OBSTETRICS

Sleep deprivation: implications for obstetric practice in the United States

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Recent advances in basic science have expanded our understanding of the function of sleep and of the effects of sleep deprivation on human cognitive and psychomotor performance. In addition, a growing volume of data documents potential detrimental effects of sleep deprivation on medical practice. Such data have special implications for a specialty in which sleep deprivation is sometimes the norm. A review of this evidence suggests the pressing need for a reassessment of individual and small group obstetric practice, particularly as it relates to labor and delivery care; the current model of care in which each woman is delivered by the same provider who delivers prenatal care is generally not tenable in a culture increasingly focused on patient safety.

Key words: patient safety, quality of care, sleep deprivation

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"Sleep that knits up the ravell'd sleave of care. . .balm of hurt minds, great nature's second course." [1]

Sleep and sleep deprivation are topics that are receiving increased attention both in the scientific and lay press. These topics are of unique importance to the practicing obstetrician, who often gets far too little opportunity to "enjoy the honey-heavy dew of slumber."[2] Disasters officially linked to workplace sleep deprivation include those involving the *Exxon Valdez*, Three Mile Island, Bhopal, and the space shuttle *Challenger*.[3] On a less dramatic but more important scale, the National Highway Traffic Safety Administration estimates that roughly 100,000 traffic accidents and 1500 fatalities annually in the United States are linked to drowsy driving.[3] Sleep deprivation adds $16 billion annually to health care costs and results in almost $50 billion of lost productivity.[4,5] This review will briefly summarize our current understanding of the phenomenon of sleep itself, examine the known effects of sleep deprivation on human health and performance, and explore the implications of these facts for the safe practice of obstetrics.

The enigma of sleep

Sleep is defined as a state of immobility with greatly reduced responsiveness, distinguished from coma or anesthesia by its rapid reversibility.[6] Sleep is a vital part of existence for most mammals; rats deprived of sleep die sooner than those deprived of food.[6] However, despite the obvious importance of sleep to human physical, emotional, and mental function, the physiologic basis for our need to sleep remains incompletely understood.[6,7]

Although body activity is markedly reduced during sleep, the brain remains highly active, especially during rapid eye movement (REM) sleep. Normal human sleep consists of 2 fundamental components: REM and nonrapid eye movement (NREM) sleep. REM sleep is generated by the pons and midbrain, and characterized by electroencephalographic high frequency beta waves, similar to those seen during wakefulness.[6] Cerebral cortical activity is high during REM sleep; although dreaming may occur in all sleep phases, the most active dreaming occurs during REM sleep.[8,9] In addition, postural muscle tone is markedly diminished during this sleep phase.[6] In contrast, NREM sleep is induced by activation of groups of neurons in the preoptic and basal forebrain regions; brainstem and cortical activity are depressed in NREM sleep.[6] This sleep phase is characterized by high amplitude, low frequency theta waves, and, as non-REM sleep progresses, an increase in very low frequency delta waves.[10]

Normal sleep consists of gradual progression through 4 stages of NREM sleep, each with an increasing proportion of delta waves, followed by a process of retracing of these stages in which stage I is replaced by REM sleep.[10,11] The average individual completes 4-5 complete cycles per night, with an average cycle duration of about 90 minutes. However, the duration of REM sleep episodes progressively increases throughout the sleep period and is maximal at the time of usual awakening. Initial REM periods may last only 5-10 minutes; later REM episodes may last up to 25 minutes.[6] By the end of a normal night's sleep, there may be virtually no demonstrable NREM activity.

A system of self-reinforcing mutual inhibition between awakening and sleep-producing neural circuits (so called "flip-flop" switches) results in discrete sleep and wake states with very sharp transitions in which the alternative state is turned off abruptly.[9] Such physiology may be adaptively advantageous by minimizing the time spent in a transition state between sleep and wakefulness, but it also has the dangerous potential for sudden loss of consciousness without warning in sleep-deprived individuals.[9] Multiple substances appear to play a role in both activation and inhibition of various sleep/wake states, including cytokines, insulin, nitric oxide, aden-

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osine, and a group of neuropeptides called orexins.[6,9]

Most theories suggest a role for energy conservation and nervous system recuperation during NREM sleep.[6] In contrast, REM sleep appears to be involved in localized recuperative processes, memory consolidation, and emotional regulation.[6,11,12] After sleep deprivation, NREM sleep is repleted first and animals that are awakened from NREM sleep have poor sensory-motor function compared with those awakened from REM sleep.[6] Humans exhibit maximal total sleep and REM sleep at birth, decreasing to adult levels as maturity approaches. This pattern is seen in all terrestrial mammals; interestingly, the opposite pattern is observed in cetaceans.[6]

