Sleep Deprivation Does Not Affect Operative Results in Cardiac Surgery

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Background. **There has been an increasing trend towards the mandatory reduction in work hours for physicians because of the fear that sleep-deprived (SD) surgeons are more prone to make mistakes. We hypothesized that sleep deprivation would not be associated with increased morbidity or mortality in cardiac operations.**

Methods. **A retrospective review was done of all cases performed by all attending cardiac surgeons from January 1994 to April 2003. Complication rates of cases performed by SD surgeons were compared with cases done when the surgeons were not sleep-deprived (NSD). A surgeon was deemed sleep deprived if he or she performed a case the previous evening that started between 10:00 PM and 5:00 AM, or ended between the hours of 11:00 PM and 7:30 AM.**

Results. **A total of 6,751 cases were recorded in the Society of Thoracic Surgeons database over the 9-year period examined. Of these, 339 cases (5%) were performed by SD surgeons, and 6,412 (95%) cases were performed by NSD surgeons. Mortality rates for coronary artery bypass operations showed no significant differences (1.7% [SD = 4/223] vs 3.1% [NSD = 133/4206)] $p = 0.34$). Operative ($p = 0.47$), pulmonary ($p = 0.60$), renal ($p = 0.93$), neurologic ($p = 0.11$), and infectious ($p = 0.87$) complications of all cases also failed to show any statistically significant differences in any group. Perfusion times, cross-clamp times, and the use of blood products were also similar between groups.**

Conclusions. **Sleep deprivation does not affect operative morbidity or mortality in cardiac surgical operations. These data do not support a need for work hour restrictions on surgeons.**

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Surgeons are stereotypically known for working long, hard hours. These long hours, it was traditionally believed, were what it took to become a skilled surgeon. However, many now believe that tired physicians are more prone to make mistakes and are also a danger to themselves. This belief has given way to the sweeping reforms and work hour restrictions put forth by the Accreditation Council for Graduate Medical Education in 2002, as well as the Patient and Physician Safety and Protection Act of 2003, a bill currently making its way through congress that would make resident work hour restrictions a federal law [1, 2]. The specifics of these work hour restrictions have been based roughly on the laws passed in New York following the death of Libby Zion, a young woman whose death was presumed to be partially due to medical errors committed by sleep-deprived resident physicians [3, 4].

Surprisingly, despite these dramatic changes, there are actually very little data on how sleep deprivation affects actual patient errors [5]. One study done thus far on surgical residents suggests sleep deprivation does not lead to an increase in operative complications [6]. Moreover, there appear to be no data on the effects of sleep deprivation on practicing surgeons who have completed their surgical training. Thus, we examined our own clinical experience to discern the effects of sleep deprivation on patient complications. Our hypothesis was that sleep deprivation in attending surgeons would not adversely affect patient outcomes.

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Patients and Methods

Patient Selection

A retrospective review was done of all cases performed by attending cardiac surgeons at the University of Virginia from January 1994 to April 2003. We wanted to establish which cases were done by sleep-deprived surgeons (SD) and compare complication rates with those cases that were done by surgeons who were not sleep deprived (NSD). Institutional review board approval was obtained for this study.

First, we had to establish whether or not the surgeon was sleep deprived. A surgeon was designated as sleep deprived if he or she performed a case that started between 10:00 PM and 5:00 AM, or ended a case between

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11:00 PM and 7:30 AM. If the surgeon then performed a subsequent case within the next 24 hours, that case was considered a SD case, while all other cases were regarded as NSD cases.

Beginning with January of 1994, we prospectively recorded detailed data as outlined by the Society of Thoracic Surgeons (STS) regarding complication and mortality rates for all cardiac procedures. We used these data as a means of objectively assessing morbidity and mortality rates in the SD and NSD groups and allowing a means for comparison.

