principles.

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To truly understand the potential for sleep deprivation and fatigue to impact on surgical performance, it is first necessary to consider the purpose that sleep serves and why, at a physiological and a neurobiological level, lack of sleep may lead to performance impairment. Human sleeping patterns are controlled by both homeostatic mechanisms that increase sleep pressure in response to time spent awake and a circadian body clock that promotes wakefulness at usual times of activity and sleep at the usual time of rest.1 The presence of such a tightly controlled system of sleep regulation and the health sequelae of short sleep duration, including cardiovascular morbidity and mortality,2 metabolic disturbance and obesity,3,4 and elevated cancer risk,5 point strongly to a basic human need for sleep.

When time awake is extended beyond a critical length and homeostatic sleep drive is resisted, neurocognitive performance begins to decay in a manner comparable with the effect of alcohol intoxication.6 The tight relationship between extended wakefulness and cognitive dysfunction may be the result of a gradual build up of synaptic connections in the waking brain.7 A reduction in size and number of these synaptic connections (renormalization) has recently been observed after sleep, suggesting that restoration of neurocognitive function is one of the key functions of sleep.8

Similarly marked neurocognitive impairments have been observed in the absence of sleep loss when demanding mental tasks are performed. Known as mental fatigue, a concept with which most surgeons will be tacitly familiar, the psychophysiological consequences of sustained demanding cognitive effort include impairments in goal-directed behavior9 and attentional failures (known as the vigilance decrement).10 This can be explained in the human brain by a progressive decline in activity within classical attentional brain networks that persists for some time after the completion of a demanding mental task.11 Few would disagree that the work hours and work practices of surgeons and other medical professionals expose them to the potential effects of sleep deprivation and fatigue. In recent years, this realization has led to the introduction of working-hours restrictions for junior doctors in both the United States (Accreditation Council for Graduate Medical Education [ACGME]-mandated working-hours restrictions) and Europe (European Working Time Directive). Despite this, sleep-deprived and fa-
tigated surgical residents and attending surgeons continue to pose a potential safety risk; resident work-hours restrictions suffer from important limitations, and attending surgeons, who frequently perform overnight work in addition to their scheduled daytime activities, are currently permitted to operate in a sleep-deprived state at their own discretion. 

WHAT RESEARCH IS AVAILABLE

Neurocognitive Effects

Acute and chronic sleep deprivation and mental fatigue impact on key cognitive functions critical for effective human performance; by reviewing these effects, it is possible to make predictions about the potential consequences for surgical performance.

Attention

Attention can be thought of simply as the brain’s spotlight illuminating information relevant to the task at hand. Hallmarks of impaired attentional performance include lapses (prolonged response times), errors of omission, errors of commission, and performance variability—all of which have been observed after extended wakefulness, chronic sleep deprivation, and mental fatigue. Knowledge of these effects is germane to a review of the effects of fatigue on surgeons for 2 important reasons: first, it is the most vulnerable domain, and second, attentional failures have been linked with serious accidents in other industries and serious medical errors in the medical profession.

Extension of wakefulness—whether the result of total sleep deprivation or chronic sleep restriction—results in a linear decline in vigilant (sustained) attention such that a sleep duration of 4-6 hours per day for 14 days results in an equivalent performance decline to 1-2 days of continuous wakefulness. This refutes the commonly held belief that it is possible to “acclimatise” to chronic sleep deprivation. Furthermore, extended wakefulness is expressed as inconsistency in attentional performance rather than global performance decline—subjects may display adequate reaction times for short periods (potentially giving the subjects the illusion that they are unimpaired) interspersed with periods of frequent errors. This “state instability” hypothesis is supported by functional neuroimaging studies where fast responses produce similar activation patterns to rested responses, only when activation in the attentional network drops, does performance begin to decline.

An especially concerning characteristic of chronically accumulated sleep loss is the dissociation between objective performance impairment and subjective reporting of fatigue, which is often less pronounced. It is also possible for individuals in total sleep deprivation experiments to feel alert but be among the worst performers when assessed objectively. These apparent discrepancies between objective performance and introspective fatigue present a potential safety risk in a profession in which self-monitoring of performance is of such great importance. The discrepancy between subjective and objective performance after sleep restriction may be greatest during night-shift hours, rendering night work after sleep restriction most vulnerable to introspection errors.

