Improving Nurse-to-Patient Staffing Ratios as a Cost-Effective Safety Intervention

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Background: Responding to research confirming the link between nurse staffing and patient outcomes, 14 states have introduced legislation to limit patient-to-nurse ratios. However, increased staffing places a considerable financial burden on hospitals.

Objective: We sought to determine the cost-effectiveness of various nurse staffing ratios.

Research Design: This was a cost-effectiveness analysis from the institutional perspective comparing patient-to-nurse ratios ranging from 8:1 to 4:1. Cost estimates were drawn from the medical literature and the Bureau of Labor Statistics. Patient mortality and length of stay data for different ratios were based on 2 large hospital level studies. Incremental cost-effectiveness was calculated for each ratio and sensitivity and Monte Carlo analyses performed.

Subjects: The study included general medical and surgical patients.

Measures: We sought to measure costs per life saved in 2003 US dollars.

Results of Base Case Analysis: Eight patients per nurse was the least expensive ratio but was associated with the highest patient mortality. Decreasing the number of patients per nurse improved mortality and increased costs, becoming progressively less cost-effective as the ratio declined from 8:1 to 4:1. Nonetheless, the incremental cost-effectiveness did not exceed $136,000 (95% CI $53,000–402,000) per life saved.

Results of Sensitivity Analysis: The model was most sensitive to the effects of patient-to-nurse ratios on mortality. Lower ratios were most cost-effective when lower ratios shortened length of stay, and hourly wages were low. However, throughout the ranges of all these variables, the incremental cost-effectiveness of limiting the ratio to 4:1 never exceeded $449,000 per life saved.

Conclusions: As a patient safety intervention, patient-to-nurse ratios of 4:1 are reasonably cost-effective and in the range of other commonly accepted interventions.

Key Words: nursing, cost-effectiveness, hospital economics, hospital staffing, quality of care

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In response to the current crisis in healthcare spending, hospitals have employed a variety of means to reduce costs, including limiting length of stay, restricting formularies, and gradually increasing patient-to-nurse (PTN) ratios, potentially undermining patient safety. In 2001, 75% of American nurses surveyed warned that increasing patient loads during the previous 2 years adversely affected quality of care,[1] and in Massachusetts, 29% of nurses surveyed knew of a patient death linked directly to understaffing.[2] A growing body of research confirms the link between nurse staffing and patient outcomes.[3–10] According to the Joint Commission on Accreditation of Healthcare Organizations (JCAHO), 24% of 1609 sentinel events (unanticipated events that result in injury, death, or permanent loss of function) were related to nurse staffing levels.[11]

In California, public concern led to legislation mandating minimum staffing levels to begin in 2004,[12] and a similar move is underway in Massachusetts.[13] At least 12 other states have introduced legislation to limit PTN ratios and have met with opposition from the hospital industry, which already is squeezed by soaring costs and shrinking reimbursement. In California, nursing unions have advocated PTN ratios as low as 3 to 1 for medical-surgical wards, whereas the California Healthcare Association (the state affiliate of the American Hospital Association) lobbied for a ratio of 10 to 1.[14] The state Department of Health Services settled on a ratio of 5 to 1 to be phased in over the course of 12 to 18 months.

Some advocates propose that lower PTN ratios might actually save money by decreasing nurse turnover, hospital complications, and length of stay.[14,15] If this were shown to be true, hospitals might limit PTN ratios without legislation.

To date, research on nurse staffing has not considered the cost-effectiveness of different PTN ratios. We hypothesize that the improved outcomes associated with lower PTN ratios are not cost-saving, but cost less than many other commonly accepted patient safety interventions.

METHODS

We calculated the cost-effectiveness in dollars per life saved of various PTN ratios using national cost estimates combined with patient mortality data from one large study[3] and length of stay data from another.[4] The incremental cost-effectiveness of each PTN ratio relative to the next higher PTN ratio was calculated by dividing the difference in total cost by the difference in 30-day mortality.

