ORIGINAL ARTICLE

Moderately premature infants at Kaiser Permanente Medical Care Program in California are discharged home earlier than their peers in Massachusetts and the United Kingdom

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Arch Dis Child Fetal Neonatal Ed 2006;**91**:F245–F250. doi: 10.1136/adc.2005.075093

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Accepted 16 January 2006
Published Online First
31 January 2006

Objective: To compare gestational age at discharge between infants born at 30–34⁺⁶ weeks gestational age who were admitted to neonatal intensive care units (NICUs) in California, Massachusetts, and the United Kingdom.

Design: Prospective observational cohort study.

Setting: Fifty four United Kingdom, five California, and five Massachusetts NICUs.

Subjects: A total of 4359 infants who survived to discharge home after admission to an NICU.

Main outcome measures: Gestational age at discharge home.

Results: The mean (SD) postmenstrual age at discharge of the infants in California, Massachusetts, and the United Kingdom were 35.9 (1.3), 36.3 (1.3), and 36.3 (1.9) weeks respectively ($p = 0.001$). Compared with the United Kingdom, adjusted discharge of infants occurred 3.9 (95% confidence interval (CI) 1.4 to 6.5) days earlier in California, and 0.9 (95% CI –1.2 to 3.0) days earlier in Massachusetts.

Conclusions: Infants of 30–34⁺⁶ weeks gestation at birth admitted and cared for in hospitals in California have a shorter length of stay than those in the United Kingdom. Certain characteristics of the integrated healthcare approach pursued by the health maintenance organisation of the NICUs in California may foster earlier discharge. The California system may provide opportunities for identifying practices for reducing the length of stay of moderately premature infants.

Industrialised countries have responded to increasing constraints on economic resources by attempting to improve both the efficiency and quality of healthcare delivery. In the United States, the “managed care model” has led to the creation of integrated healthcare delivery systems such as the Kaiser Permanente Medical Care Program (KPMCP). Recent cross national comparisons of health system performance suggest that KPMCP’s model of care may increase efficiency and improve outcomes.^{1–2} However, critics point out that such comparisons between healthcare delivery systems are limited by differences in patient populations and healthcare facilities.^{3–4}

We sought to investigate the validity of the above argument by comparing length of stay in a very homogeneous population of moderately premature infants with a gestational age at birth of 30–34 weeks admitted for care in California under the KPMCP’s Northern California Region with those admitted in Massachusetts and the United Kingdom. These infants have several characteristics that make them an ideal population for investigating differences in organisational care management: they are universally admitted to the neonatal intensive care unit (NICU); they are not usually very ill; although there are differences in medical management, the general care environment is similar across regions and countries.⁵

Moderately premature infants exhibit variable degrees of respiratory distress at birth, which resolves within a few days of appropriate care. Subsequently, these infants enter a developmental trajectory until discharge, gradually resolving issues of prematurity, including apnoea, feeding dysmaturity, and temperature control. As readiness for discharge depends

on a predictable pattern of developmental maturation consistent with gestational age, variations in length of stay are more likely to reflect differences in medical management rather than differences in case mix. Such differences have previously been documented in healthy, moderately preterm infants in a pilot study leading up to the moderately premature infant project (MPIP).⁶

Differences in length of stay are important given the concerns over rising costs of neonatal intensive care.⁷ As moderately premature infants represent about 60% of neonatal intensive care patients, even marginal differences in efficiency and quality of care have large cost implications.^{8–9} To address this question, we examined the length of stay for moderately premature infants (both those who are healthy and those who have complications) in California under KPMCP’s Northern California Region, Massachusetts, and the United Kingdom.

METHODS

We compared infants with a gestational age at birth of 30–34⁺⁶ weeks in California, Massachusetts, and the United Kingdom using data from two prospective cohort studies, the MPIP and the United Kingdom neonatal staffing study (UKNSS). Full details of these studies are described elsewhere.^{10–13} Aspects relevant to our analysis follow.