End Points

We examined in-hospital mortality rates of coronary artery bypass graft (CABG) operations, valve operations (any valve), combined CABG–valve operations, and a separate group designated "other" for all other cardiac cases that did not fall into the first three categories. As an assessment of operative efficiency, we compared cardiopulmonary bypass times and cross-clamp times. Furthermore, we looked at total in-hospital length of stay after operation (excluding patients whose length of stay was > 60 days), whether or not a patient received blood products, and operative, neurologic, renal, infectious, and pulmonary complications, which were prospectively recorded, based on the STS guidelines, in the STS database as "yes" or "no."

A patient was considered to have had an operative complication if they had reoperations for bleeding or tamponade, valvular dysfunction after a valve case, graft occlusion, other cardiac or noncardiac problems, or perioperative myocardial infarction. Neurologic complications were considered present if the patient had a perioperative stroke, transient ischemia attack, or continuous coma for more than 24 hours. Renal complications included renal failure or the need for dialysis. Infectious complications were present if the patient had a sternal, thoracotomy, or leg infection as well as any recorded septicemia or urinary tract infection. Finally pulmonary complications were present if the patient was ventilated for more than 24 hours postoperatively, or had a pulmonary embolism, pneumonia, or a pleural effusion.

Statistics

Results are summarized as mean ± standard error of the mean or n (%). Univariate statistical analysis was performed using χ^2, the Fischer exact test, and the Student t test for the comparison of relative frequencies and means, respectively. A p value of 0.05 or less was considered significant.

Results

Patient Population and Demographics

A total of 6,751 adult cardiac cases were recorded in the STS database over the 9-year period we examined. Of these, 339 (5%) were performed by SD surgeons and 6,412 (95%) cases performed by NSD surgeons (Table 1). The two groups were well matched and there were no significant differences in age, sex, race, or the operations performed. The average age was 63.4 ± 0.7 in the SD group and 63.5 ± 0.1 in the NSD group (p = 1.0). The predominant race was white, with 94.1% in the SD group and 92.4% in the NSD group (p = 0.25). Men predominated in each group as well, with 70% in the SD group and 70% in the NSD group (p = 0.94). Most of the operations performed were CABGs, with 66% in the SD group and 65% in the NSD group (p = 0.94). Valve, CABG plus valve and "other" operations were also of a similar proportion in each group.

Table 1. Patient Population

Category	SD (n = 339)	NSD (n = 6412)	p
Sex (male)	0.7	0.7	0.94
Age	63.4 ± 0.7	63.5 ± 0.1	0.84
Asian	0 (0.0%)	8 (0.0%)	1.0
Black	15 (4.4%)	382 (6.0%)	0.24
Caucasian	319 (94.1%)	5,926 (92.4%)	0.25
Hispanic	1 (0.3%)	21 (0.3%)	1.0
Other race	4 (1.2%)	62 (1.0%)	0.57
CABG	223 (66%)	4206 (65%)	0.94
Valve	45 (13.27%)	824 (12.85%)	0.82
CABG–Valve	22 (6.49%)	443 (6.91%)	0.76
Other operation	49 (14.45%)	939 (14.64%)	0.92

CABG = coronary artery bypass grafting; NSD = not sleep deprived; SD = sleep deprived.

End Points

Mortality rates for CABG, valve, CABG plus valve, and "other" mortality rates were examined (Table 2). SD and NSD mortality rates did not significantly differ. Two deaths occurred for CABG in the SD group (1.7%) and 133 in the NSD group (3.1%) (p = 0.34). Likewise, a comparison of valve, CABG plus valve, and "other" operations all demonstrated similar respective mortality rates.

Perioperatively, there appear to be no differences in a number of other important variables as well (Table 3). Cardiopulmonary bypass times and aortic cross-clamp times were similar. In both groups, 49% of the patients required the use of blood products at some point during their hospital stay (p = 0.82). There were 29 patients (9%) in the SD group with operative complications and 480 (7%) in the NSD group (p = 0.47). Univariate analysis of all neurologic, renal, pulmonary, and infectious complications failed to demonstrate any significant differences

Table 2. Mortality Rates

Operation	SD (n = 339)	NSD (n = 6412)	p
CABG	4/223 (2%)	133/4206 (3%)	0.34
Valve	2/45 (4%)	32/443 (4%)	0.69
CABG–Valve	3/22 (13%)	34/443 (8%)	0.40
Other	8/49 (16%)	97/939 (10%)	0.18

CABG = coronary artery bypass grafting.