The analysis was conducted from the institutional perspective, using 2003 US dollars. Because we did not include future earnings or healthcare costs associated with morbidity or mortality, all costs accrue during the hospitalization and are therefore undiscounted. Table 1 lists the model variables and ranges used in the sensitivity analysis. In the base case, we assumed that the cost per patient was comprised of daily nursing labor costs plus non-nursing costs times length of hospital stay. We calculated daily nursing labor costs per patient by multiplying the hourly wage by 24 and dividing by the specific PTN ratio, using 2003 Bureau of Labor Statistics[16] estimates of total hourly compensation for private hospital nurses. Because nursing salaries can vary widely, even in the same state or county, we ran sensitivity analyses from the 10th to 90th percentile nationally, representing a 2-fold variation in wages.

On the basis of a large multistate study that found an inverse linear relationship between registered nurse (RN)-hours per patient and length of stay, we then calculated length of stay for each of the PTN ratios.[4] We assumed that length of stay declines by 0.09 days for each RN-hour per patient above the average and increases by the same amount for each hour below average. The total cost for any PTN ratio was the sum of the nursing and non-nursing costs per day times the length of stay.

The amount of savings attributable to shortening the length of stay has been debated in the literature. Taheri, et al, argued that resource utilization is heaviest in the first few days of the hospital stay.[17] Therefore, shortening length of stay would result in only modest savings in variable costs. They found that the last day of a 5 day hospitalization cost $445, accounting for only 5.3% of the total variable direct cost. Using data from the pneumonia PORT, Fine et al, projected savings of $680 for a 1-day reduction in hospital stay, primarily due to decrease in room costs, which tended to be stable throughout the hospital stay.[18] In another study, hospitalist physicians were found to provide more intensive care which both shortened length of stay by one day and decreased overall costs by $917.[19]

Nurses, however, affect length of stay by preventing adverse events, which tend to be expensive. Examining a database of 232 California hospitals, Cho et al[5] found that registered nurse hours were inversely related to developing pneumonia, a complication that added 5.1–5.4 days to length of stay and $22,390–$28,505 to hospital costs or $4225 to $5279 per additional day. One study of adverse drug events

TABLE 1. Model Variables and Ranges for Sensitivity Analysis

Variable	Value	Range	Source
Mortality increase per 1 patient increase in patient-to-nurse ratio (odds ratio)	1.07	1.02–1.12	3
Mean length of stay (days)	4.6		31
Change in length of stay (days) per additional registered nurse hour	−0.09	−0.05–0.13	4
Total cost per additional hospital day, $	1,000	500–2000	5,17–23
Nursing hourly wage (total compensation), $	36.94	25–50	16
Cost per additional hospital day (excluding nursing costs), $	833	*	Calculated†
Wage elasticity for nurses	0.6	0.5–1.5	24,25,42
Increase in registered nurse supply required to meet a 4:1 ratio	5%	0–10%	26
Cost of replacing a nurse, $§	30,000	30,000–50,000	28,29
Annual nurse turnover rate§	0.20	0–0.30	29
Average cost of nurse turnover per patient per day, $§	15	*	Calculated‡
Odds of nurse turnover per 1 patient increase in patient-to-nurse ratio, odds ratio	1.0	1.0–1.5	3

*Calculated variables are given for reference only. Their ranges depend on the ranges of the underlying variables used in the calculation.
†Cost per additional hospital day–nursing hourly wage × 24 h/5.3.
§Included in sensitivity analysis only.
‡(Cost of replacing a nurse × annual turnover rate/225 annual shifts) × 3 daily shifts/5.3 patients per shift.

found an occurrence rate of 2.43 per 100 admissions, resulting in 1.74 additional hospital days and $2013 costs ($1157 per day),[20] and a second study found that adverse drug events added 2.2 hospital days at a cost of $3344 ($1520 per day).[21] In a study of 404 California hospitals, Kalish[22] found that patients experiencing complications after major surgery had stays 8.1 day longer and costs $10,700 higher than patients without ($1321/day). Finally, Zhan[23] examined medical errors in 7.45 million hospital discharge abstracts from 994 hospitals in 28 states and found 18 types of patient safety events that lengthened hospital stays by up to 11 days, commonly at a cost of $1500 to $3000/day. Based on these numbers, we conservatively estimated that decreasing length of stay would be associated with savings of $1000 per day. In sensitivity analysis, we tested estimates from $500 to $2000.