Abbreviations: IMD, index of multiple deprivation; KPMCP, Kaiser Permanente medical care program; MPIP, moderately premature infant project; NICU, neonatal intensive care unit; PMAD, postmenstrual age at discharge; UKNSS, United Kingdom neonatal staffing study

The MPIP included 10 level 2 and level 3 NICUs evenly divided between Massachusetts and California. Patients of 30–34⁺⁶ weeks gestational age at birth were prospectively enrolled just before discharge between September 2001 and January 2003. In four out of five units in California, infants received their care under the KPMCP system. In one unit a significant proportion of patients were covered under Medicaid and fewer than half the infants were Kaiser Permanente patients. Infants in Massachusetts were cared for under a variety of systems including public, private, and managed care. NICU logbooks were used to identify eligible patients up to a preset limit for each hospital based on previous birthing experience. Where the number of eligible births exceeded the preset limit, births were randomly sampled throughout the year of enrolment to achieve the limit. Infants who had been transferred between units were followed to discharge.

The UKNSS included 54 randomly selected NICUs out of 186 in the United Kingdom.¹¹ Infants were prospectively enrolled at birth between March 1998 and April 1999. We included infants with a gestational age of 30–34⁺⁶ weeks in this study. The discharge date for patients transferred out to another institution was not reliably recorded within the UKNSS, and thus transferred infants were not included in the main analysis.

Data in both studies were abstracted from patient charts. MPIP used a previously validated chart abstraction protocol, the neonatal minimum data set.¹⁴ The datasets contained a wide range of socioeconomic, perinatal, and postnatal variables. We used postmenstrual age at discharge home as the outcome variable because it takes into account the gestational age at birth. Analytically, it is also suitable for use as a dependent variable in generalised linear modelling.

Previous research has highlighted the importance of adjusting for case mix in comparing outcomes across

sites.^{15–20} In the US data set, information needed to calculate a SNAP-II score was collected.¹⁸ The United Kingdom data, however, did not allow us to construct a SNAP-II score. Thus, in both data sets, we identified as potential confounders those variables common to United States and United Kingdom data that contributed to the risk adjustment models developed in the UKNSS: birth weight, size for gestation, caesarean section, sex, Apgar score at five minutes, antenatal steroids, and mechanical ventilation.

We tested for significant differences between the three regions, using analysis of variance, Kruskal-Wallis, and χ^2 tests depending on the nature and distribution of the variable. We then used linear regression to construct a model showing the impact of these variables on the primary relation between postmenstrual age at discharge (PMAD) and location of care. We used generalised estimating equations to correct the standard errors of the hospital level variables for the effect of within hospital correlation.²¹

For illustration, we produced a funnel plot of the adjusted PMAD.²² We plotted the adjusted PMAD against the number of admissions, along with corresponding 99.9% control limits. Funnel plots are a variation on control charts identifying units with unexpectedly high (above upper control limit) or low (below the lower control limit) adjusted PMAD. Units with adjusted PMAD within the control limits are defined to have adjusted PMAD consistent with random variation. Funnel plots are a superior alternative to league tables and ranks for the presentation of performance measures.

Potential biases: socioeconomic status

We did not have available uniform measures of socioeconomic status for all three regions. Within the United States data, information was available for infants on race, income, and maternal education as markers of socioeconomic status. We collapsed race into white and non-white. We