Table 3. Perioperative Data and Complications

Category	SD (n = 339)	NSD (n = 6412)	*p*
Cardiopulmonary bypass time	107.7 ± 3.0	107.4 ± 0.7	0.91
Aortic cross-clamp time	74.9 ± 2.4	73.6 ± 0.51	0.56
Blood products (yes or no)	49%	49%	0.82
Operation to discharge (days)	7.1 ± 0.4	6.9 ± 0.07	0.58
Operative complications	29 (9%)	480 (7%)	0.47
Neurologic complications	53 (16%)	809 (13)%	0.11
Renal complications	25 (7%)	480 (7%)	0.94
Pulmonary complications	69 (20%)	1,232 (19%)	0.6
Infectious complications	23 (7%)	421 (7%)	0.87

between the groups. Likewise, length of hospital stay after operations was not different.

Comment

The tired surgeon is a familiar stereotype, perhaps even glamorized in books, television, and movies. Over time, however, it appears the pervading sentiment, particularly outside of surgery, is that the sleep-deprived surgeon is not something to be respected, but rather eliminated. This is largely based on the opinion that sleep deprivation leads to medical errors.

Recent years have seen sweeping reforms in surgeon work hours. These changes have come swiftly, and consequences for patient care and training are unknown. One may even argue that this is a medical experiment, which if proposed on a smaller scale, would have required preliminary data, approval by an institutional review board, and careful ethical, statistical, and logistical planning. So far, the sentiment in the surgical world is far from favorable. The results from a recent survey of faculty surgeons at Washington University were recently published in the *Journal of the American College of Surgeons*. Of the surgeons who responded, 87% believed reducing resident hours would compromise education, and only 11% thought the benefits of hour reduction would outweigh the negatives [7].

These reforms have occurred without hard evidence that long hours lead to mistakes and sub-par care. Can the work hour reforms be justified by data from other lines of work such as airline pilots or bus drivers? This question is difficult question to answer, and is subject to much debate.

The work hour restrictions that have been implemented in this country thus far apply only to resident doctors. Currently there are no restrictions on nonresident doctors, but it logically follows that all doctors should theoretically have their hours restricted if working too long can lead to impairments in their performance. Still, there are little data to support this assertion, and studies of sleep deprivation on the performance of trained surgeons should be done as we have in our study.

Although we could not find studies in the literature on the effects of sleep deprivation on fully trained surgeons, a few studies have looked at the effects of sleep loss on surgical residents. Though this study looked at the effects of sleep deprivation on attending physicians, we believe it is still appropriate to review the literature that does exist regarding the effects of sleep deprivation on surgical residents. Specifically, studies have examined the effects of sleep deprivation on cognition, dexterity, and mood. The results, particularly with surgical residents, are equivocal.

Wesnes and colleagues found impairments in cognitive function, as well as increased feelings of confusion and lower levels of confidence, in 10 surgical house officers in a surgical ward evaluated after a weekend of call [8].

Brown and colleagues showed no effects of reading comprehension in a crossover trial of 46 rested and nonrested residents [9]. However, the amount of sleep two nights before a longer test, the American Board of Surgery In-Training Exam, was found to contribute to a 7% variance in the scores.

Deaconsen and colleagues studied 26 surgical residents under similar states of rest and lack of rest and failed to demonstrate any difference in a battery of psychomotor tests [10]. Interestingly, one aspect of the testing, the Trail-Making Test (which requires the subject to connect 25 numbered and lettered circles in sequence in a specific length of time) was not altered in surgical residents, but another study demonstrated decrements in sleep-deprived medical residents [11]. Veasey suggests this discrepancy could be because the surgical residents were all chronically sleep deprived, and thus the "rested" control group was underperforming as well [12].

Sleep deprivation may cause alterations in mood. A study of 42 surgical residents found increased subjective feelings of confusion, anger, and fatigue after sleep loss, but again, no differences in cognitive function [13].