Reducing PTN ratios requires an increase in total nurse working hours in an already tight labor market. Although an individual institution would not likely encounter wage pressure by reducing its own PTN ratio, if all the hospitals in one state simultaneously adopted lower ratios as a result of legislation, there could be substantial pressure on wages. Contemplating minimum staffing requirements for nursing homes in 2001, the Centers for Medicare and Medicaid Services (CMS) Office of the Actuary reviewed the literature and concluded that the elasticity of supply for RNs was between 0.5 and 0.8, meaning that for every 1% rise in wages, nursing supply would increase by 0.5% to 0.8%.[24] Estimates of elasticity in the 1980s are closer to 1.5.[25] We chose 0.6 as a conservative estimate, and tested the range in sensitivity analysis. The California Workforce Initiative estimated that complying with a 4:1 ratio in California would require a 5% increase in the total number of RNs after accounting for some RNs returning to work or increasing their hours under better conditions.[26] Assuming a 5% increase in supply and an elasticity of 0.6 would result in an 8.3% increase in hourly wage at a PTN ratio of 4:1. We did not assume a decrease in wages for ratios above average, because decreased staffing at an institution is also associated with higher hourly wages.[27]

Effectiveness was measured in deaths averted. Because patient age and quality of life data were unavailable, we could not estimate the number of quality-adjusted life years gained. We based our estimates on the findings of a statewide study by Aiken and colleagues which surveyed hospitals to determine PTN ratios and surgical patient mortality rates at the hospital level (not department level).[3] Nursing time was determined for clinical care activities only and excluded administration and other nursing activities. Mortality rates were adjusted for patient characteristics and hospital variables. The authors found that a staffing ratio of 5.3 patients per nurse was associated with a mean 30-day mortality rate of 2.0%. Adjusted mortality rates were found to increase by a constant 7% for every one patient increase in the PTN ratio from 4:1 to 8:1.

Sensitivity Analysis

We performed sensitivity analyses on the following independent variables: hourly nurse compensation, cost per hospital day, supply elasticity, relative risk of mortality, relative risk of nurse dissatisfaction, and decrease in length of stay per RN-hour. Because assumptions about turnover costs were speculative, we included these in the sensitivity analysis only. Measured annual turnover costs for all nurses at a university hospital in 2001 were $23,000–$31,000 per nurse including recruitment, training and the cost of reduced productivity in the first year,[28] whereas the Maryland Hospital Association estimated that it cost between $30,000 and $50,000 per RN based on survey data.[29] Others estimate turnover costs to be one year's salary ($48,240 in 2003).[3,29] Assuming a conservative $30,000 cost per nurse and multiplying this number by the annual nurse turnover rate (currently 20%)[29] produces the incremental annual cost per nurse attributable to turnover. Assuming that each nurse works 225 8-hour shifts annually, the average cost per patient per day attributable to nursing turnover is $15. Aiken and colleagues found that for each 1-patient increase in nurse work load, nurses were 15% more likely to report job dissatisfaction. Based on their 95% confidence interval, we proposed a maximum 25% increase in the likelihood of leaving employment, leading to a maximum 25% increase in costs associated with nurse turnover. The true effect is almost certainly smaller, because not all dissatisfied nurses will leave their jobs.

Finally, using Decision Maker 7.07 (Pratt Medical Group, Boston, MA) we performed a probabilistic (Monte Carlo) sensitivity analysis in which we varied all our estimates simultaneously to put confidence intervals around our cost-effectiveness estimates. We entered all variables, except nursing wages, as normal probability distributions based on the reported 95% confidence intervals, or our best estimates. We then performed 10,000 Monte Carlo simulations. Each simulation consisted of choosing random values from within each variable's probability distribution and calculating the associated costs and mortality. The 10,000 results of the simulations comprise a distribution of the potential cost-effectiveness of the intervention for average wage nurses, including a mean and 95% confidence interval.