It is now also becoming clear that the effects of sleep deprivation and mental fatigue may display considerable intersubject variability. Indeed, it is now often referred to as a “trait” or attribute. Support for this hypothesis can be found in brain imaging studies where neurobiological correlates of vulnerability to performance decline in response to sleep deprivation have been found and in genetic studies where PERIOD3 polymorphism has been implicated.

Other Cognitive Functions

Closely associated with attentional function, working memory is thought to underpin many cognitive processes. High-quality evidence suggests that working memory is impaired in sleep-deprived subjects and is associated with altered activation of the prefrontal cortex in neuroimaging studies. Evidence also suggests that sleep loss leads to reduced cognitive flexibility, over-reliance on previously developed strategies, a tendency toward making risky decisions, and a preference for the pursuit of gain over the avoidance of loss.

Implications for Surgeons

Contrary to the commonly held belief that surgeons are technicians, effective performance in surgery is almost certainly primarily a function of cognitive and other “non-technical” skills. Approximately 27% of claims against health care organizations may result from a cognitive or diagnostic error, and lapses of judgment have been reported by surgeons as the greatest contributing factor to surgical error. Judgment of risk and estimation of time also feature prominently in self-reported accounts of challenging surgical cases. To avoid causing inadvertent injury to viscera or other structures, thought to account for approximately 48% of intraoperative errors, surgeons must also attend to salient operative cues and monitor the
operative field for infrequently occurring but important features, such as aberrant anatomical structures. Importantly, in minimally invasive surgery, where tactile feedback is reduced or lost altogether, the ability to attend to operative visual cues may take on even greater significance.35

Surgical Research

Sleep deprivation and fatigue result in important impairments of basic and higher-order cognitive functions that are conceptually relevant to surgical performance. Studies that recruit surgeons or examine surgical performance have the potential to test these expected effects empirically in this population and also to provide insights into the effects of fatigue on key aspects of surgical performance, such as the integration of cognitive and motor skill. Before reviewing this literature, it is important to acknowledge the variety of challenges faced by surgical researchers, including: lack of participant availability, selection bias, and the prevalence of chronic sleep deprivation in the surgical community. Significant methodological limitations also exist (Table 1), most important of which is the frequent inability to directly manipulate sleep schedules, shift patterns, or task conditions (as it is typically only ethically permissible to do so in a laboratory setting). This unfortunate trade-off between scientific rigor and clinical immediacy results in literature that can be difficult to interpret.

Neurobehavioral Assessment

A number of studies have demonstrated the cognitive effects of extended wakefulness in resident physicians, including polysomnographically detected attentional lapses30 and lapses in performance on neuropsychological tasks,30 suggesting that fatigue effects are indeed present in this population. However, few good-quality studies have assessed surgical residents, and only 1 recruited attending surgeons. Lehmann et al60 found no effect of a night on-call on the performance of basic attention tasks in a cohort of surgical residents. In contrast, Kahol et al41 found that “night-call” was associated with impaired combined surgical motor and cognitive skill using a series of novel tasks. The same group conducted a further study in which they recruited 9 attending trauma surgeons—the same pattern of effects was observed.42 Kahol and colleagues concluded that although pure motor skills are relatively unaffected by fatigue, combined cognitive and motor skills are impaired regardless of seniority.

<table>
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<th>Table 1. Research Methods</th>
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<td>Intervention</td>
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<td>Sleep schedule/mental fatigue intervention (ie, supervised total sleep deprivation)</td>
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<td>Clinical work schedule intervention (ie, work hours rather than sleep schedule manipulated)</td>
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<tr>
<td>Outcomes assessment (surgical morbidity and mortality)</td>
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In our department, Leff et al\textsuperscript{43} have shown that, in surgical residents, 1 night of extended wakefulness results in detectible changes in cortical hemodynamics during the performance of a basic arithmetic task. Task performance was relatively unaffected, but prefrontal cortical activity was found to rise with extended wakefulness, suggesting that compensatory processes were engaged in maintaining performance. It is important to note that no studies have assessed the impact of acute mental fatigue and none recruited cardiac or thoracic surgeons.

**Simulated Clinical Assessment**

Most simulated clinical studies have chosen to assess basic clinical motor skills. In our department, Taffinder et al\textsuperscript{36} found that surgical residents made 20% more errors and participants took 14% longer to complete a simulated laparoscopic task after a period of extended wakefulness, and Leff et al\textsuperscript{44} found similar effects on the first night of a series of night shifts. This link between extended wakefulness and laparoscopic psychomotor skill impairment has been replicated by a number of other studies.\textsuperscript{37,45} However, a minority have failed to replicate these effects.\textsuperscript{40,46} and Jakubowicz et al\textsuperscript{47} found no effect on simulated sinus surgery performance.

