Postpartum Length of Stay and Newborn Health: A Cost-Effectiveness Analysis

Jesse D. Malkin, MPhil, PhD*; Emmett Keeler, PhD‡; Michael S. Broder, MD, MSHS‡§; and Steven Garber, PhD‡

ABSTRACT. ***Objective.*** **To evaluate the cost-effectiveness of increasing lengths of brief postpartum hospitalizations.**

Methods. **A cost-effectiveness model extrapolating from secondary data was used. Social costs in 2000 US dollars were estimated using several sources, including a randomized controlled trial, a retrospective study, and survey data. Life-years saved from reduced infant mortality were estimated from administrative data from Washington State. A total of 113 147 singleton newborns who were born in nonmilitary hospitals in Washington State in 1989 or 1990 and had postpartum stays short enough to be affected by length of stay legislation were studied. The cost-effectiveness of increases in postpartum lengths of stay similar to those that would occur if all mothers and singleton newborns used at least the time allotted to them under the federal length of stay legislation was measured.**

Results. **Estimated lower-bound cost per newborn life-year saved was $19 800 (95% confidence interval: $11 600–$61 300) when only neonatal deaths were considered. The corresponding upper-bound estimate was $94 800 (95% confidence interval: $55 200–$286 800). The results were very sensitive to assumptions about the discount rate for future life-years and the time from birth during which averted deaths are considered (neonatal deaths, postneonatal infant deaths, or all infant deaths).**

Conclusions. **At hospitals that do not experience additional capacity costs as a result of increased lengths of stay, lengthening short postpartum stays seems to be more cost-effective than many common health interventions and well below cost-effectiveness thresholds suggested by the literature. Even at hospitals that experience additional capacity costs, the cost-effectiveness of lengthening short postpartum stays seems to be roughly equal to the benchmark of $100 000 per quality-adjusted life-year suggested by the literature.** ***Pediatrics*** **2003;111:e316–e322. URL: http://www.pediatrics.org/cgi/content/full/111/4/e316;** ***postpartum, length of stay, newborn, mortality, cost.***

ABBREVIATIONS. LOS, length of stay; CI, confidence interval; SES, socioeconomic status.

From *RAND, Arlington, Virginia; ‡RAND, Santa Monica, California; and §Department of Obstetrics and Gynecology, UCLA School of Medicine, Los Angeles, California.

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Reprint requests to (J.D.M.) RAND, 1200 S Hayes St, Arlington, VA 22202-5050. E-mail: malkin@rand.org

Social, regulatory, economic, and technologic forces have resulted in dramatic reductions in newborns' lengths of postpartum hospital stays in the United States, from an average of 5 days in 1970 to <3 days in 1995.[1] Similar declines have occurred in other countries. In 1991, the American Academy of Pediatrics and the American College of Obstetricians and Gynecologists expressed concern about the health effects of short postpartum stays. In response to such concerns, Congress and many state legislatures passed laws prohibiting health plans and insurers from restricting insurance coverage to fewer than 48 hours after vaginal deliveries or 96 hours after cesareans (see, eg, 42 US Code Service §300gg-4). This legislation was enacted without much knowledge about the health and economic implications of lengthening postpartum hospitalizations. Indeed, Congress called for studies to examine "the issues and consequences associated with the length of hospital stays following childbirth" (Public Law 104-204, 1997).

The belief that longer stays would improve infants' health was 1 reason Congress passed minimum length of stay (LOS) legislation, and some evidence supports this belief. Several studies have found positive associations between short postpartum stays and neonatal hospital readmission.[2–6]

