

# Acute Sleep Deprivation in the Thoracic Surgical Resident Does Not Affect Operative Outcomes

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**Background.** There is an increasing trend toward work hour restrictions for doctors world wide. These reforms have been inspired, in part, by the assertion by some that the fatigued physician is more prone to making errors. Interestingly, there is very little in the way of objective data with regard to the effects of sleep deprivation on patient outcomes. We have recently studied this in attending surgeons. The present study focused on thoracic surgical residents. Our hypothesis was that acute sleep deprivation would not lead to an increase in operative times or complications.

**Methods.** A retrospective review of all cases performed by thoracic surgical residents at the University of Virginia from January 1994 to March of 2004 was done. Complication rates of cases performed by "sleep deprived" (SD) residents were compared with cases done when the residents were "not sleep deprived" (NSD). A resident was deemed sleep deprived if he or she performed a case the previous evening that started between

10 PM and 5 AM or ended between the hours of 11 PM and 7:30 AM.

**Results.** A total of 7,323 cases were recorded in the STS database over the 10-year period examined. Two hundred and twenty-nine of these cases (3%) were performed by SD residents. Mortality rates for coronary artery bypass operations showed no significant differences (2.1% [SD = 3 of 141 patients] vs 3.1% (NSD = 143 of 4452 patients),  $p = 0.63$ ). A comparison of operative, neurologic, renal, infectious, and pulmonary complications as well as cardiopulmonary bypass times, cross-clamp times, the use of blood products, and length of stay also demonstrated no significant differences between groups.

**Conclusions.** Acute sleep deprivation in thoracic surgical residents does not affect operative efficiency, morbidity, or mortality in cardiac surgical operations.

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The surgical resident is stereotypically known for working long, hard hours. However, over the last few years a number of steps have been made with the thought that hours were too long and hard, and potentially were detrimental to both the residents and the patients. Now, all Accreditation Council for Graduate Medical Education (ACGME) accredited surgical programs are faced with the challenge of negotiating the 80 hour work week. Moreover, the Patient and Physician Safety and Protection Act of 2003 [1, 2] is a bill currently making its way through Congress that would make resident work hour restrictions a federal law. Resident work hour reforms first came to fruition in New York after 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 is actually very little data with regard to the effects of sleep deprivation on actual patient errors [5]. One study done thus far on surgical residents [6] suggests sleep depriva-

tion does not lead to an increase in operative complications. We have recently published a study [7] looking at the effects of sleep deprivation on attending physicians, given the fact that this had not been looked at previously. We found that sleep deprivation in attending physicians does not affect cardiac surgical outcomes. We have found no published studies that have looked at outcomes after acute sleep deprivation in the cardiac surgical resident. Our hypothesis, given our previous data, was that sleep deprivation in cardiac surgical residents would also not adversely affect patient outcomes.

## Patients and Methods

### Patient Selection

A retrospective review of all cases performed by thoracic surgical residents at the University of Virginia from January 1994 to March 2004 was done. It should be noted that Institutional Review Board approval was obtained for this study. We wanted to establish which cases were done by sleep-deprived (SD) thoracic surgical residents and compare complication rates of SD cases with those cases that were done by surgical residents who were not sleep deprived (NSD). First we had to establish whether the resident was sleep deprived. We used the same

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Table 1. Patient Population

Category	SD (n = 229)	NSD (n = 7,094)	p Value
Sex (male)	0.67	0.7	0.37
Age	64.1 ± 0.8	63.4 ± 0.1	0.37
Asian	0 (0.0%)	9 (0.1%)	0.59
Black	16 (7.0%)	425 (6.0%)	0.53
Caucasian	209 (91.3%)	6552 (92.4%)	0.54
Hispanic	2 (0.9%)	24 (0.3%)	0.18
Other race	2 (0.9%)	70 (1.0%)	0.84
CABG	144 (62.9%)	4585 (64.8%)	0.56
Valve	36 (15.7%)	934 (13.2%)	0.26
CABG + valve	14 (6.1%)	521 (7.3%)	0.47
Other	35 (15.3%)	1044 (14.7%)	0.81

