

SPECIAL ARTICLE

Cost Implications of Reduced Work Hours and Workloads for Resident Physicians

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ABSTRACT

BACKGROUND

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Although the Accreditation Council for Graduate Medical Education (ACGME) limits the work hours of residents, concerns about fatigue persist. A new Institute of Medicine (IOM) report recommends, among other changes, improved adherence to the 2003 ACGME limits, naps during extended shifts, a 16-hour limit for shifts without naps, and reduced workloads.

METHODS

We used published data to estimate labor costs associated with transferring excess work from residents to substitute providers, and we examined the effects of our assumptions in sensitivity analyses. Next, using a probability model to represent labor costs as well as mortality and costs associated with preventable adverse events, we determined the net costs to major teaching hospitals and cost-effectiveness across a range of hypothetical changes in the rate of preventable adverse events.

RESULTS

Annual labor costs from implementing the IOM recommendations were estimated to be \$1.6 billion (in 2006 U.S. dollars) across all ACGME-accredited programs (\$1.1 billion to \$2.5 billion in sensitivity analyses). From a 10% decrease to a 10% increase in preventable adverse events, net costs per admission ranged from \$99 to \$183 for major teaching hospitals and from \$17 to \$266 for society. With 2.5% to 11.3% decreases in preventable adverse events, costs to society per averted death ranged from \$3.4 million to \$0.

CONCLUSIONS

Implementing the four IOM recommendations would be costly, and their effectiveness is unknown. If highly effective, they could prevent patient harm at reduced or no cost from the societal perspective. However, net costs to teaching hospitals would remain high.

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FATIGUE AMONG RESIDENT PHYSICIANS has been linked to medical errors, motor-vehicle crashes, and occupational injuries.¹⁻³ In 2003, the Accreditation Council for Graduate Medical Education (ACGME) implemented reforms to reduce resident fatigue.⁴ Studies analyzing these reforms have shown equivocal results, however; two studies showed absolute reductions of 0.25 to 0.70 percentage point in mortality among medical patients, whereas several other studies showed no changes.⁵⁻¹⁰ At least three factors could explain the negative findings. First, resident surveys indicate that nonadherence to the limits has been widespread.¹¹⁻¹⁶ Second, the reforms increased handoffs of patient care from resident to resident, which are associated with medical errors.^{17,18} Third, clinical performance decreases substantially during and after extended shifts.¹⁹ In a randomized trial in medical intensive care units, interns were responsible for half of injuries due to medical errors (preventable adverse events) and made 36% more serious errors (i.e., medical errors that cause harm or have substantial potential to cause harm) during schedules with 30-hour shifts than during schedules with 16-hour shifts.³ The Institute of Medicine (IOM) recently investigated these issues. The resulting report, *Resident Duty Hours: Enhancing Sleep, Supervision, and Safety*, recommends additional reductions in work hours, a reduced workload, greater supervision, and improved management of handoffs of patient care.²⁰ The current and proposed limits are listed in the Supplementary Appendix, available with the full text of this article at NEJM.org.

This analysis extends a study commissioned to assist the deliberations of the IOM's Committee on Optimizing Graduate Medical Trainee (Resident) Hours and Work Schedules to Improve Patient Safety.²¹ Our objective was to estimate the labor costs associated with implementing four major IOM recommendations in ACGME-accredited residency programs: adherence to the 80-hour workweek, a 5-hour nap during extended shifts, a 16-hour limit for shifts without naps, and a reduced workload. Additional recommendations that appeared to be unlikely to generate substantial costs were not included. Shifting residents' work to substitute providers or an expanded population of residents would generate the labor costs.

Secondary objectives included estimating potential net costs to major teaching hospitals and

cost-effectiveness to society — specifically, costs per averted death. Preventable adverse events generate costs during and after hospitalization^{22,23}; therefore, if the changes decreased these events, labor costs would be offset by the reduction in costs related to preventable adverse events. Because handoffs of patient care would increase, increases in these costs would also be possible. We drew the framework for this study from an analysis of the 2003 reforms but considered the new recommendations, current working patterns of residents, and cost-effectiveness.²⁴

METHODS

STUDY DESIGN

Our analysis involved two main steps. First, we estimated labor costs across 1206 hospitals with ACGME-accredited programs by considering the current working patterns of residents and the providers who are able to perform residents' work. Second, to estimate net costs and cost-effectiveness at major teaching hospitals (defined as members of the Council of Teaching Hospitals), we developed a probability model representing labor costs as well as mortality and costs associated with preventable adverse events.²⁵ The model simulates hypothetical changes in preventable adverse events, ranging from a 10% increase to the percentage decrease that would exactly offset the labor costs. The reference year was 2006.