Sleep regulation appears to involve both a homeostatic mechanism (in which sleep is induced caused by a period of wakefulness) and an innate, 24-hour circadian mechanism that functions independently of the physiologic need to sleep.[9] Homeostatic sleep (ie, the need to sleep) appears to be modulated at least in part by the central accumulation of adenosine, the metabolic end product resulting from central nervous system glycogen depletion and ATP degradation. On the other hand, circadian sleep patterns are driven by neurons in the suprachiasmatic nucleus, cells that continue to be activated in a 24-hour cycle, which persists even in cell culture.[9,13] Daily input from light impacting the retina during daylight hours and from pineal melatonin during darkness keeps this intrinsic 24-hour clock synchronized with the external day-night cycle.[9] This intrinsic cycle is clearly of physiologic importance, but is disrupted in night-shift workers and by nighttime sleep disruption and deprivation.

Sleep deprivation

Sleep deprivation decreases frontal lobe metabolic activity, particularly in the anterior cingulated cortex.[14] From a clinical standpoint, the detrimental effects of both acute and chronic sleep deprivation on physical and particularly on cognitive performance are well documented. In sleep-deprived individuals, cognitive skills are affected more than psychomotor skills.[15-21] Pure psychomotor skills such as ring-transfer exercises or suturing are minimally affected by sleep deprivation. However, in tasks requiring both cognitive and psychomotor performance (including most surgical skills), sleep deprivation also significantly impacts the latter.[21] In a study of surgical resident skills, night call increased cognitive errors by 32% across a broad range of exercises.[21] In contrast, physical strength is unaffected by even prolonged sleep deprivation.[22]

Less than 5 hours of sleep in 24 hours has also been shown to have a significant impact on proficiency of resident physicians.[16] Sleep deprivation in general surgical residents has been associated with impairment in surgical performance and an increase in surgical complication rates.[23-26] The same has not been shown for patients undergoing cesarean delivery at night.[27] However, in analyzing such comparative studies it is critical to realize that differential performance in well-rested vs sleep-deprived cohorts may be greater than in comparative groups in which "control" subjects are also chronically sleep deprived. Indeed, in 1 review of 13 studies of sleep deprivation and surgical resident performance, none included a control group with normal sleep in the week before the study.[24] More consistent adverse effects are found in verbal processing and complex problem-solving skills and errors in interpretation of imaging studies.[21,24,28] Sleep deprivation has been shown to negatively impact the ability of physicians to accurately interpret an electrocardiogram, a finding with potential special significance for both obstetric nurses and physicians who interpret electronic fetal heart rate monitor tracings.[29,30] Of particular concern in this regard is the finding that errors in the interpretation of diagnostic tests with sleep deprivation are overwhelmingly false-normal interpretations.[28] Sleep deprivation impairs both medical error detection and error remediation, suggesting a concern for the ability of the sleep-deprived obstetrician to effectively function as the obstetric team leader.[14,31] Sleep deprivation also contributes to the inability to avoid making the same error again even after it has been recognized once, and perseverance in solutions that do not work, thus producing a vicious cycle leading to additional errors.[31,32]

Of equal interest are studies of sleep deprivation conducted in military personnel. In 1 study, the ability of highly trained, sleep-deprived soldiers to acquire a simulated target and deliver rapid, accurate fire was unimpaired. Unfortunately, the ability of these individuals to consistently distinguish enemy from friendly targets was lost, again highlighting the preferential loss of cognitive, as opposed to psychomotor skills.[22]

These findings have important implications for those involved in clinical decision making, particularly in obstetrics, in which the unique requirements of managing 2 patients with differing physiologies simultaneously highlights the need for sound judgment and decisiveness in the face of rapidly changing conditions. Sleep-deprived individuals take longer time to make a decision when faced with the need to do so and lose the ability to adapt to changing circumstances. The ability to take independent initiative is also impaired.[22] It is possible that these factors, coupled with the prevalence of false-normal test interpretation by sleep-deprived physicians contribute to the frequency with which failure to recognize and respond to an abnormal fetal heart rate tracing results in obstetric litigation.[33]

Some of the most compelling evidence regarding the detrimental effects of sleep deprivation derives from comparisons between the effects of acute sleep deprivation and those of ethanol intoxication on cognitive performance.[34,35] As outlined in the Table, even 17 hours of continued wakefulness decreased performance similar to that seen with a blood alcohol concentration of 0.05%.[36,37] Sleep deprivation of 24 hours results in cognitive performance impairment equivalent to a serum alcohol concentration of 0.10%, a level considered functionally intoxicated in all the US states.[38,39] These facts suggest the need for a serious self-assessment of practice patterns for many obstetricians.