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

criteria we previously used in examining the effects of sleep deprivation on attending cardiac surgeons [7]. A thoracic surgery resident was designated as sleep deprived if he performed a case that started between 10 PM and 5 AM, or ended a case between the hours of 11 PM and 7:30 AM. If the resident 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. Since January of 1994 we have prospectively recorded detailed data as outlined by the Society of Thoracic Surgeons (STS) regarding complication and mortality rates for all cardiac procedures. Thus, noncardiac thoracic cases were not examined in this study as they are not logged in the STS database. 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. Further-

more 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, as well as operative, neurologic, renal, infectious, and pulmonary complications, which were prospectively recorded based on the STS guidelines and are recorded 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 ischemic attack, or continuous coma for greater 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 greater than 24 hours postoperatively, had a pulmonary embolism, pneumonia, or a pleural effusion.

#### Statistics

Results are summarized as mean ± standard error of the mean, or n (%). Univariate analyses to include the  $\chi^2$  test, the Fisher exact test, and Student's *t* test were used to compare variables with regard to sleep deprivation. The data were also analyzed using a forward and backward logistic regression analysis to determine whether the possible predictors of mortality were correlated with each other as well as with mortality.

## Results

### Patient Population and Demographics

A total of 7,323 adult cardiac cases were recorded in the STS database over the 10-year period examined. Of all cases, 229 (3%) were performed by SD residents, compared with 7,094 (97%) cases performed by NSD residents (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 64.1 ± 0.8 in the SD group and 63.4 ± 0.1 in the NSD group. The

Table 2. Perioperative Data and Complications

Category	SD (n = 229)	NSD (n = 7,094)	p Value
Cardiopulmonary bypass time	106.5 ± 3.6	107.4 ± 0.7	0.92
Aortic cross-clamp time	74.4 ± 2.4	74.1 ± 0.55	0.83
Blood products (yes or no)	49%	49%	0.91
Operation to discharge (days)	7.5 ± 0.55	7.7 ± 0.13	0.83
Operative complications	15 (6.6%)	541 (7.6%)	0.76
Neurologic complications	35 (15.3%)	840 (11.8%)	0.163
Renal complications	14 (6.1%)	502 (7%)	0.71
Pulmonary complications	39 (17%)	1342 (18.9%)	0.66
Infectious complications	15 (7%)	467 (6.6%)	0.81

NSD = not sleep derived; SD = sleep derived.

Table 3. Mortality Rates

Operation	SD (n = 229)	NSD (n = 7,094)	p Value
CABG	3/141 (2.1%)	143/4,452 (3.1%)	0.629
Valve	0/36 (0%)	44/890 (4.7%)	0.403
CABG + valve	2/12 (14.3%)	38/483 (7.3%)	0.28
Other	7/28 (20%)	98/946 (9.4%)	0.07

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

predominant race was Caucasian, with 91.3% in the SD group and 92.4% in the NSD group. Males were the predominant sex in each group as well, with 67% in the SD group and 70% in the NSD group ( $p = 0.37$ ). A majority of the operations performed were CABGs, with 62.9% in the SD group and 64.8% in the NSD group. Valve, CABG + valve, and other operations were also of a similar proportion in each group.

#### End Points

Perioperatively, there appear to be no differences in a number of other important variables (Table 2). Cardiopulmonary bypass times and aortic cross-clamp times were similar in both groups, with approximately 107 minutes of bypass time and 74 minutes of cross-clamp time, respectively, in each group. In both groups, 49% of the patients required the use of blood products at some point during their hospital stay ( $p = 0.91$ ). There were 15 patients (6.6%) in the SD group with operative complications, and 541 (7.6%) in the NSD group ( $p = 0.76$ ). Univariate analysis of all neurologic, renal, pulmonary, and infectious complications also failed to demonstrate any significant differences between groups. Likewise, length of hospital stay after operation was not different.