Some have shown that manual dexterity and operative efficiency in surgical residents may be affected by sleep deprivation. Goldman and colleagues compared videotapes of operations performed by residents who had less than 2 hours of sleep with those that had longer periods of sleep [14]. Some degree of operative inefficiency was noted, as was an increase in surgical time in four of five residents with little sleep; however, the groups were very small. Additionally, two simulated laparoscopy studies found significantly more errors and longer time to perform procedures on post-call mornings [15, 16]. These suggest sleep deprivation can indeed affect operative skills. However, we could not find a well-powered study that demonstrated negative effects of sleep deprivation on operative efficiency in real life operative cases.

A very interesting question that remains to be answered is: Can the incentive to perform on live subjects overcome some of the negative effects of sleep deprivation? In a nonphysician-based study, Horne and Pettit demonstrated that the effects of up to 36 hours of sleep deprivation can be overcome if the subject has an incentive for better performance [17]. We can only speculate that their study holds true with regards to surgical performance. We tried to indirectly evaluate the effects of sleep deprivation on operative efficiency by looking at cross-clamp and perfusion times. There were no significant differences between the SD and the NSD groups.

We did not find any studies that demonstrated a higher incidence of operative complications in those cases done by SD surgeons. In 1995 Haynes and colleagues compared the frequency of significant surgical complications for residents who had been on call the previous night [6]. The investigators concluded there was no overall difference in complication rates after breaking down the operations into emergent and nonemergent operations. Residents who were on call or were post-call had a higher percentage of emergent cases, and when this was accounted for, there was no significant difference.

Are surgeons different than nonsurgical doctors? A number of studies have looked at the effects of sleep deprivation on nonsurgical residents and the results of these studies are equivocal—not unlike the studies on surgical residents. A review of this literature leaves one feeling uncertain whether or not sleep really does have an effect on performance or patient outcomes [11, 18–37]. Sleep deprivation does appear to have an affect on mood, however, and the evidence shows that SD physicians, not unlike SD workers in other fields, have more accidents while driving cars [38, 39].

Our study has several weaknesses. Because it was a retrospective study, it carries with it the usual confounding factors involved with such studies. A randomized prospective trial would be the best way to study the effects of sleep deprivation on patient outcomes, but such a study has never been done. Most likely, institutional review board approval would be difficult to obtain for such a study because it would be deemed unethical to have an SD surgeon operate on patients, as Altshuler pointed out in 1999 [40]. If one were able to obtain approval, however, such a study would still be confounded by the fact that the surgeons would know they were being tested. Thus the strength of this current study is the fact that the surgeons went about their business as usual.

Some might question our definition of being sleep deprived. We felt that just "being on call" was not enough to establish sleep deprivation. We wanted to be sure that the surgeons were up operating the night before the study cases, and in doing so we created strict criteria that would have had the surgeon in the operating room in the middle of the night, rather than sleeping. We also looked only at cardiac surgeons, rather than at all surgical subspecialties. This was because the database we used had been kept just for cardiac cases back to 1993.

Some may argue that the attending surgeon would not be the best person on the operating team to study, that residents might be more even more fatigued than the attending surgeons due to the cumulative effects of sleep deprivation. However, in our institution the attending surgeon is heavily involved in operative and postoperative management. Furthermore, in our database, the most accurate data are attending-specific, and the role of the resident is occasionally difficult to discern.

This study only examines the effects of acute sleep deprivation, not chronic sleep deprivation. It should be noted, however, that almost all of the studies on sleep deprivation to which we compare this study also only examine the effects of acute sleep deprivation. Moreover, in our institution this would be extremely difficult to examine because attending cardiac surgeons are rarely on call more than one night in a row. Clearly, future studies should examine the effects of chronic sleep deprivation on operative outcomes.

Another weakness is that this study does not take into account SD surgeons who might have postponed elective cases because they didn't feel well or were too tired to operate. This strategy may have been employed, though none of our coauthors could recall a specific instance of this being done. Obviously, we believed that this approach is one that should be decided by specific circumstances rather than by laws or regulations.