RESULTS

We examined the results from 3 viewpoints: (1) labor costs alone, (2) labor costs plus savings from decreased length of stay, and (3) total costs assuming increased wage pressure from mandated 4:1 ratios (Table 2). In each scenario, 8 patients per nurse is the PTN ratio with the lowest costs, but it is associated with the highest patient mortality. For each decrement in the ratio, nurse labor cost per patient increases and overall mortality declines. However, the rate of incremental cost increase accelerates, while the rate of mortality decrease decelerates, resulting in progressively higher incre-

TABLE 2. Mortality Rates, Costs, and Incremental Cost-Effectiveness of 5 Different Patient-to-Nurse Ratios

PTN Ratio	Mortality Rate, %	LOS	Nursing Cost Per Patient, $	Incremental Lives Saved/1000 Admissions	Incremental Nursing Cost Increase Per Patient, $	Incremental Cost/ Life Saved (Labor Costs Only), $	Incremental Savings Per Patient Related To LOS, $	Incremental Cost/Life Saved Including LOS Costs, $
8	2.39	4.74	525					
7	2.24	4.70	595	1.5	70	45,900	32	24,900
6	2.09	4.65	687	1.4	92	63,900	43	34,000
5	1.96	4.58	811	1.3	125	92,800	60	48,100
4	1.83	4.47	990	1.3	179	142,100	90	70,700
4*	1.83	4.47	1,073	1.3	261	207,700	90	136,300

*Assuming increased wage pressures associated with a ratio of 4:1.
LOS indicates length of stay; PTN, patient-to-nurse staffing.

mental cost-effectiveness ratios for each one-patient decrement in the PTN ratio. Considering labor costs only and excluding savings from decreased length of stay, the cost associated with saving one life by changing from 8 to 7 patients per nurse is $46,000. By comparison, the cost of saving additional lives by changing from 5 to 4 patients per nurse is $142,000 per life saved. Including the savings from shortened length of stay improves the cost-effectiveness of increased staffing, but the savings offset only one-half of the increase in labor costs. In addition, if mandatory PTN ratios translate into higher wages for nurses, the incremental cost per life saved would be $71,000 at 5 patients per nurse and $136,000 at 4 patients per nurse.

Sensitivity Analysis

The incremental cost-effectiveness of decreasing PTN ratios was sensitive to variations in several parameters. The model was most sensitive to the ability of low PTN ratios to reduce mortality. When the relative risk of mortality increased from 1.02 to 1.12 per additional patient, the marginal cost-effectiveness of changing from 5 to 4 patients per nurse improved from $449,000/death averted to $84,000/death averted (Fig. 1). Low PTN ratios were most cost-effective when hourly wages were low, cost per additional hospital day was high, additional RN-hours decreased length of stay, and wage elasticity was high. However, throughout the ranges of all these variables, the incremental cost-effectiveness of limiting the PTN ratio to 4:1 did not exceed $449,000 per life saved (Fig. 2). Analyzing the same variables using wages in the 90th percentile shifted all values to the right.

Including the added cost of increased turnover due to job dissatisfaction had little effect on the outcome, because at a ratio of 8:1 there are half as many nurses employed as at a ratio of 4:1. As a result, the turnover rate must be twice as high at 8:1 to have the same absolute number of nurses leave. Even when the relative risk of leaving exceeded 1.5 for every one unit increase in PTN ratio, consideration of turnover did not substantially improve the cost-effectiveness of low PTN ratios.