There is also evidence that short stays increase neonatal mortality. Of the 4 million infants born in the United States each year, approximately 20 000 (5 of 1000) die during the neonatal period (ie, during the first 28 days of life), and another 10 000 die after the neonatal period but before their first birthday.[7] Some of these deaths are caused by conditions that can be treated successfully if they are diagnosed promptly, such as congenital heart disease, infection, and other health problems that may not be evident until 2 or more days after the delivery.[8,9] We are aware of only 3 studies published within the past 30 years that evaluated the association between early discharge and infant mortality. One study focused primarily on readmissions during the first 6 weeks of life among South Carolina newborns but also reported results on mortality.[10] The second study assessed neonatal mortality associated with early discharge among Utah newborns.[11] Both of these studies found higher risks of death with early discharge (odds ratios: 1.65 and 4.04, respectively), but the confidence intervals (CIs) included 1.00 (ie, the associations between early discharge and infant mortality were not statistically significant). More recently, a third study, based on more data, found a substantial and statistically significant association between early discharge and mortality among Washington State newborns (odds ratio: 3.65 for early versus late discharge; 95% CI: 1.56–8.54).[12]

After the postpartum laws were enacted, the mean postpartum stay in the United States increased from 2.8 days to 3.1 days, according to data from the Health care Utilization Project Nationwide Inpatient Sample. Two studies of costs concluded that increasing postpartum LOS is associated with additional hospital costs of $20 to $23 per hour (in 2000 dollars).[13,14] Thus, according to these studies, extending the average postpartum stay by 12 hours would cost a hospital between $240 and $276 per birth. These estimates seem to be too high for hospitals where longer stays do not affect hospital capacity. Most important, it remains unclear how the costs of extending postpartum stays compare to the benefits. The present study evaluates the social cost-effectiveness of lengthening postpartum hospitalizations, focusing on infant mortality as the health outcome.

METHODS

We considered the increases in postpartum LOS that would occur if all mothers and newborns used at least the time allotted to them under the federal postpartum LOS legislation. Our study adopted the social perspective. Specifically, we treat all costs and benefits to all members of society as relevant, and we value resources according to the value to society (rather than according to prices paid by purchasers). We were not able to quantify all social costs and benefits, however. Our cost measure included direct medical costs but not postdischarge care provided by the mother and her family. Our effectiveness measure was years of life gained by reducing newborn mortality, which ignores other health benefits. We chose this outcome because it is clinically important, it can be estimated using administrative data, and a previous study found a medically and statistically significant association between postpartum LOS and infant mortality.[12] We assessed nonmedical costs and health benefits other than reduced mortality qualitatively (see Discussion section).

Costs

We estimated the increase in direct medical costs as a result of increases in postpartum LOS. To do so, we considered costs associated with changes in use of 3 categories of resources expected to vary with LOS: 1) hospital inputs (nursing labor, janitorial services, consumables, capacity, additional postpartum recovery beds, and cribs), 2) physician (pediatrician and obstetrician) labor, and 3) postdischarge professional care for the mother or newborn (newborn or maternal hospital readmissions, home nursing visits, visits to clinics, physician offices, hospital outpatient and emergency departments). We expect the first 2 to increase with longer LOS and the third to decrease.

Development of a single estimate of additional costs of longer stays was not appropriate because of uncertainty about changes in resource use, which we would expect to vary considerably from hospital to hospital. Instead, we developed 2 estimates that define a range in which we expect costs to fall for almost all hospitals. Our lower-bound cost estimate incorporated labor costs but ignored hospital and physician overhead costs, which may or may not be affected by an increase in the length of postpartum stays, depending on the setting. Our upper-bound estimate incorporated all resources that might be required in any setting, including potential increases in physician and hospital overhead. To calculate the lower- and upper-bound cost estimates, we relied on data from surveys,[15,16] a randomized controlled trial,[17] and administrative records.[6,13,18]

All costs were expressed in 2000 US dollars using the medical care component of the Consumer Price Index. We did not discount costs because almost all costs attributable to increased postpartum LOS are incurred within the first few weeks after birth. Our cost estimation methods are detailed in Table 1.