No studies have included assessments of more complex whole surgical procedures, and none have assessed simulated cardiac surgical techniques, despite the availability of validated high-fidelity models.\textsuperscript{48} Frustratingly, no studies in the surgical literature have assessed simulated nontechnical skills; in the only study to do so, internal medical residents made more errors in the management of complex critically ill patients after extended wakefulness but were unimpaired in the protocol-driven management of cardiac dysrhythmias.\textsuperscript{49}

Importantly, no studies have assessed the effect of acute mental fatigue on simulated clinical performance and none recruited cardiothoracic surgeons.

**Clinical Assessment**

A wide array of valid and reliable performance assessment tools—suitable for use in the laboratory and operating room\textsuperscript{50}—now exist and could provide important insights into the effects of sleep deprivation and fatigue on clinical performance. Measures of technical performance include the Imperial College Surgical Assessment Device\textsuperscript{50} and observational rating scales such as the Objective Structured Assessment of Technical Skill, which has been used successfully to assess many surgical techniques, including vascular anastomosis.\textsuperscript{46} Nontechnical skill and teamwork can also now be assessed by using rating scales of performance such as the Observational Teamwork Assessment in Surgery scale, which was successfully validated for use in surgical teams by our department.\textsuperscript{51} However, to our knowledge, no studies have attempted to determine the impact of sleep deprivation or mental fatigue on actual surgical performance.

**Surgical Outcomes**

The surgical outcomes literature regarding the link between sleep deprivation and surgical error is conflicting (Tables 2 and 3). A number of large observational studies conclude that no link exists between sleep deprivation and surgical outcomes,\textsuperscript{32,54,59-63} whereas others link sleep deprivation to mortality after liver transplant\textsuperscript{33}; surgical complication rates after a range of general, cardiac, and obstetrical procedures\textsuperscript{36}; morbidity after emergency surgery\textsuperscript{37}; re-operation for removal of orthopedic hardware\textsuperscript{38}; long-term graft failure after kidney transplant\textsuperscript{37}; and morbidity after elective general and vascular surgery.\textsuperscript{39} Of the 3 studies that explicitly examined the effect of sleep deprivation on cardiac and thoracic surgery,\textsuperscript{51,61-63} all concluded that patient outcomes were not affected (Table 3). Of note, although many studies purported to explore the effects of sleep deprivation on surgical outcomes, only Chu et al\textsuperscript{61} and Rothschild et al\textsuperscript{59} included a measure of sleep (sleep length and opportunity for sleep, respectively) in their analyses. Chu et al concluded that operative outcomes in cardiac surgery were not related to sleep duration, whereas Rothschild et al concluded that opportunity for sleep of <6 hours was associated with increased complications after a range of general and cardiac cases.