Results of Probabilistic Sensitivity Analysis

In 99.8% of 10,000 analyses in which the values of key parameters were randomly chosen from a distribution of their ranges, lower PTN ratios resulted in fewer deaths than higher ratios. Lower PTN ratios always increased costs. Compared with a PTN ratio of 5:1, a ratio of 4:1 had an incremental cost-effectiveness of less than $316,000 per death averted 95% of the time. The 25th, 50th, and 75th

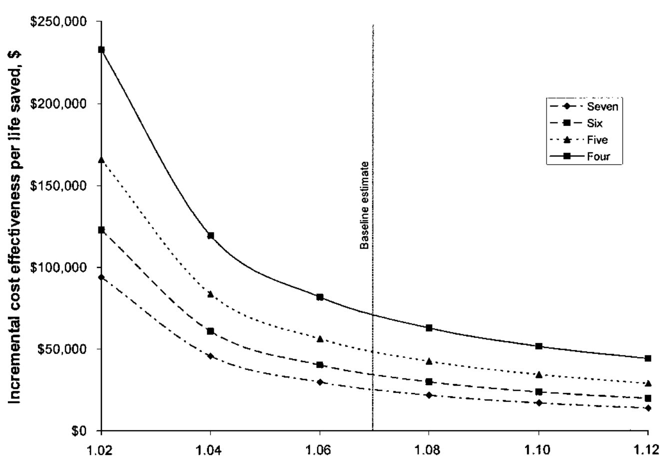

FIGURE 1. Incremental cost per life saved of 4 different patient-to-nurse ratios as a function of the relative increase in mortality associated with each additional patient per nurse.

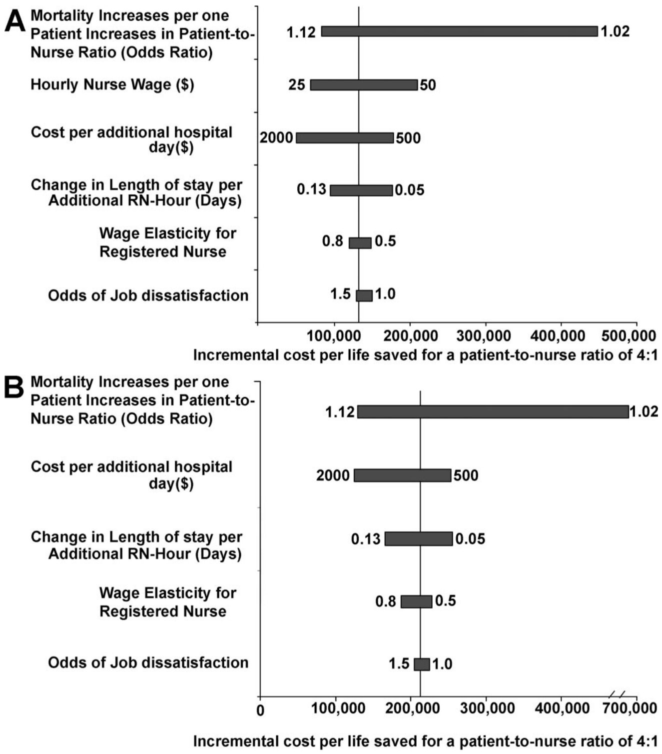

FIGURE 2. One-way sensitivity analysis of all model variables showing the incremental cost effectiveness of a PTN ratio of 4 to 1 compared with 5 to 1 assuming (A) average nurse wages and (B) wages at the 90th percentile. The dashed line represents the base case.

percentiles were $101,000, $133,000, and $179,000 per death averted.

DISCUSSION

The United States has a severe shortage of nurses, with an estimated 126,000 nursing jobs unfilled.[15] With an aging population of 78 million baby boomers and an aging population of nurses, the shortage is projected to expand to 400,000 by 2020.[11] At the same time, career dissatisfaction associated with high PTN ratios leads to burnout and may exacerbate the situation. As inpatient care has become more clinically challenging, there is a growing consensus that high PTN ratios are dangerous. At the same time, stagnant or diminished reimbursement combined with continued advances in technology and pharmaceuticals have created a financial crisis for US hospitals. According to the American Hospital Association, one in 3 hospitals lost money in 2000, 58% reported negative margins on Medicare patients, and 73% lost money treating patients with Medicaid.[30] In advocating for minimum PTN ratios as high as 10:1,[15] hospitals have correctly assessed that increasing nurses' patient loads decreases labor costs, but until now no formal economic analysis of the consequences of these savings has been undertaken.