Why and when an SD surgeon should do an elective case is another major question. Typically, the case may have been scheduled in advance and the patient has made plans. Likely the surgeon has bonded with the patient preoperatively. Finally, the surgeon may be the only one in the area with the skills to do the procedure.

In summary, we believe this is the first data of any sort looking at the effect of sleep deprivation on trained surgeons. We found that sleep deprivation of attending surgeons had no effect on operative outcomes in cardiac operations. We stress that we do not believe this supports the notion that sleep is not important, nor do we believe that it is permissible for a severely fatigued surgeon to operate. Our opinion is that this study suggests the operative skills of a surgeon are unchanged the day after he has been up the night before operating. These data do not necessarily support work hour reforms based on other studies that suggest acute sleep deprivation leads to medical errors.

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DISCUSSION

DR CRAIG R. SMITH (New York, NY): We have just heard that sleep deprivation had no impact on performance in trained surgeons. Critics will quibble with the retrospective nature of the study, and with the soft definition of sleep deprivation. They will also suggest that the outcomes measures used can't detect subtle differences in performance, and completely neglect the impact on other domains of the surgeon's life. Valid points, but to put this in context, let's review why this discussion is suddenly so relevant.

What drove the ACGME to action on resident hours was a petition to OSHA requesting federal regulation, summarized on the first two slides. On the surface, it would seem to be authoritative. A closer look reveals that there were 54 citations, less than half, from peer-reviewed journals, only a handful from major journals, and almost half of these were editorials. The majority of the references, which I have listed as "miscellaneous," came from a variety of soft sources, including the news and entertainment media and various oral statements. And what is the largest single source? A third-year surgery resident at Hopkins whose performance on ABC Nightline was memorialized in three paragraphs. With this kind of scholarship in evidence, the presentation today suddenly becomes much more significant.

The vast majority of peer-reviewed articles came from anesthesia, emergency medicine, internal medicine, and pediatrics. On the non-peer-reviewed side, much time was spent on analogies between medicine and activities like long-distance trucking. To see where I am going with this discussion, I need to introduce the concept of a vigilance task. This behavioral psychology concept was a byproduct of new military technology in World War II. The original studies were intended to model the radar screens used to detect submarines from aircraft. In all subjects, the ability to detect positive signals showed a decrement after 30 minutes, reversible with any of three interventions, the first two (stimulant drugs, rest periods) are somewhat impractical. "Knowledge of results" means positive or negative feedback, and is nothing more than an easily applied psychological motivator.

Where does sleep deprivation come into the picture? Fast-forward through 35 years of vigilance research to a study of college students subjected to 72 hours of complete sleep deprivation and tested against a vigilance task of the radar screen type, with and without incentives. In the control group, performance declined rapidly without incentives, as Mackworth would predict. In the motivated group, performance declined only after 36 hours of complete sleep deprivation. And there was a very interesting bonus observation: Subjects were allowed to play a competitive computer game, of the Space Invaders type, to unwind after testing sessions. Scores on the game increased steadily throughout the testing period and were invariably highest on the last day after 72 hours of complete sleep deprivation. The lesson for us is that sleep deprivation is just another task variable. Its impact may depend more on the task and its incentives than on the number of hours.

The authors today bravely raise the question, are surgeons different from non-surgeon doctors? I will suggest to you that the specialties authoring the OSHA polemic are dominated by vigilance tasks. These are the doctors that have to watch the radar screen while we get to sink the submarine! This fact colors the way these specialities view the world, and in that world, analogies to things like long-distance trucking begin to make sense, and hours restrictions may be more relevant. Although much of what we do in surgery is inherently compelling, we would be missing the point to forget that surgery also contains vigilance tasks.

Ideally what we should do is match the working conditions to the task at hand. If rest is important to a particular task, and appropriate incentives are already in place, then we should assure that the doctor is rested. If enforcing regimented rest is difficult, we should consider adjusting other working conditions. I'll give a very simple example: consider providing a limousine service for tired physicians. And why should we do that? There are five long paragraphs in the OSHA polemic devoted to motor vehicle accidents in sleep-deprived residents. A car service might be simpler and cheaper than enforcing hours restrictions. It might even be more effective.