PubMed searches provided model variables. For working patterns and substitutes, we gave preference to studies that included national samples, multiple hospitals, multiple specialties, or specialties involving many residents.²⁶ We searched the literature in PubMed for a combination of the terms "resident" and "duty hour" and "resident" and "work hour," with the limit "after July 1, 2003." For variables related to preventable adverse events, we selected studies that used medical-record review to identify various preventable events in U.S. hospitals; we searched for a combination of the terms "preventable adverse events" and "rate"; "cost" and "medical error"; "cost" and "preventable adverse events"; and "cost" and "medical injuries" and "adverse events" — all with the limit "after 1993." We also examined the first 20 articles that PubMed listed as being related to each study, references from the relevant articles, and publicly available data.²⁴

WORKING PATTERNS

Variables in the model included current workweek, duration and frequency of extended shifts, and time on inpatient rotations (Table 1). Data sources comprised a national survey of first-postgraduate-year (PGY-1) residents in all specialties; three multihospital surveys of residents in general surgery, orthopedics, and pediatrics in multiple class years; and two surveys of residents in multiple specialties and class years at three major teaching hospitals. Respondents in the PGY-1 survey reported longer workweeks than did those in the other surveys (in which PGY-1 residents accounted for 35% or fewer of the respondents).^{12,13,15,16,28,29} One survey of residents in multiple specialties and multiple class years showed that workweeks exceeding the 80-hour limit were common in some specialties (among 22% of respondents); we therefore assumed that 22% of residents in the second postgraduate year (PGY-2) or beyond had workweeks similar to those of PGY-1 residents.¹³ This survey provided information on the duration of extended shifts for residents in PGY-2 or beyond.¹³ The general-surgery survey provided information on the frequency of extended shifts.¹⁵

SUBSTITUTE PROVIDERS

Since the 2003 reforms, residency programs have often employed midlevel providers (physician assistants and nurse practitioners) to replace resident labor, but many residents still spend 9 to 24 hours per week on noneducational tasks that lower-level providers can perform.^{13,15,64-73} Programs have also shifted work among residents, but this can detract from educational opportunities.¹⁷ The IOM committee advocated greater involvement of attending physicians.

For each of the four recommendations, we assessed the transfer of current work beyond the proposed limit (“excess work”) to substitute providers (Table 2). Attending physicians are logical substitutes for subspecialty residents; specialty residents are discussed below. We considered implementation of the recommendations serially to prevent double counting. For example, the workload would not need to be reduced during hours eliminated by adhering to the 80-hour workweek.

Adherence to an 80-Hour Workweek

In the base-case scenario, midlevel providers and attending physicians assumed most of the excess

work. A total of 3.9% of specialty residents working more than 100 hours transferred 12 hours to lower-level providers; the types of substitutes used were derived from an internal-medicine substitution model.⁷⁴ We assumed that adherence to the 80-hour workweek would make adherence to the other limits of the 2003 reforms possible at no additional cost.

Protected Naps during Extended Shifts

Residents currently nap for 2 to 3 hours, but interruptions are frequent. Protected (i.e., uninterrupted) 5-hour naps would require 300 minutes of coverage (100 to 300 minutes in sensitivity analyses).^{14,15,75,76} Attending physicians may be the preferred substitutes because many patients are admitted during extended shifts and newly admitted patients often require a high level of care.

16-Hour Limit for Shifts without Naps

Residency programs can shorten extended shifts to 16 or fewer hours instead of providing for uninterrupted naps. Providing for naps when current shifts exceed 21 hours and shortening shifts when they last up to 21 hours limit the excess work to 5 hours per shift. The base-case scenario involved midlevel providers and attending physicians as substitutes.

Reduced Workload

The IOM report did not specify which residents would have reduced workloads or by how much the workloads would be reduced.²⁰ In the base-case scenario, we assumed a 10% decrease for PGY-1 residents (5 to 20% in sensitivity analyses). We used midlevel providers as substitutes and assumed that costs would be the same as those for equivalent reductions in work hours because workload is not easily quantifiable.

Assumptions Relevant to All Four Recommendations

We assumed that individual substitutes would perform excess work transferred from multiple residents. Sensitivity analyses were performed to account for the following possibilities: the types of substitutes used may vary, rested substitutes may be more or less efficient than fatigued residents, providers' wages may be higher in urban areas than in rural areas, demand for midlevel providers and physicians could increase their wages, and some excess work may not be transferred to substitutes for several reasons.