Unadjusted mortality rates for CABG, valve, CABG + valve, and other mortality rates were examined (Table 3). There were no significant differences when SD mortality

rates were compared with NSD mortality rates. There were 3 deaths for CABG only in the SD group (2.1%) and 143 in the NSD group (3.1%) ( $p = 0.629$ ). Likewise, a comparison of valve, CABG + valve, and other operations all demonstrated similar respective mortality rates.

A forward and backward logistic regression analysis was performed to determine whether sleep deprivation alone was a risk factor for mortality. This correlation analysis (Table 4) demonstrated that the type of operation that was done, any complication, sex (females having a higher mortality), age, and length of stay all were significantly associated with mortality in the analysis. However, sleep deprivation was not associated with increased mortality in this multivariate analysis.

#### Comment

Recent years have seen sweeping reforms in resident work hours. What is surprising is the fact that these reforms have occurred without much good evidence that long hours lead to mistakes and sub par care. Reforms were made based on the assumption that long hours predisposed doctors to sleep deprivation, and therefore would make them more prone to harming others and/or themselves. There are very little data regarding actual objective evidence to support the fact that sleep deprivation leads to medical errors. This, certainly, is a difficult subject to study given the overwhelming number of potential confounding factors. Perhaps because of this, so few studies have been done. We have previously demonstrated that sleep deprivation in attending surgeons does not lead to a higher mortality or number of complications [7]. Some critics of that study felt that perhaps the attendings were well-rested, given the fact that the study was done at a university program, and perhaps if we looked at the same data in the residents we would see different results. Using the same criteria we used in the original study on residents, we have found that acute

Table 4. Analysis of Mortality Risk Factors

Category	Death (n = 335)	No Death (n = 6,988)	p Value
CABG	146/335 (43.6%)	4,591/6,988 (62.7%)	< 0.001
Valve	45/335 (13.4%)	925/6,998 (13.2%)	0.91
CABG + valve	40/335 (11.9%)	496/6,998 (7.1%)	< 0.001
Other	38/335 (11.3%)	1,041/6,998 (14.2%)	0.73
Renal	147/335 (43.9%)	369/6,988 (5.3%)	< 0.001
Pulmonary	229/335 (68.4%)	1,152/6,988 (16.5%)	< 0.001
Operative complications	167/335 (49.9%)	398/6,988 (5.6%)	< 0.001
Neurologic	150/335 (44.8%)	725/6,988 (10.4%)	< 0.001
Infect	78/335 (23.3%)	404/6,988 (5.8%)	0.001
Sex (male)	188/335 (56.1%)	4,930/6,988 (70.5%)	< 0.001
Age	66.97 ± 0.70	63.2 ± 0.14	< 0.001
LOS	12.19 ± 0.88	7.49 ± 0.12	< 0.001
Sleep deprivation <sup>a</sup>	12/335 (3.1%)	217/6,998 (3.6)	0.62
Blood <sup>a</sup>	283/335 (84%)	3,314/6,998 (47.4%)	< 0.001

<sup>a</sup> Forwards and backwards logistic regression analysis found all but sleep deprivation and the use of blood products to be associated with mortality.

CABG = coronary artery bypass graft; LOS = length of stay.

sleep deprivation in the cardiac resident does not affect cardiac surgical outcomes. This study looks at the effects of sleep deprivation on cardiac surgical residents.

Interestingly, there were a smaller percentage of sleep-deprived cases performed by the residents compared with the attendings (3% vs 5%). There are a few possible explanations for this. One is that all of our cardiac surgical attendings also take vascular surgery call. Thus, a number of the cases that they did at night the day before they did their sleep-deprived cases were emergent vascular cases. Given this fact, cardiac surgical fellows probably simply do not do as many emergent night cases as the attendings. Another explanation may be that the cardiac fellows were postcall, and thus not operating the day after they have been on call.