Effects on Infant Mortality

We used a historical cohort design to estimate the effects of additional LOS on infant mortality. The source population was drawn from a data set of newborns in Washington State in 1989 and 1990 developed by the RAND Management and Outcomes of Childbirth Patient Outcomes Research Team. Approval to use this database was obtained from the RAND Human Subjects Protection Committee and the Washington State Department of Health. These data were used in an earlier study that found a significant association between early discharge and infant mortality.[12]

The Birth Event Record Database contains linked birth certificates, hospital discharge records, and death certificates for 126 370 newborns accounting for 84% of births in Washington State during 1989 and 1990. Approximately two thirds of the unrepresented births occurred at military hospitals or in homes; the remainder were multiple births ($n = 1067$), newborns under 2500 g of birth weight ($n = 6120$), and cases with extensive missing data ($n = 32$). Additional information is available in Keeler et al.[18]

For this study, we excluded 4 additional groups: newborns who were transferred to another facility on discharge or died before they were discharged ($n = 1204$), newborns with estimated stays of <5 hours ($n = 610$) because stays recorded to be this short are likely to involve coding error, newborns whose birth certificate was missing the hour of birth ($n = 31$), and vaginally delivered newborns with stays of more than 2 nights ($n = 8911$) and cesarean section newborns with stays of >4 nights ($n = 2760$) because these stays are too long to be affected by the LOS mandate. The sample size for analysis was 113 147.

Estimation Strategy

We used logistic regression to predict changes in the probabilities of newborn mortality as a result of changes in LOS. The dependent variable equals 1 if the newborn died during the neonatal period (the first 28 days of life), during which time the association between early postpartum discharge and infant mortality is strongest.[12] The explanatory variable of primary interest was LOS in hours.

Measurement of LOS was complicated because time of discharge was not reported in our data, a problem shared by other studies of postpartum LOS based on administrative data.[2,4,12,19] Two previous studies responded to this difficulty by comparing deaths among newborns with stays of <30 hours to deaths among newborns with stays of 30 to 78 hours.[2,12] Following a previous study of newborn readmissions,[6] however, we estimated LOS in hours using the known hour of birth and number of nights stayed along with assumptions about the time of discharge. We tested our estimation strategy on 1993 RAND survey of 2447 newborns born in Los Angeles and Iowa for whom actual LOS in hours was measured.[20] For the surveyed population, LOS as estimated for the present study was within 3 hours of true LOS for 71.1% of newborns. In addition, among 1125 women in the RAND survey who had vaginal deliveries and had postpartum stays of <3 nights, regressing actual LOS on LOS as estimated for the present study yielded an R^2 statistic of 0.94, meaning that our algorithm explained 94% of variation in actual LOS.

To reduce possible confounding of the association between LOS and infant mortality, we controlled for other possible predictors of mortality. Control variables included whether the mother was married at the time of the birth, her Medicaid status, whether she was multiparous, whether she was <18 years old, the newborn's gender, and the newborn's race. Clinical variables such as infection, respiratory problems, and trauma had little effect in a previous study that considered the effect of LOS on infant mortality.[12] Therefore, we did not include these variables in our base case analysis. We did, however, include them in a sensitivity analysis (ie, an analysis designed to assess the impact of alternative assumptions on results). We did not include interaction terms. We prespecified the variable list; we did not modify the model on the basis of the significance of coefficients.

To predict the effect of longer stays on the infant mortality rate, we estimated each newborn's probability of death assuming 2 alternative LOS: the actual estimated LOS and the LOS projected if all mothers and newborns used at least the time allowed under the federal mandate. For vaginal deliveries that occurred during

TABLE 1. Methods Used to Develop Cost Estimates: Assumptions and Sources

Cost Category	Lower-Bound Cost Estimate		Upper-Bound Cost Estimate	
	Resource Effect	Cost per Unit	Resource Effect	Cost per Unit
Hospital (increases with longer LOS)	Additional nursing labor of 2.5 h for each additional 12 h of LOS[17]	$6.67/h of extra stay*	Additional nursing and other labor, consumables (eg, ice packs, drugs), hospital overhead costs	$23/h of extra stay†
Physician (increases with longer LOS)	Two additional 15-min visits—1 by a pediatrician and 1 by an obstetrician/gynecologist—for every additional night's stay; no additional overhead (authors' assumption)	$33 per pair of physician visits‡	Two additional 30-min visits—1 by a pediatrician and 1 by an obstetrician/gynecologist—for every added night's stay; plus additional physician overhead (authors' assumption)	$94 per pair of physician visits‡
Postdischarge medical care (decreases with longer LOS)	Hospital resources saved as a result of reduced newborn readmissions; varies according to LOS§		None	
Postdischarge informal care (decreases with longer LOS)	None		None	