On the basis of national nursing wage data, we found that increasing the PTN ratio results in moderate labor cost savings. For example, increasing the PTN ratio from 6:1 to 7:1 would save hospitals $92 in labor costs per case on average, representing 1% of total hospitalization costs.[31] This savings is halved when additional costs related to increased length of stay are included. Moreover, as nurses are assigned additional patients, the associated savings in labor cost per patient declines, while the probability of a fatal error occurring increases, making higher ratios increasingly unattractive. Moving from a ratio of 6:1 to 7:1 costs 1.4 additional lives per 1000 admissions. Put more simply, we can prevent additional hospital deaths at a labor cost of $64,000 per life saved by decreasing the average PTN ratio from 7:1 to 6:1. Including all hospital costs, even if implementing lower ratios requires an increase in nursing wages, decreasing the PTN ratio from 5 to 4 would save additional lives at a cost of $136,000 per life saved.

Figure 3 shows some relevant comparisons. Testing the US blood supply for HIV costs $22,000 per life saved.[32] Thrombolytic therapy in acute myocardial infarction costs $182,000 per life saved[33] and routine cervical cancer screening with PAP tests costs $432,000 per life saved.[34] Compared with these commonly accepted interventions, a PTN ratio of 4:1 seems reasonably priced.

Considering that there are approximately 38 million hospital admissions in the United States each year,[31] small changes in hospital mortality could result in a substantial number of lives saved. A recently introduced bill, the Nurse Staffing Standards for Patient Safety and Quality Care Act of 2004 (H.R. 4316), calls for mandatory federal staffing ratios,

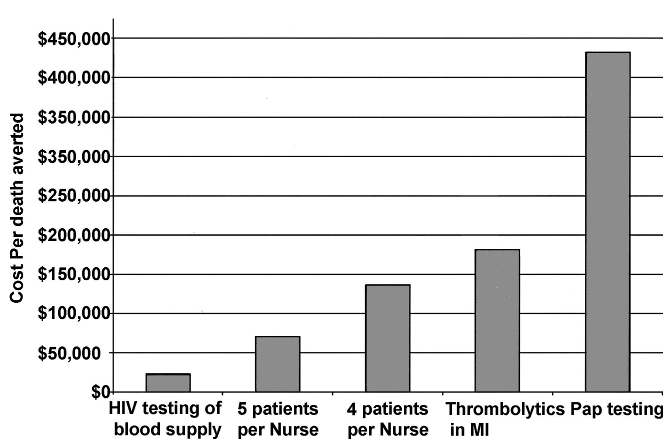

FIGURE 3. Comparison of incremental cost-effectiveness ratios for 2 different patient-to-nurse ratios, each compared with the next higher patient-to-nurse ratio, and 3 other patient interventions.

with a maximum PTN ratio of 4:1 on general medical and surgical wards. There are no available data on national PTN ratios, but if the national ratios resemble those in Pennsylvania, then mandating a ratio of 4:1 could potentially save 72,000 lives annually at a projected cost of $4.2 billion to $7.3 billion. If national ratios are higher than those in Pennsylvania, then both the number of lives saved and the costs will be greater.

Our study has several limitations. Our mortality data is drawn from a single, large study of Pennsylvania hospitals. Although many authors have found a similar impact of nursing on mortality,[3,5–8,35,36] some have not.[4,37] In the largest hospital level study to date, Needleman, et al found strong associations between nurse staffing and pneumonia, shock, and cardiac arrest. On the mortality side, nurse staffing was associated with higher failure to rescue rates and, though not statistically significant, overall mortality.[4] It was not possible to combine estimates from various studies because methodologies varied widely. The inconsistency in results may be due to methodological weaknesses, including small sample size, failure to adequately adjust for patient or hospital characteristics, and inability to distinguish nurses in patient care roles from those in administrative roles. Understanding the true effect is important, because small increases in relative risk render low PTN ratios cost-effective. Alternatively, if PTN ratios do not affect mortality, then cost-effectiveness estimates would have to include other measures of effectiveness, such as decreases in morbidity.