Finally, whatever the task, and whatever the working conditions, we should not be embarrassed to point out that sleep is only one variable, and the right kind of motivation easily compensates. Coming back to today's presentation, one way to interpret the results is to say that some combination of incentives overwhelmed any effect of sleep deprivation.

That concludes the sermon. I do have one question for the authors. Is it possible that their study design concentrated the busiest surgeons in the sleep-deprived group, and might they also be the best surgeons?

DR ROSS UNGERLEIDER (Portland, OR): This is an important study, and it is important because of the work hours issue that we all now confront and wrestle with.

I would like to point out that there has been considerable work on this topic. Bud Baldwin, who is the scholar-in-residence at the ACGME and who is an authority on this topic, has actually been on the surgeon's side, and he points out the distinction between work hours and sleep hours, and I think it is important for us, because the big difference is that future studies probably should focus on this distinction. The work hours limitation is Procrustean and I think it needs to be challenged. There is, however, abundant data on sleep deprivation, and although Craig presented some data, there are so much data available about what happens to humans with sleep deprivation. Inadequate sleep in any of us will result in judgment errors and abnormal behaviors, and I think we as CT surgeons have to be careful about the abnormal behaviors! And this has been well proven. So that true sleep deprivation will affect outcomes in surgery, and we need to be careful, I believe, not to suggest that we don't need sleep. There are, however, some individuals who do need less sleep than others, but we all need sleep. We all need REM sleep to reorder our brains.

And so I have these questions for you and perhaps a suggestion. First of all, what really constitutes sleep deprivation and how do we measure it? Were your surgeons really sleep-deprived? The database, as far as I can understand it, doesn't say anything about sleep. It only says things about work hours. And so I wonder if you can review your data in terms of work hours as opposed to sleep hours, since we really don't know much about the sleep of your surgeons, and the issue that we confront is one about work hours.

It is important for us to evaluate our ability to work and perhaps not dispute the well-known data that we need sleep. This would be a much more helpful "spin" on your data. If we acknowledge that sleep is important and look at data regarding work hours, we may be better able to construct what our futures as CT surgeons would look like. I wonder if you could rephrase your comments and your paper's conclusions with respect to work hours?

Thanks for having the courage to stand up there and present this paper.

DR ELLMAN: Dr Smith and Dr Ungerleider, thanks for your comments. To answer the first question regarding potential confounding factors one might have with busier surgeons, there were about 10 surgeons that were involved over this nine-year period, and some were busier than others. It seemed like the proportion of sleep deprivation cases was appropriate for each one of those surgeons. It was not our goal to try and look at individual surgeon performances. We felt that we needed to put all the data together and accept the fact that there would be some people that would have better results than others.

We are not trying to assert that surgeons don't need sleep. In fact, what we are trying to assert is the idea that surgeons should not have mandatory restrictions on their work hours. A part of the process of becoming a trained surgeon is realizing your limits and knowing when you have to sleep. Now, some people would obviously argue that self-restriction like that wouldn't necessarily work. Our attempt in this study was to at least demonstrate that sleep deprivation didn't lead to medical errors.

In terms of the sleep hours, it is literally impossible in a retrospective study to actually tell how much sleep these surgeons had over this time period. With our guidelines, we felt that we limited it in such a way that the only possible amount of sleep that they could have had was no greater than four hours. Many authors suggest that less than 5 hours of sleep constitutes sleep deprivation, and this was the definition we used. Moreover, we designed our study based on the Accreditation Council for Graduate Medical Education work-hour guidelines that essentially forbid operating the day after a night's call.

With regards to looking back over these data as a means to assess work hours rather than sleep, I think that would bring in even more problems and confounding factors than we already have. Objectively, we only really knew when the surgeon was in the operating room, and thus used these data as the main determinants for sleep deprivation in our study. Future studies regarding work hours would be very helpful, but would most likely require a prospective study design. Again, I appreciate your comments.