* Mean compensation of hospital nurses in 2000 was $32/hour.[16] For every 4.8 hours of additional LOS (12/2.5 = 4.8), 1 additional hour of nursing care is assumed to be provided. Thus, the cost of additional nursing care is assumed to be $6.67 for each hour added to the patient's LOS ($32/4.8 hours = $6.67/hour).
† In Maryland, LOS increased by 0.51 per day per delivery after implementation of that state's postpartum mandate, and inflation-adjusted charges increased by $282.31,[13] suggesting an increase in charges of $23.06/hour. Incremental charges should overstate incremental hospital costs because 1) charges may include overhead costs that are not sensitive to LOS and 2) many variable costs that may be built into charges on a flat per diem basis are higher on earlier days than on later days of a stay.
‡ Pediatricians' mean income (after expenses, before taxes) in 1998 was $139 600, or $150 272 in 2000 dollars, or $57.93/hour assuming 54.5 hours of work per week, 47.6 weeks/year.[15] Obstetrician/gynecologists' mean income in 1998 was $214 400, or $230 790 in 2000 dollars, or $75.64/hour assuming 63.7 hours of work per week, 47.9 weeks/year.[15] For the upper-bound cost estimate, we added 40% of physician labor costs to represent physician overhead.[37]
§ Calculated as ([prob(readmission | old LOS)] − [prob(readmission | new LOS)]) × (mean charge for readmission × 0.8). The predicted probabilities are for readmission within 28 days of birth[6] assuming all newborns weigh 3500 grams, have no congenital anomalies or newborn abnormalities, have a gestational age of 40 weeks, are male, and are born to mothers who are at least 18 years of age and married. Mean charge for readmission is from the Birth Event Record Database. Charges were multiplied by 0.8, the mean hospital-level cost to charge ratio for Washington State hospitals in 1989 and 1990, according to data provided by the Washington State Department of Social and Health Services.

normal business hours (ie, between 8:00 AM and 7:59 PM), we assumed that stays of <48 hours would be extended to 48 hours. For cesarean section deliveries that occurred during normal business hours, we assumed that stays of <96 hours would be extended to 96 hours. For deliveries that occurred outside normal business hours (when discharges generally do not occur), we assumed that stays would be extended to 48 or 96 hours plus the additional time required for discharge to occur at 8:00 AM. For example, if a vaginal delivery occurred at 5:00 AM on a Monday, then we assumed that the mandate would extend the LOS to 8:00 AM on Wednesday (51 hours).

We estimated lives saved from increasing LOS by subtracting the mean predicted probability of death with the increased LOS from the mean predicted probability of death based on observed LOS. Resulting additional years of life were obtained by multiplying the number of lives saved by the estimated discounted life-years gained per life saved. To estimate discounted life-years per life saved, we assumed that newborns saved by the increase in LOS would have lived 76 years after their death[21] and used a 3% annual discount rate, as recommended by Lipscomb et al.[22] In sensitivity analyses, we considered postneonatal infant deaths, different transformations of LOS, and alternative life expectancies and discount rates.

In summary, the numerator of the cost-effectiveness ratio was the estimated direct medical costs per birth as a result of increasing LOS. The denominator was the estimated additional discounted years of life saved. We used bootstrapping[23] with 1000 resamples to develop 95% CIs for the cost-effectiveness ratios. Statistical analysis was performed using Stata version 7.0 (Stata Corp, College Station, TX).