**What Does This Literature Tell Us?**

Surgeons work long hours, perform frequent on-call work, and engage in long, demanding, and high-risk activities. This is particularly true of cardiothoracic surgeons, 30% of whom work more than 80 hours per week and 44% of whom cover more than 3 on-calls per week.\textsuperscript{64} A detailed understanding of the effects of sleep deprivation and fatigue on surgical performance is therefore of great importance and presents an opportunity for academicians to study these effects in a high-risk operational setting. Surgeons are, without question, at risk of fatigue-related performance impairment, but, disappointingly, the literature tells surgeons little about the pattern of these effects and
<table>
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<tr>
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<tbody>
<tr>
<td>Yaghoubian et al52</td>
<td>Retrospective outcomes comparison between day (6 AM-10 PM) and night (10 PM-6 AM) procedures</td>
<td>Residents</td>
<td>Laparoscopic cholecystectomies and laparoscopic appendectomies</td>
<td>Total complications, bile duct injury, conversion to open, length of surgery, and mortality</td>
<td>No effect of time of day on surgical outcomes</td>
</tr>
<tr>
<td>Lonze et al53</td>
<td>Retrospective outcomes comparison between day (3 AM-3 PM) and night (3 PM-3 AM) procedures</td>
<td>Not stated</td>
<td>Liver transplants</td>
<td>Wound, vascular, biliary and other complications, duration of surgery, and mortality</td>
<td>Nighttime operations longer in duration and associated with double the risk of death within 7 days of transplant No effect of time of day on complications</td>
</tr>
<tr>
<td>Yaghoubian et al54</td>
<td>Retrospective outcomes comparison between day (6 AM-10 PM) and night (10 PM-6 AM) procedures</td>
<td>Residents</td>
<td>Trauma surgery</td>
<td>Morbidity (wound infections, cardiac arrest, coagulopathy, disseminated intravascular coagulation, empyema, evisceration, liver failure, pneumonia, deep venous thrombosis, sepsis, renal failure, pulmonary embolism, and pulmonary insufficiency) and mortality</td>
<td>No association between time of surgery and morbidity or mortality</td>
</tr>
<tr>
<td>Rothschild et al38</td>
<td>Retrospective cohort study comparing post-nighttime procedures (surgeon involved in other procedure between 12 AM and 6 AM with matched controls. A secondary analysis compared sleep opportunity of &gt;6 hours with sleep opportunity of &lt;6 hours</td>
<td>Attendings</td>
<td>All obstetrical/gynecologic and general surgery procedures</td>
<td>Surgical complications (infection, massive hemorrhage, organ injury, wound failure, and other complications) and obstetrical complications (greater than 1000-mL blood loss, stillbirth, umbilical cord prolapse, shoulder dystocia, birth trauma, and fourth-degree perineal tear) Mortality and any morbidity at 30 days postoperatively</td>
<td>No effect of post-nighttime procedure on outcomes Sleep opportunity of &lt;6 hours associated with higher incidence of complications</td>
</tr>
<tr>
<td>Kelz et al55</td>
<td>Retrospective cohort study comparing overnight cases (9:30 PM-7:30 AM) with day cases</td>
<td>Not stated</td>
<td>All elective and emergency cases performed at 14 academic medical centers</td>
<td>Mortality and any morbidity at 30 days postoperatively</td>
<td>All nighttime procedures associated with higher adjusted morbidity Nighttime elective procedures associated with higher morbidity</td>
</tr>
<tr>
<td>Ricci et al56</td>
<td>Prospective nonrandomized comparison between overnight cases (4 PM-6 AM) and day cases (6 AM-4 PM)</td>
<td>Not stated</td>
<td>Femoral and tibial shaft fixation procedures</td>
<td>Fracture healing, complications, operative time, and fluoroscopy time</td>
<td>Nighttime procedures associated with more reoperations for removal of hardware</td>
</tr>
<tr>
<td>Fechner et al17</td>
<td>Cohort study comparing overnight cases (8 PM-8 AM) and day cases (8 AM-8 PM)</td>
<td>Not stated</td>
<td>Kidney transplant</td>
<td>Graft function, graft failure, reoperation for complications</td>
<td>Nighttime procedures associated with higher rate of long-term graft failure and higher incidence of surgical complications</td>
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</tbody>
</table>
reveals little about how complex real-world tasks may be affected. Crucially, only a narrow spectrum of activities has been assessed; "non-technical skill" has been neglected; and high-risk groups, such as cardiothoracic surgeons, who frequently work overnight and perform technically demanding surgery, are underrepresented.

A lack of good-quality laboratory and clinical data and the absence of a mechanistic account of the impact of sleep deprivation and fatigue on surgical performance make the interpretation of heterogeneous and contradictory outcomes literature difficult. Data are not yet available to support the selection of appropriate outcome measures; criteria used to define sleep deprivation and fatigue are highly variable between publications, and most are not carried out prospectively. Additionally, outcomes studies are frequently single center and, as they report the results of small groups of surgeons, are usually not generalizable to the surgical community at large.

**WHAT CAN BE DONE TO MITIGATE THE EFFECTS OF FATIGUE**

**Working Hours**

Shift pattern manipulation has been the primary method with which intern and resident fatigue has been addressed—in both the United Kingdom (European working time directive) and the United States (ACGME working-hours restrictions). A major change in recent years in the United States has been the inclusion of a mandated rest period of 5 hours for all interns working extended shifts and a maximum shift length of 16 hours. However, this does not apply to residents, and there is currently no