ADDITIONAL RESIDENTS

The Council on Graduate Medical Education recommends expanding the number of residency positions, which could reduce the work hours and workloads of residents.⁷⁷ We determined the minimum overall increase in positions required, calculating excess work as described above. Costs per resident were based on stipends and benefits, average expenditures from public sources for graduate medical education (GME), excluding indirect payments, and average GME expenditures from all sources. Stipends remained stable after the 2003 reforms.³⁹

PREVENTABLE ADVERSE EVENTS

We based mortality and costs associated with preventable adverse events on one study that met our inclusion criteria. Thomas et al.²² identified preventable adverse events by examining medical records from 14,000 hospitalizations in Utah and Colorado, and they used consensus judgments to estimate disability and lifetime health care utilization related to these events. The authors projected the rate and number of preventable adverse events and attributable health care costs, lost wages, and the cost of hiring other persons to perform household duties in the two states in 1996 (discounting future costs at 2.75%).²² Rates of preventable adverse events did not vary according to hospital teaching status.^{43,78}

STATISTICAL ANALYSIS

To derive labor costs, we calculated the total excess hours for each recommendation (number of excess hours per resident per week multiplied by numbers of affected weeks and residents) and then multiplied the result by substitutes' hourly wages plus benefits. When additional residents were considered, we divided total excess hours by the hours residents would work annually and multiplied the result by the annual per-resident costs. Sensitivity analyses (SA) (performed with the use of Stata software) examined how alterations in the variables and assumptions (sensitivity-analysis numbers SA1 through SA19) affected labor costs.

Estimating net costs and cost-effectiveness involved the following: calculating labor costs at major teaching hospitals; determining mean costs per preventable adverse event in 2006 (1996 costs multiplied by geographic and temporal adjustment factors); applying rates of preventable adverse events, mortality, and costs to

admissions at major teaching hospitals; calculating changes in the incidence of preventable adverse events, mortality, and costs across changes in the rate of preventable adverse events; determining net costs to major teaching hospitals; and determining incremental cost-effectiveness ratios (performed with the use of Excel software). The teaching-hospital model included labor and inpatient costs related to preventable adverse events. The societal model included labor and all costs related to preventable adverse events.

RESULTS

Annual labor costs under the base-case scenario were \$1.6 billion (in 2006 U.S. dollars) (Table 3), a quarter of which pertained to improving adherence to the 80-hour workweek and half of which pertained to reducing fatigue related to extended shifts. Expanding residency positions appears to be less costly (approximately \$500 million) when calculated on the basis of stipends and benefits but slightly more costly (\$1.7 billion) based on per-resident GME expenditures from all sources. Costs per major teaching hospital would be \$3.2 million for substitute providers and \$990,000 to \$3.5 million for additional residents (data not shown).

In sensitivity analyses, annual labor costs ranged between \$1.1 billion and \$2.5 billion (Table 4), unless some excess work was not transferred to substitute providers (SA17 through SA19). Extended-shift frequency (SA2 and SA4), substitutes' efficiency (SA14 through SA16), substitutes' wages (SA6), minutes of nap coverage (SA11), and reduction in workload (SA13) had the greatest effects on costs; the type of substitute was less influential. The number of midlevel providers and physicians needed would be too modest to increase their wages nationally.

Table 5 lists the potential net costs and cost-effectiveness of using substitute providers. With a hypothetical 10% increase in preventable adverse events, net costs per admission would be \$183 for major teaching hospitals and \$266 for society. With a 10% decrease, net costs would be \$99 and \$17, respectively. A 2.5% to 10% decrease would yield an incremental cost-effectiveness ratio of \$3.36 million to \$127,000 per averted death. At an 11.3% decrease, there is no cost to society for using substitute providers.