Previously, people have examined the effects of sleep deprivation on cognition, dexterity, and mood in surgical residents. There is little consistency in the results. One study [8] demonstrated impairments in cognition as well as increased feelings of confusion and lower levels of confidence in sleep-deprived surgical residents after a weekend of call. Another study [9] of 42 surgical residents found increased subjective feelings of confusion, anger, and fatigue after sleep loss; however, there were no differences in cognitive function. Others [10, 11] have shown no effects on reading comprehension or psychomotor tests. Interestingly, one aspect of the testing called 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 [12] demonstrated decrements in sleep-deprived medical residents. It has been suggested that this discrepancy could be due to the fact that the surgical residents were all chronically sleep deprived, and thus the "rested" control group was underperforming as well [13]. But perhaps there is an element of self-selection; those who thought they could work when tired chose a career in surgery. In a recently published study by the Harvard Work Hours, Health and Safety Group, Landrigan and colleagues [14] examined the effects of reducing work hours of interns working in intensive care units on medical errors. Interestingly, while they found the interns committed fewer "errors" on the lighter work schedule, there was no difference in the number of preventable adverse events, which they state is a result of the fact that the study was not designed to assess the effect of the sleep schedule intervention on adverse events. Perhaps most analogous to our study, they found no difference in the number of procedural errors.

Two simulated laparoscopic studies [15, 16] found significantly more errors and longer time to perform tested skills on postcall mornings. These suggest sleep deprivation can indeed affect operative skills. However, there are no well-powered studies that demonstrate negative effects of sleep deprivation on operative efficiency in real-life operative cases. Perhaps incentive is an important factor, as a sleep-deprived resident may not have the same level of interest or attentiveness in a simulated situation when compared with a situation

involving a living patient. Interestingly, one nonmedical study [17] found that the effects of up to 36 hours of sleep deprivation can be overcome if the subject has an incentive for better performance. In our study the effects of sleep deprivation on operative efficiency can be indirectly assessed by looking at cross-clamp and perfusion times. There were no significant differences between the sleep-deprived and the nonsleep-deprived groups.

There is only one other study in the literature [6] that has looked at the effects of sleep deprivation on surgical outcomes. This study was different in design to ours, as it looked at residents who had been on call, versus those who had not. We took this one step further; in the subgroup of cardiac surgical fellows who were on call, we looked at those who we knew had been operating for a significant period of time during the night. The study compared the frequency of significant surgical complications for residents who had been on call the previous night to those who had not. They found there was no overall difference in complication rates after breaking down the operations into emergent and nonemergent operations.

There are several weaknesses of our study. This study was a retrospective study, and thus it carries with it the usual confounding factors involved with such studies. As we pointed out in our previous paper [7], 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, and probably never will, as it would be too difficult to gain institutional board approval for such a study. Most likely, institutional review board approval would be difficult to obtain for such a study given the fact that it would be deemed unethical to have a sleep-deprived surgeon operate on patients. Some might question our definition of being sleep deprived. In the discussion of our previous study, one critic felt it would be more important to look at work hours, rather than hours slept. We feel this is perhaps even more difficult to study, if one is interested on the effects of fatigue on operative performance, because there is really no way of knowing whether or not someone is sleeping or working when they are home. We were interested in examining the effects of acute sleep deprivation on operative performance, and thus the only real way we knew someone was sleep deprived was if they were in the operating room during a documented time frame. Moreover, 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 surgical residents, rather than at all surgical subspecialties. There may be a difference in the ability for cardiac surgical residents to deal with sleep deprivation compared with other surgical specialties. This clearly deserves more investigation. Critics of our previous paper also pointed out that we examined the effects of acute sleep deprivation, not chronic sleep deprivation. It should be noted, however, that a majority of the few studies on sleep deprivation that the ACGME has used to justify work hour restrictions examined the effects of acute sleep deprivation. Clearly, future studies should

examine the effects of chronic sleep deprivation on operative outcomes. And finally, given the fact that the many checks and balances built into the health system provide a safety net for errors, it is possible that errors committed by sleep-deprived residents did not result in an observable increase in adverse events.