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### Table 2. Continued

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<th>Source</th>
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<th>Procedures</th>
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<tbody>
<tr>
<td>Kelz et al⁵⁸</td>
<td>Retrospective analysis of audit data</td>
<td>Not stated</td>
<td>All nonemergency general and vascular procedures</td>
<td>Mortality and any morbidity at 30 days postoperatively</td>
<td>Nighttime procedures associated with higher postoperative morbidity.</td>
</tr>
<tr>
<td>Schieman et al⁵⁹</td>
<td>Retrospective case note review comparing nighttime cases (after 10 pm)</td>
<td>Not stated</td>
<td>Anterior resection for rectal cancer</td>
<td>Perioperative complications, long-term complications, and cancer recurrence</td>
<td>No association between nighttime procedures and outcomes.</td>
</tr>
<tr>
<td>Haynes et al⁶⁰</td>
<td>Retrospective case review comparing sleep-deprived cases (post 24 hours on-call) with non-sleep-deprived cases</td>
<td>Residents</td>
<td>All surgical cases</td>
<td>Presence of postoperative complications</td>
<td>No association between sleep deprivation and surgical outcomes.</td>
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### Table 3. Outcomes Research (Cardiothoracic Surgery)

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<tr>
<th>Source</th>
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<th>Conclusions</th>
</tr>
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<tbody>
<tr>
<td>Chu et al⁶¹</td>
<td>Prospective cohort study</td>
<td>Consultant surgeons (attendings)</td>
<td>Coronary artery bypass, valve, combined valve-coronary artery bypass, and aortic surgery</td>
<td>Morbidity and mortality (10 complications)</td>
<td>No association between sleep deprivation and surgical outcomes.</td>
</tr>
<tr>
<td>Ellman et al⁶²</td>
<td>Retrospective case review comparing sleep-deprived cases (performed a case the previous evening) with non-sleep-deprived cases.</td>
<td>Residents</td>
<td>All thoracic cases</td>
<td>Operative efficiency, length of stay, use of blood products, postoperative complications, mortality</td>
<td>No association between sleep deprivation and surgical outcomes.</td>
</tr>
<tr>
<td>Ellman et al⁶³</td>
<td>Retrospective case review comparing sleep-deprived cases (performed a case the previous evening) with non-sleep-deprived cases.</td>
<td>Attendings</td>
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<td>Operative efficiency, length of stay, use of blood products, postoperative complications, mortality</td>
<td>No association between sleep deprivation and surgical outcomes.</td>
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restriction on the number of hours that attending surgeons may work.

Beyond Working Hours

Sophisticated detection methods, such as polysomnography, brain imaging, and eye tracking, could be used in the future to help warn surgeons of impending performance failure. For example, increased pretask activity in the thalamus and middle frontal gyrus has been predictive of acute mental fatigue.11 Also, in surgical residents, increased activation in the prefrontal cortex has been seen in the presence of increasing subjective fatigue but independent of performance decline43; such compensatory measures may predict impending surgical error. Once imminent performance decline has been signaled, a number of potential restorative measures could be undertaken.

Warm up on a surgical simulator before performing a laparoscopic cholecystectomy has been shown to improve operating room performance (measured using the Objective Structured Assessment of Technical Skill scale).65 Kahol et al.66 have demonstrated that warm up on a laparoscopic simulator conferred substantial benefits in economy of movement and error rates when postcall residents performed a series of abstract tasks. Although the laboratory evidence is promising and warm-up sessions would be feasible to implement, the effects are likely to be slight and important cognitive impairments are likely to be unaffected.

It is clear from the literature on extended shift work that doctors avail themselves of sleep whenever they have the opportunity. Napping for as little as 30 minutes during a night shift can produce measurable benefits in cognitive performance and subjective feelings of fatigue.67 However, “sleep inertia” may temporarily impair performance on waking from a nap, and although naps of up to 1 hour effectively restore some aspects of cognitive performance, gains may be overestimated, as other functions critical for effective functioning, such as error monitoring, appear to be unaffected.68 A study of the effects of a 40-minute nap in emergency room physicians during an on-call shift confirmed these predictions: memory impairment was evident immediately after the nap, but this was followed by improvements in attention and driving performance.69 Unfortunately, no research has been carried out to investigate the effects of napping on surgical performance.