TABLE
Correlation between cognitive performance with sleep deprivation and ethanol intoxication[35-39]

Sleep deprivation (h)	Functional serum ethanol level (%)
17-19	0.05
19-21	0.08
24	0.10

Clark. Sleep deprivation. Am J Obstet Gynecol 2009.

Performance is worse if sleep is disrupted in the first third of the night, consistent with the greater importance in this respect of NREM sleep.[40] Brief (30-minute) naps are sufficient to slow, but not halt the progressive degradation of cognitive performance seen with ongoing sleep deprivation.[22] Contrary to popular belief, a healthy adult cannot acclimate to chronic sleep deprivation, and a "sleep debt" inevitably ensues. Thus, even a seasoned clinician cannot "get used" to sleep deprivation in terms of maintenance of cognitive and combined cognitive-psychomotor function. Rather, the effects of sleep deprivation are invariably cumulative.[6,24] After significant sleep deprivation, recovery of performance is not complete until 3 consecutive nights of normal (8 hours) sleep.[41]

Unfortunately, the detrimental effects of physician sleep deprivation do not end at the hospital door; automobile accidents are also significantly increased in postcall resident physicians.[34,38,39] In the rat model, sleep deprivation is accompanied by increased oxidative stress and membrane disruption in the hippocampus and subcortical brain tissue.[6] Sleep deprivation has also been associated with obesity, although a cause and effect relationship between the 2 is not unequivocally established.[42] Elevation of C-reactive protein, a strong predictor of cardiovascular risk, is seen in individuals who lose only small amounts of sleep on a daily basis, and the proinflammatory cytokines interleukin 6 and tumor necrosis factor-alpha are secreted in increased amounts with just modest sleep deprivation in humans.[9,43,44] Further, disruption of circadian rhythm in night-shift workers has been linked to an increased risk of breast cancer, although this relationship remains disputed.[45] In pregnant women, sleep disruption has been associated with longer labors and an increased rate of cesarean delivery.[46] Thus, sleep deprivation is hazardous both to patients and to their health care providers.

Regulation and the future

In response to these and similar, job-specific findings, the government has instituted mandatory work/rest regulations governing industries such as commercial aviation and commercial trucking.[41,47] Despite such regulatory activity and an enviable safety record, the National Transportation Safety Board has linked fatigue to 10 commercial aviation accidents since 1993, killing 260 people. Indeed, pilot unions see fatigue as 1 of the top safety concerns in their industry, despite current regulations.[47] Mandatory regulation of resident work hours began in New York State in 1989, prompted by the case of Libby Zion, a young woman whose death was initially linked to extended work hours and fatigue of resident staff caring for her.[24] This was followed by the imposition of current national resident work hour restrictions. Although such regulations have improved the quality of life of resident physicians, no data exist to document that medical errors have decreased or that patient outcomes have improved as a result of these regulations.[48,49] Indeed, the possibility exists of an overall detrimental effect of these regulations on patient care in some busy facilities, as services left understaffed by mandatory resident departures from the hospital leave the remaining staff with unmanageable patient loads.[49] However, such problems are rooted in deep seated faults within the health care delivery system; their solution probably does not lie with resumption of care by sleep-deprived resident physicians.

The average practicing obstetrician gynecologist works hours significantly in excess of those allowed for younger resident physicians.[50,51] In addition, obstetrics remains the only medical specialty in which the attending physician is routinely expected to both manage a critical and potentially life-threatening process for 2 patients during labor and at the same time seeing office patients or performing elective surgery. Although some might see this as part of a general devaluation of women and children's health care, patient expectations are at least as much to blame. Given the realities of clinical practice, it is simply impossible for every woman to be delivered by the obstetrician of her choice, without accepting the occurrence of sleep deprivation-induced cognitive impairment of that health care provider. In a recent editorial commenting on sleep deprivation in medicine, an independent government safety consultant observed, "work shifts of 32 hours with 2-3 hours sleep are egregiously beyond current hours-of-service limits, yet they can go undetected by the present enforcement system."[38] Indeed, a recent report from the Joint Commission concluded, "The weight of evidence strongly suggests that extended-duration work shifts significantly increase fatigue and impair performance and safety. From the standpoint of both providers and patients, the hours routinely worked by health care providers in the United States are unsafe. To reduce the unacceptably high rate of preventable fatigue-related medical errors and injuries among health care workers, the United States must establish and enforce safe work-hour limits."[52]