In summary, this study looks at the effect of acute sleep deprivation on cardiac surgical residents. We found that sleep deprivation of cardiac surgical residents had no effect on operative outcomes. The authors would like to stress that we do not feel this supports the notion that sleep is not important, nor do we feel that it is permissible for a severely fatigued surgeon to operate. We feel this study suggests the operative skills of a cardiac surgical fellow 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 DARRYL S. WEIMAN** (Memphis, TN): It seems to me that you have a system where you have a safety net. In most cardiothoracic training programs such as yours or mine, the cases are done with the resident and an attending. The attending is either the surgeon or he is the first assistant, and in most training programs is the first assistant.

You seem to be looking at a situation where the resident might be tired but the attending might be okay and he won't let the resident do something bad.

In your previous study, the attending might have been tired but the resident might have been okay, so the resident wouldn't let the attending do anything bad. How many of these cases that you described were both the resident and the attending tired at the same time?

**DR ELLMAN:** Thank you. That is a great question. We did not specifically look at cases done where both the resident and the attending were post call. The idea of a safety net is an interesting concept with regards to medical errors in general. A recent paper published in the *New England Journal of Medicine* [14] found a higher rate of what they described as "errors" but no difference in the rate of adverse events. They suggest this may be due to the "safety net" of which you speak. I think it is important to note that in our institution the cardiac fellows do a significant portion of the operating at our hospital. Thus, the idea that errors could be prevented by a nonsleep-deprived attending is less plausible than it would be comparatively in a program

where the fellows are less involved in the key technical portions of the case.

**DR W. RANDOLPH CHITWOOD, JR** (Greenville, NC): Dr Ellman, I applaud you for these kinds of studies, and I know that Dr Kron has had a real interest in this, and with his role in surgical education I think this will be very important. There are always criticisms of these studies, they are retrospective, as the previous discussion brought up, it is a team sport, not an individual sport when you are doing heart surgery; you are working together.

Also, I think it is important to know that people have different energy levels. It depends on whether you love it or just like it. You know, if you are kind of getting trained and you kind of like it, well, you are going to get tired quicker than if you love it, and I think most of us realize that. We all have different metabolic rates. I have a higher metabolism than some of my younger folks and some of them have a higher metabolism than I do. So I think it is important for us to think about the individual person who is doing the surgery versus just the data, because I really believe that most people when they are fatigued to the point they can't operate will sit down and not operate. I think the biggest problem we have now is poorly trained residents who miss good operations because they can't be there because of the rules.

So I guess my comments, they are more comments than questions, we need more studies like this, the *New England Journal* article, this study and other studies, but we have to put

some real metrics in this some way, and there are really no studies that I know of in other specialties.

Do you know in other specialties, such as the cognitive specialties, such as family practice and internal medicine, because they really believe that they can't make decisions as well if they are tired? Since we are noncognitive, do you know of any studies in those areas?

**DR ELLMAN:** Looking at family medicine residents?

**DR CHITWOOD:** Family medicine, internal medicine, primary care.

**DR ELLMAN:** There is a lot of interesting data with regards to looking at the differences between how surgery residents have performed on some of the behavioral and neurocognitive tests that were done on sleep-deprived residents, surgery residents versus medicine residents. A review of this literature suggests there may be some differences in the ways that surgical residents perform when they have not had sleep, compared to medicine residents.