With the use of additional residents and with

Table 1. Model Variables.*				
Variable	Base Case	Sensitivity Analysis		Reference
		<i>range</i>	<i>no.</i>	
Current working patterns of residents				
Specialty and subspecialty residents in ACGME-accredited programs — no.	104,879	No change		Brotherton and Etzel ²⁶
Residents at hospitals that are members of the Council of Teaching Hospitals — %	75	No change		Association of American Medical Colleges ²⁵
Workweeks/yr — no.	49	No change		Davenport et al. ¹⁵
PGY-1 specialty residents — no.	24,772			Brotherton and Etzel, ²⁶ ACGME ²⁷
Workweek duration — % of all workweeks			SA1	Landrigan et al. ¹²
105 hr	3.9	0–3.9		
95 hr	8.2	0–8.2		
85 hr	20.8	0–20.8		
Extended shift of >21 hr — % of extended shifts	100	No change		Landrigan et al. ¹²
Frequency of extended shifts on inpatient rotations	Every 6th night	Every 3rd–7th night	SA2	de Virgilio et al., ¹⁰ Davenport et al. ¹⁵
Weeks on inpatient rotations — %	50.6	No change		Landrigan et al. ¹²
≥PGY-2 residents — no.				Brotherton and Etzel, ²⁶ ACGME ²⁷
Specialty	64,497			
Subspecialty	15,610			
Workweek duration — % of all workweeks			SA1	Landrigan et al., ¹² Jagsi et al., ¹³ Davenport et al., ¹⁵ Cull et al., ¹⁶ Carpenter et al., ²⁸ Kusuma et al. ²⁹
105 hr	3.9	0–3.9		
95 hr	8.2	0–8.2		
85 hr	20.8	0–20.8		
Residents working such workweeks — %	22	0–44	SA3	Jagsi et al. ¹³
Extended shifts — % of extended shifts				Jagsi et al. ¹³
>21 hr	23.1	No change		
21 hr	26.6			
18 hr	4.0			
Frequency of extended shifts on inpatient rotations	Every 6th night	Every 3rd–7th night	SA4	de Virgilio et al., ¹⁰ Davenport et al. ¹⁵
Weeks on inpatient rotations — %	50.6	25.3–50.6	SA5	Landrigan et al. ¹²
Wages and benefits				
Substitute providers				
Hourly wages — \$			SA6	Bureau of Labor Statistics, ³⁰ Medical Group Management Association, ³¹ Census Bureau ^{32–37}
Nursing aide	11.21	10.48–12.02		
Laboratory technician	16.55	16.55–21.54		
Licensed vocational nurse	18.12	18.12–18.55		
Midlevel provider	37.84	28.63–37.84		
Physician	58.76	58.76–112.53		
Benefits — % of total compensation	30.1			Bureau of Labor Statistics ³⁸

Table 1. (Continued.)				
Variable	Base Case	Sensitivity Analysis		Reference
		<i>range</i>	<i>no.</i>	
Residents		No change		
Annual stipend — \$				Association of American Medical Colleges ³⁹
PGY-1 specialty residents	44,747			
≥PGY-2 specialty residents	48,419			
Subspecialty residents	54,494			
Benefits — % of stipend	29			Association of American Medical Colleges ³⁹
Annual GME support, averaged per resident — \$				Wynn et al., ⁴⁰ Bureau of Labor Statistics, ⁴¹ Brotherton et al. ⁴²
Public sources†	74,000			
All sources	211,000			
Preventable adverse events, mortality, and costs		No change		
Hospitalizations with preventable adverse events, Utah and Colorado, 1996 — no. (%)	8859 (1.9)			Thomas et al., ^{22,43} Hayward et al., ⁴⁴ Woods et al., ⁴⁵ Rothschild et al., ⁴⁶ Baker et al., ⁴⁷ Thomas and Brennan ⁴⁸
Hospitalizations with fatal preventable adverse events — %	0.13			Thomas et al., ²² Encinosa and Hellinger, ²³ Baker et al., ⁴⁷ Hayward and Hofer ⁴⁹
Costs in Utah and Colorado, 1996 — \$				
Inpatient medical care	83,505,000			Thomas et al., ²² Kaushal et al., ⁵⁰ Bates et al., ⁵¹ Classen et al., ⁵² Zhan and Miller ⁵³
Outpatient medical care	75,740,000			Thomas et al., ²² Encinosa and Hellinger ²³
Lost wages and cost of hiring persons to perform household duties	149,137,000			Thomas et al. ²²
Geographic cost adjustments, Utah and Colorado vs. U.S. — inflation factor				
Population-weighted cost-of-living index, 1996	1.04			Nuckols and Escarce, ²⁴ Census Bureau, ⁵⁴ Berry et al. ⁵⁵
Wages, 1997	1.08			Bureau of Labor Statistics ⁵⁶
Temporal cost adjustments, 1996–2006 — inflation factor				
Inflation of medical costs	1.35–1.74			Nuckols and Escarce, ²⁴ Bureau of Labor Statistics, ^{41,57}
Increases in utilization	1.30			American Hospital Association, ^{58,59} Maxwell et al. ⁶⁰
Wage inflation	1.42			Nuckols and Escarce, ²⁴ Bureau of Labor Statistics ^{61–63}
Council of Teaching Hospitals				American Hospital Association ⁵⁸
Members — no.	367			
Hospital admissions — no./yr	8,368,859			

* All costs are expressed in 2006 U.S. dollars. ACGME denotes Accreditation Council for Graduate Medical Education, GME graduate medical education, PGY-1 first postgraduate year, and ≥PGY-2 second postgraduate year or beyond.