To date, our profession has demonstrated little willingness to implement self-regulation in this respect. Thus, government imposed regulation of physician work hours seems increasingly likely in a health care system that appears to be invariably headed toward increasing federal control. Given the regulatory track record of the US government, it seems likely that coming physician work hour restrictions will be both more intrusive and less effective than self-imposed regulation formulated by those most qualified to make such judgments, namely, the medical community itself. In obstetrics, this would likely require the

widespread adoption of a hospitalist model of care for laboring patients in a reduced number of facilities, with exceptions being made for critical access, rural hospitals. Such a change would require a drastic paradigm shift involving physicians, patients, and third-party payers. However, the above considerations suggest that the current system of inpatient obstetric care is not tenable in the long run. If we, as a specialty continue to ignore the problem, we will have no cause to complain when we find ourselves on the receiving end of government regulations that do not. ■

REFERENCES

1. Shakespeare W. Macbeth. Act 2, scene 2, lines 46-51.

2. Shakespeare W. Julius Caesar. Act 2, scene 1, lines 248-251.

3. Mahowald MW, Schenck CH. Insights from studying human sleep disorders. Nature 2005;437:1279-85.

4. Report of the National Commission of Sleep Disorders Research. DHHS publication number 92. Washington, DC: U.S. Government Printing Office; 1992.

5. Overview of the findings of the National Commission on Sleep Disorders Research 1992. Available at: http://www.stanford.edu/~dement/overview-ncsdr.html. Accessed Sept. 19, 2008.

6. Siegel JM. Clues to the function of mammalian sleep. Nature 2005;437:1264-71.

7. Rechtschaffen A. Current perspectives on the function of sleep. Perspect Biol Med 1998; 41:351-90.

8. Nielsen TA, Stenstrom P. What are the memory sources of dreaming? Nature 2005; 437:1286-9.

9. Saper CB, Scammell TE, Lu J. Hypothalamic regulation of sleep and circadian rhythms. Nature 2005;437:1257-62.

10. The stages of sleep. Available at: http://www.dreamviews.com/sleepstages.php. Accessed Sept. 19, 2008.

11. Hobson JA. Sleep is of the brain, by the brain and for the brain. Nature 2005; 437:1254-6.

12. Stickgold R. Sleep-dependent memory consolidation. Nature 2005;437:1272-8.

13. Reppert SM, Weaver DR. Coordination of circadian timing in mammals. Nature 2002; 418:935-41.

14. Hseih S, Cheng IC, Tsai LL. Immediate error correction process following sleep deprivation. J Sleep Res 2007;16:137-47.

15. Hart RP, Buchsbaum DG, Wade JB, et al. Effect of sleep deprivation on first year residents' response times, memory, and mood. J Med Educ 1987;62:940-2.

16. Denisco RA, Drummond JN, Gravenstein JS. The effect of fatigue on the performance of a simulated anesthetic monitoring task. J Clin Monit Comput 1987;3:22-4.

17. Weinger MB. Ancoli-Isreal S. Sleep deprivation and clinical performance. JAMA 2002; 287:955-7.

18. Pilcher JJ, Huffcutt AI. Effects of sleep deprivation on performance: a meta-analysis. Sleep 1996;19:318-26.

19. Grantcharov TP, Bardram L, Funch-Jensen P, et al. Laparoscopic performance after one night on call in a surgical department: prospective study. BMJ 2001;323:1222-3.

20. Taffinder NJ, McManus IC, Gul Y, et al. Effect of sleep deprivation on surgeons' dexterity on laparoscopy simulator. Lancet 1999;352: 1191.

21. Kahol K, Leyba MJ, Deka M, et al. Effect of fatigue on psychomotor and cognitive skills. Am J Surg 2008;195:195-204.

22. Belenky G. Sleep, sleep deprivation and human performance in continuous operations. Available at: www.usafa.edu/isme/JSCOPE97/Belenky97/Belenky97.htm. Accessed Sept. 1, 2008.

23. Goldman LI, McDonough MT, Rosemond GP. Stresses affecting surgical performance and learning. J Surg Res 1972;12:83-6.

24. Friedman WA. Resident duty hours in American Neurosurgery. Neurosurgery 2004; 54:925-33.

25. Haynes DF, Schwedler M, Dyslin DC, et al. Are post-operative complications related to resident sleep deprivation? South Med 1995; 88:283-9.