As it is not always possible to obtain rest or sleep in an attempt to restore function, interest in a range of substances, including caffeine and modafinil, that are capable of improving certain aspects of cognition in varying conditions of sleep deprivation and fatigue is growing.70 Consumption of caffeine, the most widely used stimulant, produces feelings of subjective alertness and promotes extended wakefulness. Recent laboratory research has also shown that 150 mg of caffeine reverses some of the effects of sleep deprivation on simulated laparoscopic performance in novices.71 However, much higher doses of approximately 600 mg are required to achieve significant sustained improvements in cognitive function.72 Modafinil, in addition to its licensed indications, shows considerable promise as a wakefulness promoter and cognitive enhancer in healthy individuals.

Table 4. Practical Recommendations

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<thead>
<tr>
<th>Primary Recommendations</th>
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<tr>
<td>Periods of challenging work should be followed by short breaks to allow time for recuperation—consider canceling nonurgent cases if necessary.</td>
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<tr>
<td>Only nonclinical duties should be scheduled to take place after an overnight on-call, if a surgeon has had the opportunity for &lt;6 hours of sleep in the previous 24 hours:</td>
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<tr>
<td>Complex cases should be canceled or another surgeon should be found.</td>
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<tr>
<td>The decision to operate on less-challenging cases should be made after discussion with a colleague.</td>
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<tr>
<td>If any procedures are undertaken, patients should be reconsented and “fatigue related error” should be included in the list of possible complications.</td>
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<tr>
<th>Secondary Recommendations</th>
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<tr>
<td>Introduce mandatory training for all clinical staff on the neurobehavioral effects of sleep deprivation and fatigue.</td>
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<tr>
<td>Provide a designated area for surgeons to rest between cases or to nap.</td>
</tr>
<tr>
<td>Introduce local measures to monitor the working practices of attending surgeons and record adverse events related to sleep deprivation or fatigue.</td>
</tr>
<tr>
<td>Consider the development of local guidelines and procedures for surgeons to follow in circumstances where sleep deprivation or fatigue may impair performance.</td>
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</table>
Many studies have found modafinil capable of ameliorating the cognitive effects of sleep deprivation and fatigue, including attention, working memory, and subjective fatigue during simulated night-shift work and attention, working memory, and cognitive flexibility after a period of extended wakefulness. In our department, we recently found that modafinil ameliorated the effects of extended wakefulness on working memory, attentional flexibility, and impulsivity in a cohort of resident doctors but did not improve simulated laparoscopic performance. However, as this was conducted in a laboratory setting, the implications for real-world clinical performance remain uncertain.

Practical Recommendations
Until more detailed evidence emerges as to the specific effects of sleep deprivation and fatigue on surgical performance and the efficacy of novel remedial strategies, we believe that simple measures to provide education, monitor and regulate working patterns, and reduce patient exposure to sleep-deprived and fatigued surgeons are likely to be the most effective (Table 4).

ETHICAL ISSUES
Nonmaleficence
The principle of nonmaleficence requires that medical physicians and surgeons not subject patients to unnecessary harm through either the omission or commission of action. In the context of sleep deprivation and fatigue, surgeons who operate in a functionally impaired state would clearly violate this principle. However, a lack of detailed evidence linking specific clinical circumstances to functional impairment and patient harm makes it difficult to isolate unethical practices. With further research, certain actions, such as undertaking complex surgery after total sleep loss, may be considered unethical, as might the failure to use countermeasures with proven efficacy.

Distributive Justice
Sleep deprivation and fatigue may lead to violation of the justice principle by creating inequalities in the standard of care delivered. Patients operated on by a surgeon after a good night's sleep may receive a higher standard of care than those after a night on-call. Furthermore, resilience to the effects of sleep loss and fatigue displays considerable interindividual variability. Therefore, employers, professional bodies, and health care organizations that condone work under sleep-deprived and fatigued conditions or fail to take steps to mitigate its effects may violate this principle.

Respect for Autonomy
Coercion by an institution or health care system culture or even by patients or their relatives to oper-
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Baldwin DC, Daugherty SR: Sleep deprivation and fatigue in residency training: Results of a national survey of first- and second-year residents. Sleep 27:217-223, 2004


Chee MW, Tan JC: Lapsing when sleep deprived: Neural activation characteristics of resistant and vulnerable individuals. Neuroimage 51:835-843, 2010


Mu Q, Mishory A, Johnson KA, et al: Decreased brain activation during a working memory task at rested baseline is associated with vulnerability to sleep deprivation. Sleep 28:433-446, 2005

Harrison Y, Horne JA: One night of sleep loss impairs innovative thinking and flexible decision making. Organ Behav Hum Decis Process 78:128-145, 1999


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