† These sources exclude indirect medical education payments.

Table 2. Institute of Medicine Recommendations Included in the Model and Model Assumptions.*

Variable	Base Case	Substitute Providers Assume Excess Work	Sensitivity Analysis <i>range</i>	<i>no.</i>	Additional Residents Assume Excess Work	Reference
Recommendation						
Adherence to 80-hr workweek averaged over 4 wk†						
Specialty residents — % of excess work transferred	0–24, nursing aides; 0–4, laboratory technicians; 0–20, nurses; 32–100, midlevel providers; 0–33, attending physicians	From base case to 100, midlevel providers; or from base case to 16–50, midlevel providers, and from base case to 36–50, physicians		SA7 SA8	100 (specialty residents)	Knickman et al. ⁷⁴
Subspecialty residents — % of excess work transferred	100, attending physicians	0–50, midlevel providers; 50–100, attending physicians		SA9	100 (subspecialty residents)	
Protected naps during extended shifts‡						
Specialty residents — % of excess work transferred	100, attending physicians	0–100, midlevel providers; 0–100, attending physicians		SA10	100 (specialty residents)	
Subspecialty residents — % of excess work transferred	100, attending physicians	0–50, midlevel providers; 50–100, attending physicians		SA9	100 (subspecialty residents)	
Coverage by substitutes/extended shift — min	300	100–300		SA11	300	Arora et al., ¹⁴ Morton et al., ⁷⁵ Arora et al. ⁷⁶
16-hr limit for shifts without naps						
≥PGY-2 specialty residents — % of excess work transferred	50, midlevel providers; 50, attending physicians	0–100, midlevel providers; 0–100, attending physicians		SA12	100 (specialty residents)	
Subspecialty residents — % of excess work transferred	100, attending physicians	0–50, midlevel providers; 50–100, attending physicians		SA9	100 (subspecialty residents)	
Reduced workload						
PGY-1 specialty residents — % of current workload transferred	10	5–20		SA13	10	
Other model assumptions						
Hr of substitute work to replace an hr of resident work — no.						
Residents	NA	NA			1	
Lower-level providers	1	0.5–3.0		SA14	NA	
Midlevel providers	1	0.8–2.4		SA15	NA	
Physicians	1	0.5–1.0		SA16	NA	

Not all excess work transferred to substitutes — % of excess work transferred		
Nonadherence to new IOM recommendations	100	0–100 excess transferred (recommendations 2–4) [§] SA17
Resident productivity gains due to reduced fatigue	100	70–100 excess transferred (recommendations 1, 3, and 4) SA18
Work shifted among residents	100	50–100 excess transferred (recommendations 1–4) SA19

* Data on recommendations are from the Institute of Medicine.²⁰ NA denotes not applicable, PGY-1 first postgraduate year, and ≥PGY-2 second postgraduate year or beyond.

† For the base-case scenario for the adherence to an 80-hour workweek, residents currently working 105 hours transferred 12 hours to lower-level providers, 8 hours to midlevel providers, and 5 hours to attending physicians; those working 90 to 100 hours transferred 2 hours to lower-level providers, 8 hours to midlevel providers, and 5 hours to attending physicians; and those working 80 to 90 hours transferred 5 hours to midlevel providers. In the sensitivity analyses, 50% of the hours of midlevel providers were transferred to physicians instead, such that physicians assumed up to 9 hours.

‡ Extended shifts should be limited to 30 hours if a 5-hour, uninterrupted period of continuous sleep is provided between 10 p.m. and 8 a.m.

§ Of the total excess work calculated in these recommendations, the sensitivity analysis considered the possibility that between 0% and 100% would be transferred to substitutes. The remaining recommendation or recommendations were unaffected.

a 10% increase in preventable adverse events, net costs per admission would be \$86 to \$198 for hospitals and \$169 to \$280 for society. With a 10% decrease, net costs would be \$3 to \$114 per admission for hospitals and –\$80 to \$32 for society. Implementation would be free to society at a 3.6% to 12.5% decrease in preventable adverse events.