RESULTS

Comparisons of characteristics of newborns with relatively short and long postpartum stays, stratified by method of delivery (vaginal versus cesarean section) are provided in Table 2. Newborns with short stays had lower socioeconomic status than newborns with longer stays according to Medicaid status, marital status, and age. Other measures indicated that the newborns with short stays were healthier on average. Among vaginal deliveries, newborns with short stays were more likely to have multiparous mothers. The infant mortality rate, however, was higher among newborns with short stays than for newborns with longer stays.

Estimated coefficients for our base-case logistic regression are presented in Table 3. There was a significant negative association between LOS and infant mortality. The coefficient on LOS was −0.026 (95% CI: −0.044 to −0.008), meaning that a 1-hour increase in LOS was associated with a reduction in the probability of neonatal death of approximately 2.6%.

The mean increase in estimated LOS to conform with the mandate, assuming that all patients in our sample used at least the time allotted to them and all

TABLE 2. Characteristics of Sample*

Estimated LOS (Hours) Sample Size	Vaginal Delivery			Cesarean Delivery		
	<24 (n = 16 904)	24–48 (n = 53 320)	>48 (n = 20 550)	<72 (n = 5633)	72–96 (n = 11 604)	>96 (n = 5136)
Maternal characteristics (%)						
Covered by Medicaid	39.12	30.21	21.67	31.23	25.90	21.32
Married	71.79	75.57	80.44	75.57	80.04	82.17
Multiparous	65.62	59.03	59.13	47.75	52.54	61.97
<18 y of age	4.44	3.93	2.80	3.18	2.23	1.36
Newborn characteristics (%)						
Male	48.08	50.58	51.54	52.60	53.97	53.29
Black	2.58	4.17	4.78	3.91	4.51	5.37
Hispanic	14.59	9.90	6.24	10.42	8.92	6.93
Any congenital anomaly	1.33	1.56	1.83	1.74	1.63	2.12
Low Apgar score†	0.30	0.50	0.63	1.05	0.78	1.03
Mild or moderate trauma	5.99	8.38	9.85	3.85	4.17	3.33
Infection	0.11	0.12	0.36	0.36	0.52	0.72
Severe respiratory problems	0.98	1.49	2.00	2.75	3.11	3.56
Other severe outcomes	0.12	0.24	0.31	0.28	0.43	0.58
Preterm	2.33	3.00	3.18	3.44	3.19	3.19
Mortality rate (per 1000 births)						
Deaths within 28 d of birth	0.9	0.3	0.2	0.9	0.3	0.0
Deaths within 90 d of birth	3.0	1.8	1.3	2.3	1.2	0.8
Deaths within 1 y of birth	4.9	3.2	2.7	3.2	2.3	2.3

* Among vaginal deliveries, $P < .01$ for Fisher exact tests between LOS categories for each characteristic listed. Among cesarean section deliveries, $P < .01$ for Fisher exact tests between LOS categories for maternal characteristics and newborn race variables; $P < .05$ for Fisher exact tests between LOS categories for mild/moderate trauma, infection, and deaths within 28 days.
† Five-minute Apgar score of <7.

TABLE 3. Estimates From Logistic Regression Analysis for Neonatal Death

	Coefficient	Standard Error	P Value	95% CI
Estimated LOS (h)	−0.026	0.009	.004	[−0.044 to −0.008]
Infant male	0.456	0.310	.142	[−0.152 to 1.063]
Mother or father or both Hispanic	−0.491	0.539	.363	[−1.548 to 0.566]
Mother or father or both black	0.416	0.613	.498	[−0.786 to 1.618]
Mother married	0.061	0.387	.876	[−0.698 to 0.819]
Mother on Medicaid	0.703	0.355	.048	[0.008 to 1.398]
Mother multiparous	0.286	0.336	.394	[−0.372 to 0.945]
Mother <18 y of age	1.142	0.647	.401	[−0.725 to 1.812]

Sample size: 113 147; LR χ^2 (8) = 21.17; P value for model as a whole = .007.

discharges occur between 8 AM and 8 PM, was 15 hours. The mean predicted probability of neonatal death fell from 0.039% using estimated actual LOS to 0.025% assuming increased LOS—a decline of 36%. The mean projected increases in total direct medical costs were $84 and $401 per birth for the lower and upper bounds, respectively. Table 4 presents a decomposition of predicted cost changes by type of medical resource and provides information on sampling variability.