26. Henriques JP, Haaskijk AP, Zijlstra F. Outcome of primary angioplasty for acute myocardial infarction during routine duty hours versus during off hours. J Am Coll Cardiol 2003; 41:2138-42.

27. Bailit JL, Landon MB, Thom E, et al. The MFM Cesarean Registry: impact of time of day on cesarean complications. Am J Obstet Gynecol 2006;195:1132-7.

28. Mann FA, Danz PL. The night-stalker effect: quality improvement with a dedicated night-call rotation. Invest Radiol 1993;28:92-6.

29. Friedman RC, Bigger JT, Kornfeld DS. The intern and sleep loss. N Engl J Med 1971; 285:201-3.

30. Lingenfelder T, Kaschel R. Weber A, et al. Young hospital doctors and night duty: their task specific cognitive and emotional condition. Med Educ 1994;28:566-72.

31. Tsai LL, Young HY, Hseih S, et al. Impairment of error monitoring following sleep deprivation. Sleep 2005;28:707-13.

32. Nelson CS, Dell'Angela K, Jellish WS, et al. Resident performance before and after night call as evaluated by an indicator creative thought. J Am Osteopath Assoc 1995; 95:600-3.

33. Clark SL, Belfort MA, Dildy GA, et al. Reducing obstetric litigation through alterations in practice patterns. Obstet Gynecol 2008; 112:1279-83.

34. Barger LK, Cade BE, Ayas N, et al. Extended work shifts and the risk of motor vehicle crashes among interns. N Eng J Med 2005; 352:125-34.

35. Arendt JT, Owens J, Crouch M, et al. Neurobehavioral performance of residents after heavy night call vs. after alcohol ingestion. JAMA 2005;294;1025-33.

36. Dawson D, Reid K. Fatigue, alcohol and performance impairment. Nature 1997;388: 235-7.

37. Williamson AM, Feyer AM. Moderate sleep deprivation produces impairment in cognitive and motor performance equivalent to legally prescribed levels of alcohol intoxication. Occup Environ Med 2000;57:649-55.

38. Arendt JT, Wilde GJS, Munt PW, et al. How do prolonged wakefulness and alcohol compare in the decrements they produce on a simulated driving task? Accid Anal Prev 2001;33:337-44.

39. Wylie DC. Sleep, science and policy change. N Engl J Med 2005;352:196-7.

40. Murray D, Dodds C. The effect of sleep disruption on performance of anaesthetists— a pilot study. Anaesthesia 2003;58:520-5.

41. Effects of sleep schedule on commercial motor vehicle driver performance. Department of Transportation report number DOT-MC-00-133. Available at: www.fmca.dot.gov/documents/highlights.pdf. Accessed Sept. 19, 2008.

42. Pearson H. Sleep it off. Nature 2006;443: 261-3.

43. Meyer-Ewert HK, Ridker PM, Rifai N, et al. Effect of sleep loss on C-reactive protein, an inflammatory marker of cardiovascular risk. J Am Coll Cardiol 2004;43:678-83.

44. Vgontzas AN, Zoumakis E, Bixler EO, et al. Adverse effects of modest sleep restriction on sleepiness, performance, and inflammatory cytokines. J Clin Endocrinol Metab 2004;89: 2119-26.

45. Davis S, Mirick DK, Stevens RG. Night shift work, light at night, and risk of breast cancer. J Natl Cancer Inst 2001;93:1557-62.

46. Lee KA, Gay CL. Sleep in late pregnancy predicts length of labor and type of delivery. Am J Obstet Gynecol 2004;191:2041-6.

47. Levin A, Heath B. Fatigue key to air crew errors. USA Today, Nov. 8, 2007.

48. Kelly A, Marks F, Westhoff C, et al. The effect of New York State restrictions on resident work hours. Obstet Gynecol 1991;78:468-73.

49. Barden CB, Specht MC, McCarter MD, et al. Effects of limited work hours on surgical training. J Am Coll Surg 2002;195:531-8.

50. Promecene PA, Schneider KM, Monga M. Work hours for practicing obstetrician-gynecologists: the reality of life after residency. Am J Obstet Gynecol 2003;189:631-3.

51. Schuaberger CW, Gribble RK, Rooney BL. On call: a survey of Wisconsin obstetric groups. Am J Obstet Gynecol 2007;196:39.e1-4.

52. Lockley SW, Barger LK, Ayas RT, et al. Effects of health care provider work hours and sleep deprivation on safety and performance. Jt Comm J Qual Patient Saf 2007;33(suppl):7-18.