DISCUSSION

Reducing resident physicians' work hours and workloads in accordance with four IOM recommendations would involve \$1.6 billion of substitute labor; costs would range from \$1.1 billion to \$2.5 billion, depending on the current working patterns of residents, the wages and efficiency of substitute providers, and other considerations. With the use of additional residents instead of substitute providers, at least 8% more residency positions would be required, costing up to \$1.7 billion annually.

Although the Council on Graduate Medical Education recommends expanding residency positions, the use of this approach to reduce residents' work raises three considerations.⁷⁷ First, it will expand the long-term supply of physicians. Basing residency positions for each specialty on its residents' current work hours could alleviate shortages in some specialties but create surpluses in others. Pediatrics residents work long hours, for example, but the supply of pediatricians appears to be sufficient; therefore, expanding residency positions could create a surplus.^{12,79} Second, the additional graduates from U.S. or international medical schools might have weaker qualifications than current trainees. Third, admissions to teaching hospitals have been increasing; therefore, more residents may be needed in the future.^{58,59}

With the use of either substitute providers or additional residents to reduce current residents' work, annual implementation costs would be high as compared with both GME expenditures and other interventions for patient safety. In 2006, direct Medicare GME payments were \$2.3 billion and indirect Medicare GME payments were \$5.9 billion.⁸⁰ Public and private support totaled \$18.7 billion in 2003.⁴⁰ The three new IOM recommendations that we analyzed (i.e., protected naps, 16-hour shifts, and reduced workload) would cost more than the 2003 reforms may have

Table 3. Annual Labor Costs Associated with Implementing the Institute of Medicine's Four Major Recommendations.*

Recommendation and Affected Residents	Base Case: Substitute Providers Assume Excess Work Base		Additional Residents Assume Excess Work		
	Annual Cost per Affected Resident \$	Total Cost for All Residents millions of \$†	Minimum No. of New Residents Needed no. (% increase)†	Costs of Stipends and Benefits millions of \$†	Costs Based on Current GME Expenditures per Resident millions of \$‡
Adherence to 80-hr workweek					
Specialty residents	2,069–3,638	330	2,121 (2.6)	126	157–448
Subspecialty residents	4,017–5,068	46	187 (1.2)	13	14–39
Subtotal		376		139	171–487
Protected naps during extended shifts					
Specialty residents	12,906	512	2,085 (2.3)	124	154–440
Subspecialty residents	12,906	47	190 (1.2)	13	14–40
Subtotal		559		137	168–480
16-hr limit for shifts without naps					
≥PGY-2 specialty residents	4,243–10,609	193	956 (1.1)	60	71–202
Subspecialty residents	5,162–12,906	57	231 (1.5)	16	17–49
Subtotal		250		76	88–251
Reduced workload					
PGY-1 specialty residents	15,814	392	2,477 (3.1)	143	183–523
Total					
Specialty residents	15,985	1,427	7,639 (8.6)	453	565–1,612
Subspecialty residents	9,609	150	608 (3.9)	43	45–128
Overall		1,576	8,247 (7.9)	496	610–1,740

* All costs are expressed in 2006 U.S. dollars. Numbers may not sum to subtotals or totals because of rounding. GME denotes graduate medical education, PGY-1 first postgraduate year, and ≥PGY-2 second postgraduate year or beyond.

† To determine estimates for major teaching hospitals as a group, multiply by 0.75. To determine estimates per major teaching hospital, multiply by 0.002.

‡ The lower number is based on average per-resident GME expenditures from all public sources excluding indirect medical education payments. The higher number includes all public and private sources, including indirect medical education payments.

cost (\$1.2 billion vs. \$0.7 billion to \$1.1 billion).²⁴ The cost per hospital (\$3.2 million annually) is higher than the cost associated with computerized physician order entry (\$3.3 million to \$11.8 million over a period of 10 years) and medication bar-coding systems (\$2.2 million over a period of 5 years).^{50,81,82} However, the cost per admission (\$141) is lower than the cost associated with implementation of policies requiring one nurse for every four patients (\$261).⁸³

It remains unknown whether implementing the IOM's recommendations would reduce preventable adverse events. Although a randomized trial of shorter shifts suggests that a 25% decrease in serious errors might be plausible in medical intensive care units, few errors cause injuries, and effects could differ in other clinical settings.³ Also, the additional handoffs of pa-

tient care among residents could increase preventable adverse events.