For our base case, incremental costs per discounted life-year gained were $19 800 (95% CI: $11 600–$61 300) and $94 800 (95% CI: $55 200–$286 800) based on our lower- and upper-bound estimates, respectively (Table 5). We conducted a series of 1-way sensitivity analyses to assess the robustness of these findings. The results, presented in Table 5, were robust to exclusion of observable socioeconomic status variables, changes in the specification of the LOS variable, assumed life expectancy, inclusion of additional clinical variables in the regression, and a 50% reduction in the assumed increases in LOS. The results were moderately sensitive, however, to the addition of an indicator of method of delivery to the logistic regression. The results were very sensitive to the definition of the dependent variable. As

TABLE 4. Change in Medical Cost per Birth as a Result of the Postpartum LOS Legislation

Type of Resource	Lower-Bound Estimate					Upper-Bound Estimate				
	Mean	Median	Standard Deviation	25th Percentile	75th Percentile	Mean	Median	Standard Deviation	25th Percentile	75th Percentile
Hospital	$98	$127	$87	$5	$145	$340	$437	$301	$18	$499
Physician labor	$22	$33	$21	$0	$33	$62	$94	$59	$0	$94
Postdischarge medical care	−$36	−$39	$34	−$2	−$53	$0*	$0*	$0*	$0*	$0*
All medical costs	$84	$110	$76	$3	$130	$401	$531	$359	$18	$593

* For the upper-bound estimate, we assumed that the increase in postpartum LOS has no impact on the cost of postdischarge medical care.

TABLE 5. Sensitivity of Cost-Effectiveness Ratios to Key Assumptions

Parameter	Estimated Cost-Effectiveness Ratio	
	Lower Bound	Upper Bound
1. Base case*	$19 800	$94 800
2. Do not control for observed SES variables (Medicaid status, race, maternal marital status, and maternal age) in the logistic regression	$19 000	$91 200
3. LOS specified as ln (LOS)	$17 300	$83 200
4. LOS specified as 1/LOS	$24 200	$116 300
5. Life expectancy of 66 y	$20 600	$98 900
6. Life expectancy of 86 y	$19 200	$92 000
7. Control for clinical variables (infection, severe respiratory problems, trauma, other severe outcomes, preterm delivery) in logistic regression	$16 900	$81 100
8. Assume increase in LOS is half what would occur if all newborns and mothers used up the full amount of time allotted to them under federal law	$19 600	$90 200
9. Include an indicator variable for method of delivery in the logistic regression	$11 500	$55 000
10. Include all deaths that occurred within 90 d of birth in the dependent variable	$7100	$34 000
11. Include all deaths that occurred within 1 y of birth in the dependent variable	$6200	$29 900
12. Discount rate of 0% annually	$8000	$38 300
13. Discount rate of 5% annually	$29 600	$142 200

* LOS untransformed; life expectancy of 76 y after time of infant death; 3% annual discount rate; ignore postneonatal deaths.

alternatives to considering only those deaths that occurred within 28 days of birth, we also considered all deaths within 90 days of birth and all deaths within 1 year of birth. Changing the dependent variable in this manner reduced the cost-effectiveness ratios considerably. The results were also very sensitive to the discount rate. A higher discount rate reduces the present value of future life-years gained and increases the cost-effectiveness ratios. For a 5% discount rate, the last 20 years of an infant's life, for example, have a present value of only 0.85 life-years in total, as compared with 2.93 life-years when a 3% discount rate is used.