We assumed that shortened length of stay would translate into lower hospital costs. We believe this is a reasonable assumption because decreased staffing has been linked to costly complications,[5,7,9,10,38] and these presumably account for the increased length of stay. Needleman, however, did not collect data on hospitalization costs. Establishing a direct relationship between nurse staffing and hospitalization costs would be a welcome addition to the literature and bolster the argument for lower ratios. In addition, using length of stay as a proxy for morbidity counts only the short-term economic cost of hospital errors. Including quality of life adjustments pertaining to morbidity would make lower PTN ratios even more appealing, but would require us to express effectiveness in quality-adjusted life years, which was not possible given the available data.

Aiken and colleagues relied on hospital level data, so it is not known how staffing ratios in different departments contribute to overall mortality, nor how nurses should best be allocated within the hospital setting. For example, it is common for the PTN ratio to vary by as much as 8-fold across nursing units within the same institution. It is also not known if the observed differences in surgical mortality will translate into decreases in other sorts of mortality, or whether results in Pennsylvania can be generalized to other regions of the country.

Advocating for more staffing could exacerbate the current nurse shortage, and may require higher wages to attract new nurses. We tried to adjust for this by assuming higher wages for lower PTN ratios. Such adjustments are tricky because nonmonetary benefits, such as improved working conditions, may also attract more people to hospital nursing. One survey found that 65% of nurses working outside of hospitals would consider returning to hospital care if Safe Staffing legislation was enacted.[39] In short, lessons from nursing shortages caused by adverse working conditions may not apply to a shortage caused by mandated improvement in working conditions. Alternatively, by relying on average wages, we may have underestimated the cost of compliance in those areas where high wages have driven hospitals to adopt high PTN ratios. Our analysis suggests that even for areas in the 90th percentile of wages, a ratio of 4:1 is reasonably cost-effective ($211,000 per life saved).

What is the optimal level of staffing? It depends on what we as a society are willing to pay to decrease hospital patient mortality. The California Nurses Association called for PTN ratios of 3:1, while the State Hospital Association requested a level of 10:1.[15] Beginning in 2004, California medical and surgical nursing staff ratios will be set at 6:1, and decrease to 5:1 in 2005. Other states are considering similar initiatives. Some private health care providers, such as Kaiser Permanente in California, recognize nurse staffing as a quality issue, and have voluntarily chosen a staffing level of 4:1. Based on our analysis, Kaiser's choice seems a cost-effective one. However, state-mandated ratios may not produce the intended outcomes.[14] More research is needed to define how best to implement improved staffing in individual units.

Can the same benefits be achieved though the use of licensed practical nurses and nursing extenders? Both Aiken[3] and Needleman[4] found that decreases in adverse outcomes were related to registered nurse staffing alone. Increases in licensed practical nurse hours or the use of nurses' aides had no effect on any patient outcome. In another study, Aiken found that nurses' education level was also inversely correlated with patient mortality.[40] Results of other studies have been mixed.[38]

Conspicuously absent from this debate are physicians' voices, despite the fact that more than 50% of physicians identified understaffing of nurses in hospitals to be a very important cause of medical errors.[41] With the exception of a few articles published in medical journals, research of this type has appeared primarily in nursing journals, newspapers, and editorial pages. Physicians and hospital administrators have tended to view nurse staffing levels as part of the hospital infrastructure, as opposed to an intervention aimed at decreasing hospital-associated morbidity and mortality. Considering our results, hospital directors have correctly judged that increasing PTN ratios noticeably reduces labor costs. The resultant rise in mortality, complications and length of stay, however, are more difficult to measure at the level of a single institution. To truly estimate the impact of PTN ratios on patient outcomes, a large randomized trial with an accompanying economic analysis is in order.

Considered as a patient safety intervention, improved nurse staffing has a cost-effectiveness that falls comfortably within the range of other widely accepted interventions. If a hospital decided, for economic reasons, not to provide thrombolytic therapy in acute myocardial infarction, physicians would likely refuse to admit to that hospital, and patients would fear to go there. Physicians, hospital administrators and the public must now begin to see safe nurse staffing levels in the same light as other patient safety measures.

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