I am not aware of any sleep deprivation studies that have specifically attempted to compare surgical residents versus nonsurgical residents. However, there are a number of studies that have found sleep deprivation does affect nonsurgical residents with regards to attention, EKG reading, and cognition. Conversely, there are few studies found there was no difference in reading comprehension and neurocognitive tests in sleep deprived surgical residents. Specifically, one neurocognitive test called the Trail-Making test was not altered in surgical residents, but another study demonstrated decrements in sleep deprived medical residents. Thus, there certainly is some data to suggest surgical residents are less prone to the effects of sleep deprivation than medical residents.

**DR CHITWOOD:** The problem is we can't legally do the study we want to do, can we? We can't take one group and randomize them and stress them and sleep deprive them and put them in the operating room and do metrics on them, can we? So the problem is the study can't be done now, and I guess, do you think studies like this will reverse some of the notions of the limited work hours? Do you think that will happen?

**DR ELLMAN:** The Harvard Work Hours, Health and Safety Group has recently published two papers in the New England Journal where they attempted to look at errors in a group that had restricted work hours versus those who had a "traditional" work schedule. Thus, there are clearly ways that we can study this. I think it is important, however, to do it on real patients; or create some sort of incentive. Having sleep deprived residents perform on laparoscopic simulators, like some authors have done, is not a true simulation, because there is no incentive to perform.

I am not sure if work hour restriction reforms would occur if there was good evidence that sleep deprivation in surgical residents does not affect patient outcomes. I think it would be very difficult at this point to reverse it. There are other issues at stake, though, with regards to work hour restrictions. There is some data that suggests the increased turnover of patients, that

is a necessity of work our reforms, may actually lead to more errors than those that were presumed to be occurring due to sleep deprivation. Thus, work hour reforms may not only have a negative effect on surgical training but patient care as well. I do think that it is still worth studying, and perhaps eventually people will come to the conclusion that work hour restrictions were not in the best interests of physicians or patients. Perhaps some of these observations will cause the pendulum to swing back a bit, and surgical programs will at least be granted 88 hours a week, which currently is only conditionally granted for busier rotations within a program.

**DR JOHN OSWALT (Austin, TX):** I enjoyed your paper very much, Peter, and thank you for the abstract earlier. Comments and then questions. Comments first of all.

It is my belief that we are becoming a soft society and society is making us soft and therefore it is a perpetuation of this softness. Having been one of the older generations that of course walked to school barefoot 10 miles in the snow like most of the older guys here, it doesn't necessarily mean that we all have to walk to school barefoot, but I think we are missing the opportunity to do some great cases. Most of the dissecting aneurysms are done in the middle of the night and ruptured VSDs and whatnot like this that have to be taken care of, and there is a big experience to be lost by not being able to be there.

I don't know that we are going to be able to change this around other than we, as a society, saying that it is okay to go through the appropriate kind of training that will prepare you for the kind of practice you are going to have once you are out on your own. And I think something to suggest to you might be that rather than studying this in a training situation, where the limitations are being placed, one might also correlate that with the private situation, where you see physicians that have to stay up all night, work, and then still take the calls from the ICUs because they don't have the residents doing that. And then they still operate the next day. You might be able to correlate that with some in-town practitioners and make this more meaningful.

I also would like to ask you if you all had looked at the comparisons of those operations that were done the night before between the hours of 10:00 PM and 5 AM and see if there was any difference in those, as you were also comparing them with the following day and the next 24 hours?

**DR ELLMAN:** Thank you, Dr Oswalt. We did not look specifically at the operations that were done the night before that were used for the sleep deprivation criteria, unless they were a sleep deprivation case. To be clear, cases that were done the previous night were usually nonsleep-deprived cases.

With regards to looking at the effects of sleep deprivation in a private practice setting, I certainly think it would be interesting, and probably should be done. I'm not sure what the outcomes would be, but I would imagine you would see the same results we found in this study, as well as our previous study on attending surgeons. One might argue that if private practitioners want to keep their autonomy and ability to take care of patients when they want to, it would probably be in their best interests to look into this issue before federal restrictions occur, which is entirely a possibility.