DISCUSSION

We assessed the cost-effectiveness of lengthening short postpartum hospital stays to the levels specified in federal legislation. Our estimated lower-bound cost-effectiveness ratio of $19 800 per life-year saved compares favorably to several other interventions commonly provided to newborns:

- Palivizumab, a medication routinely given to premature newborns to prevent respiratory syncytial virus, has been estimated to cost society between $39 000 and $1 430 000 per life-year saved relative to no prophylaxis.[24] On the basis of worldwide sales of about $500 million in 2001 (MedImmune 2001 Annual Report: 2), a US average wholesale price of $700 to $1400 per injection,[25] and 5 injections per infant,[26] we estimate that 70 000 to 140 000 infants received palivizumab worldwide in 2001.
- Pneumococcal conjugate vaccine, which is used to protect infants against certain pneumococcal bacteria that can cause life-threatening meningitis and blood infections, has been estimated to cost society $80 000 per life-year saved.[27] The American Academy of Pediatrics recommends the routine intramuscular administration of pneumococcal conjugate vaccine to all children 23 months and younger.[28] With worldwide sales totaling about $800 million in 2001 (Wyeth 2001 Annual Report: 4), a US average wholesale price of $70 per injection,[25] and several injections per infant per year, we estimate that at least 3 million infants received pneumococcal conjugate vaccine worldwide in 2001.
- Neonatal intensive care for premature newborns weighing 0.5 to 1 kg has been estimated to cost $55 000 per quality-adjusted life-year saved.[29]

The denominator in our study was life-years saved, not quality-adjusted life-years saved, as in the neonatal intensive care analysis. It is likely, however, that the cost per quality-adjusted life-year gained as a result of an increase in postpartum LOS is not much higher than the cost per life-year gained. In a cost-utility model, outcomes are adjusted for quality of life using utility weights ranging from 0 (death) to 1 (perfect health). Assuming that most newborns saved by an increase in postpartum LOS live normal lives, their utility weights would be close to 1 in most years, except during old age, when the effect of quality-of-life adjustment would have little impact on the cost-effectiveness ratios because of discounting.

Regarding our upper-bound estimated cost-effectiveness ratio, there is no consensus on what threshold should be used to identify cost-effective interventions. Cutler and McClellan[30] valued quality-adjusted life-years at $100 000, based on their reading of the literature. A review by Hirth et al,[31] however, suggested that the social value of 1 quality-adjusted life-year exceeds $100 000. According to these thresholds, longer hospital stays resulting from the federal postpartum mandate would be economically efficient even according to our upper-bound estimate of $94 800 per life-year saved.

All of the estimated cost-effectiveness ratios assume that our estimated relationships between early discharge and increased infant mortality are causal. Because our data are not from a randomized controlled trial data, however, our estimates may be confounded by uncontrolled variables, such as unobserved newborn health status and unmeasured aspects of socioeconomic status (SES). Any effects of such differences would tend to average out in a randomized trial, but such a trial is not feasible because, for example, of the large study population required.

Regarding unobserved health problems, sicker newborns tend to have longer stays than healthier newborns and also are more likely to die. Thus, by not controlling for health status, our analysis would tend to underestimate benefits of longer stays and overstate cost-effectiveness ratios. In fact, controlling for infection, severe respiratory problems, trauma, other severe outcomes, and preterm status lowers both the lower- and upper-bound cost-effectiveness ratios by approximately 15% (Table 5).

Potential biases as a result of unobserved aspects of SES may work in the opposite direction, however. Our mortality regressions (Table 3) control for the mother's Medicaid and marital status, as well as her age and race, but they do not include other SES variables, such as family income, employment status, education levels, and wealth (which are not included in our data). If, holding constant the measured SES variables, unmeasured SES variables tend to predict longer stays and lower mortality probabilities when SES is higher, then our estimates will tend to overestimate benefits of longer stays and understate cost-effectiveness ratios. To probe the potential importance of unobserved SES variables, we reestimated the mortality regression excluding all of our observed SES variables (Medicaid, marital status, race, and age). Doing so had virtually no effect on our results (Table 5). Because our estimates are largely insensitive to the inclusion of several important SES variables, we infer that they are very unlikely to be substantially confounded by omission of additional, unobserved SES variables.