If the number of preventable adverse events is reduced, will the investments of teaching hospitals in reducing residents' work hours and workloads lead to net savings?^{84–86} A return on investment has been shown for computerized physician order-entry systems, bar-coding systems, and having more registered nurses care for hospitalized patients.^{50,81,87} However, hospitals are likely to incur losses under the IOM-recommended changes. Averting preventable adverse events may, in addition to reducing the costs of inpatient medical care, avert malpractice claims, preserve the hospital's reputation, and improve patient throughput, but these latter effects on hospital profitability appear to be modest and unpredictable.⁸⁴ For example, data on the asso-

Table 4. Range of Annual Labor Costs Associated with Implementing the Institute of Medicine's Four Major Recommendations.*

Focus of Sensitivity Analysis	Sensitivity Analysis	Range of Total Labor Costs
	<i>no.</i>	<i>millions of \$</i>
Current working patterns of residents		
PGY-1 specialty residents		
Workweek duration	SA1	1,576–1,200
Call frequency during inpatient rotations	SA2	1,576–1,896
≥PGY-2 specialty and subspecialty residents		
Working >80 hr per week	SA3	1,410–1,742
Call frequency during inpatient rotations	SA4	1,576–2,064
Frequency of inpatient rotations	SA5	1,332–1,576
Transfer of work to substitute providers		
Adherence to 80-hr workweek		
Specialty residents transfer a percentage of excess work to midlevel providers	SA7	1,576–1,581
Specialty residents transfer a percentage of excess work to attending physicians and midlevel providers	SA8	1,576–1,619
Protected nap during extended shifts		
Specialty residents transfer a percentage of excess work to midlevel providers rather than attending physicians	SA10	1,394–1,576
Minutes transferred to achieve 5-hr nap	SA11	1,203–1,576
16-hr limit for shifts without naps		
Specialty residents transfer a percentage of excess work to midlevel providers	SA12	1,534–1,618
Reduced workload		
PGY-1 residents transfer a percentage of excess work	SA13	1,380–1,968
Other variables and assumptions		
Hourly wages for substitute providers	SA6	1,411–2,378
Subspecialty residents transfer a percentage of excess work to midlevel providers rather than attending physicians in recommendations 1, 2, and 3	SA9	1,549–1,576
Substitution ratios†		
Lower-level providers	SA14	1,562–1,630
Midlevel providers	SA15	1,441–2,519
Attending physicians	SA16	1,138–1,576
Not all excess work transferred to substitutes		
Nonadherence to new recommendations	SA17	376–1,576
Resident productivity gains due to reduced fatigue	SA18	1,272–1,576
Work shifted among residents	SA19	788–1,576

* All costs are expressed in 2006 U.S. dollars. PGY-1 denotes first postgraduate year, ≥PGY-2 second postgraduate year or beyond, and SA sensitivity analysis.

† Substitution ratios are defined as an hour of substitute work to replace an hour of residents' work.

ciation between negligent injuries and malpractice claims are equivocal, and hospitals bear only 22% of event costs, even when malpractice is considered.⁸⁸⁻⁹³

From the societal perspective, the cost-effectiveness of the recommendations depends on

their success in reducing preventable adverse events and the overall effect of these events on health-related quality of life. Eighty percent of these events cause temporary disability.²² With regard to mortality, regulatory agencies have valued a "statistical life" at \$1.7 million to \$6.3

Table 5. Net Cost and Cost-Effectiveness of Implementing the Institute of Medicine's Four Major Recommendations According to Their Effect on the Rate of Preventable Adverse Events (PAEs).*

Assumed Percent Change in PAE Rate	Net Cost of Substitute Providers			Effectiveness			Incremental Cost-Effectiveness Ratio	
	Overall Cost for Society	Cost for Major Teaching Hospitals per Admission	Cost for Society per Admission	New or Averted PAEs	New or Averted Fatal PAEs		Net Cost to Society for Each Averted PAE	Net Cost to Society for Each Averted Fatal PAE
	millions of \$	\$	total no.				\$	
+10.0	2,224	183.10	265.78	15,901	1.9	0.13	Dominated	Dominated
+7.5	1,964	172.63	234.64	11,926	1.4	0.10	Dominated	Dominated
+5.0	1,703	162.16	203.50	7,950	0.9	0.07	Dominated	Dominated
+2.5	1,442	151.69	172.36	3,975	0.5	0.03	Dominated	Dominated
Current	1,182	141.22	141.22	0	0.0	0.0	—	—
-2.5	921	130.75	110.08	-3,975	-0.5	-0.03	231,753	3,358,742
-5.0	661	120.28	78.94	-7,950	-0.9	-0.07	3,098	1,204,320
-7.5	400	109.81	47.80	-11,926	-1.4	-0.10	33,546	486,179
-10.0	139	99.34	16.66	-15,901	-1.9	-0.13	8,770	127,108
-11.3	0	93.90	0	-17,968	-2.1	-0.15	—†	—

* All costs are expressed in 2006 U.S. dollars. Dominated refers to dominated strategies, which are both more harmful and more expensive than competing strategies.