We assumed that all mothers and newborns used at least the time allowed under the federal mandate, resulting in an increase in mean LOS of 15 hours among the newborns in our sample. The actual average increases in LOS since the mandate, however, are smaller than this, according to nationally representative hospital discharge data (Healthcare Utilization Project Nationwide Inpatient Sample). The discrepancy is partly explained by differences in the population being assessed: our sample excludes newborns with stays too long to be affected by the LOS mandate, whereas national hospital discharge data include them. Even so, it is likely that our model overstates the increase in LOS caused by the legislation, because many mothers may not want to use all of the time allotted to them under the federal law (ie, they may prefer to go home sooner). Also, many hospitals and physicians are reimbursed for deliveries on a capitated or case rate basis, which gives them an incentive to discharge postpartum patients quickly. Involuntary early discharges may still occur because federal law and virtually all state laws apply only to insurers. Even if postpartum laws are having a smaller effect than that assumed in our analysis, the cost and the effectiveness of postpartum LOS laws decline together, resulting in little change in the cost-effectiveness ratios (Table 5).

Five other considerations suggest that our analysis understates the cost-effectiveness of lengthening postpartum stays. First, Washington has proportionately fewer teen births and racial and ethnic minority births than the national average.[2] If an increase in postpartum LOS has a disproportionately beneficial effect on minorities or teen mothers (for example, teen mothers may benefit more than older mothers from receiving instructions on newborn care), then the mortality effects of early discharge estimated using data from Washington might understate those effects nationally.

Second, the most important initiative in pediatric care since 1990 was the Back to Sleep campaign by the American Academy of Pediatrics to educate parents about proper sleep position to decrease the risk of sudden infant death syndrome. To the extent that this campaign has been successful, we expect, other things equal, that infant mortality decreases more rapidly with longer postpartum stays today than was the case in our data.

Third, we took into account the possibility that longer postpartum stays would reduce the number of newborn rehospitalizations. However, we did not quantify maternal rehospitalizations or reductions in postdischarge outpatient care (home nursing visits, visits to clinics, physician offices, hospital outpatient departments, and emergency departments) because of lack of data.

Fourth, we did not quantify nonmedical costs such as those associated with postdischarge care provided by the mother and her family and friends. Such informal postdischarge care involves a net social cost if it prevents caregivers from engaging in activities that they prefer to providing care. Longer postpartum hospitalizations are likely to reduce the costs of informal care, but we lack data to estimate the magnitude of such an effect.

Fifth, we did not quantify some potential benefits of longer stays, such as fewer cases of nonfatal brain damage caused by untreated jaundice,[32] fewer cases of dehydration caused by improper breastfeeding by inadequately trained mothers,[33] improved maternal health outcomes,[34] increased opportunities for mothers to rest and recover,[35] and increased patient satisfaction.[36]

In sum, our estimated cost-effectiveness ratios are likely to be somewhat high relative to the true social cost per quality-adjusted life-year. Our lower-bound estimates are <\$30 000 per life-year saved. Our upper-bound estimates are predominately below \$100 000 per life-year saved, which the literature suggests is an appropriate (and perhaps too stringent) standard for gauging economic efficiency.

Our upper-bound estimates are pertinent only for hospitals at which the postpartum law will require new construction or prevent conversion of maternity capacity to alternative uses. Thus, we conclude that the social benefits of the mandate almost certainly exceed its social costs at hospitals where the mandate does not affect capacity. In addition, assuming that capacity costs per maternity day are similar to those reflected in the charge data from Maryland (that we used to construct our upper-bound estimates), our estimates suggest that the social benefits and social costs of the mandate are roughly equal for hospitals that have experienced additional capacity costs.

CONCLUSION

At hospitals that do not experience additional capacity costs as a result of increased LOS, lengthening short postpartum stays seems to be more cost-effective than many common health interventions and well below benchmarks suggested by the literature. Even at hospitals that experience additional capacity costs, the cost-effectiveness of lengthening short postpartum stays seems to be roughly equal to the $100 000 per quality-adjusted life-year benchmark suggested by the literature.

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Jesse D. Malkin, Emmett Keeler, Michael S. Broder and Steven Garber

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