† Cost-effectiveness is not reported for decreases of 11.3% or more because these decreases in PAEs are not associated with costs.

million (\$2.0 million to \$7.4 million in 2006 U.S. dollars).^{41,94} Although even a 2.5% reduction in preventable adverse events yields a cost-effectiveness ratio within this range (\$3.4 billion), the life expectancy of patients who have these events appears to be much shorter than that assumed by the “statistical life” valuations. For example, one study showed that adjustment for the probability of living until hospital discharge if no preventable adverse event occurred reduced mortality rates associated with these events by a factor of four.⁴⁹

The fact that the recommended changes may be cost-effective for society but cost-generating for teaching hospitals makes financing a complex issue. Possible strategies that teaching hospitals could use to manage the additional costs include reducing residents' salaries, increasing the workload of faculty physicians without increasing compensation, increasing charges to patients, allowing profitability to decrease, reducing clinical services, allowing quality of care to decline, improving efficiency, and securing subsidies — or not implementing the recommendations.

If the recommendations are implemented,

oversight will be important because of the financial incentives for hospitals to minimize expenditures. Nonadherence to the 2003 limits can contribute to a program's loss of accreditation and Medicare GME support.⁹⁵ The ACGME cited 8.8% of programs for nonadherence in 2006–2007, but this rarely affected accreditation.⁹⁶ Yet researchers have documented widespread nonadherence, lack of attention to handoffs of patient care, and some erosion of educational opportunities.^{12,13,17,28,97} To address these issues, the IOM committee recommended greater oversight.²⁰

The available data create uncertainty in our estimates. Work-hour data for PGY-1 residents are from 2004. For residents in PGY-2 and beyond, available studies have either focused on one specialty or on one or two hospitals; however, these studies were large, addressed major specialties, and were based at major teaching institutions. Few studies have indicated which substitutes can perform the tasks of residents, but midlevel providers and attending physicians are widely accepted as substitutes. The recommended changes could alter patterns of health care utilization measures such as length of stay, which

would have unpredictable effects on costs and clinical outcomes. Additional IOM recommendations, including an additional day off per month, were omitted from our study, but they appear to be unlikely to involve substantial costs. The costs of training substitutes and managing residents' work hours have seldom been described.⁷⁰ The omission of the costs of providing the additional day off, training substitutes, and managing residents suggests that \$1.6 billion could be too low, whereas several sensitivity analyses suggest that this amount may be too high. Although we performed sensitivity analyses for various scenarios, we are unable to predict with certainty how teaching hospitals would choose to implement these recommendations.

Preventable adverse events have not been assessed in teaching hospitals recently. Thomas et al.²² may have overestimated the rate of these events.^{44,49,98} We excluded studies that assessed rates or costs of one type of event or of negligent adverse events, studies that were limited to specific populations or settings, those that used administrative data, and those conducted in other countries, but the estimates of Thomas et al.²² were not markedly different from estimates in the studies we excluded.^{23,44-47,49,99,100} Care costs more at teaching hospitals; therefore, preventable adverse events may also cost more.^{101,102} Payers sometimes reimburse the costs associated with these events; however, this decreases the

likelihood of net savings to hospitals, and Medicare has stopped reimbursing hospitals for the costs associated with certain events.^{86,89} Reducing residents' motor-vehicle crashes and occupational injuries would provide additional benefits to society.

In conclusion, the IOM has recommended improved implementation of the 2003 reforms, a 5-hour nap during extended shifts, a 16-hour limit for shifts without naps, and reductions in residents' workloads. The labor costs associated with transferring all the excess work to alternative providers would be relatively high (\$1.1 billion to \$2.5 billion), and the effectiveness of doing so is unknown. If the changes were highly effective, they could prevent patient harm at reduced or no cost to society. However, financial incentives for teaching hospitals are not well aligned with the implementation of these reforms.

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