Table 1 Infant characteristics by region of care

	California	Massachusetts	United Kingdom	Total	p Value
Number of infants	390	460	3509	4359	
Mother received antenatal steroids					
Yes/total	259/387	305/460	2285/3485	2849/4332	0.839
Percentage	66.9	66.3	65.6	65.8	
Delivered by caesarean section					
Yes/total	223/390	269/460	1988/3508	2480/4358	0.758
Percentage	57.2	58.5	56.7	56.9	
Gestational age at delivery (weeks)					
Mean (SD)	32.8 (1.3)	32.7 (1.3)	32.7 (1.3)	32.7 (1.3)	0.280
Sex of infant					
Male/total	193/390	236/460	1862/3508	2291/4358	0.342
Percentage	49.5	51.3	53.1	52.6	
Birth weight (g)					
Median (25th, 75th centile)	1885 (1615, 2191)	1975 (1670, 2237)	1905 (1619, 2200)	1910 (1622, 2200)	0.009
Apgar score at 5 min					
Median (25th, 75th centile)	9 (8, 9)	9 (8, 9)	9 (9, 10)	9 (8, 9)	<0.001
Infant received mechanical ventilation					
Yes/total	89/390	136/460	936/3484	1161/4334	0.084
Percentage	22.8	29.6	26.9	26.8	
Postmenstrual age at discharge (weeks)					
Mean (SD)	35.9 (1.3)	36.3 (1.3)	36.3 (1.9)	36.2 (1.8)	<0.001
Maternal race					
White/total	109/306	296/367	na	405/673	<0.001
Percentage	26.9	73.1		60.2	
Family income					
Income >\$50 000/total	204/306	317/370	na	521/676	<0.001
Percentage	66.7	85.7		77.1	
Maternal education					
Graduated from high school/total	229/305	313/370	na	542/675	0.002
Percentage	75.1	84.6		80.3	
Index of multiple deprivation					
Median (25th, 75th centile)	na	na	22.3 (14.6, 34.4)		

p Value indicates whether the distribution of each infant characteristic differs significantly across region of care.
na, Not available.

Table 2 Relation between postmenstrual age at discharge, characteristics of the infant, and region of care

	Coefficient (PMAD in weeks)	SE	95% CI	p Value
Constant	32.93	1.05	(30.87 to 35.00)	<0.001
Region of care				
California	-0.56	0.19	(-0.93 to -0.19)	0.003
Massachusetts	-0.13	0.15	(-0.43 to 0.17)	0.385
United Kingdom	0			
Mother received antenatal steroids				
Yes	-0.005	0.05	(-0.10 to 0.09)	0.920
No	0			
Infant delivered by caesarean section				
Yes	0.07	0.05	(-0.02 to 0.16)	0.121
No	0			
Gestational age at delivery (weeks)	0.11	0.03	(0.06 to 0.16)	<0.001
Sex of infant				
Male	0.15	0.05	(0.05 to 0.24)	0.003
Female	0			
Size for gestation (birthweight z- score)	-0.70	0.04	(-0.78 to -0.62)	<0.001
Apgar score at 5 min	-0.06	0.04	(-0.13 to 0.01)	0.103
Infant received mechanical ventilation				
Yes	0.75	0.06	(0.64 to 0.87)	<0.001
No	0			

The adjusted postmenstrual age at discharge (PMAD) is shown together with the 95% confidence interval (CI). All coefficients are adjusted for the clustered nature of the data ($n = 4216$; 143 patients with missing covariates were excluded).

examined the relation of each variable to PMAD separately. To assess the impact of socioeconomic status on the California and Massachusetts comparison, we included these socioeconomic factors in the case mix model, including a term to indicate whether the infant was treated in California or Massachusetts.

Within the United Kingdom data, we matched the infant's family postcode with the United Kingdom census ward-level 2000 index of multiple deprivation (IMD).^{23, 24} We assessed the impact of socioeconomic status by including a term for IMD in the case mix model.

Potential biases: transferred infants

Within the United Kingdom, we investigated the extent of potential bias of excluding the transferred infants. We applied the final case mix model above to both transferred and non-transferred infants in the United Kingdom data and compared the predicted PMAD between transferred and non-transferred infants.

We used Stata version 8.0 (StataCorp LP, College Station, Texas, USA) for all combined dataset analyses as well as SAS version 9.1 (SAS Institute Inc, Cary, North Carolina, USA) for statistical analyses restricted to MPIP.

RESULTS

Characteristics of the study sample

Overall, we analysed 4332 infants, including 387 from California, 460 from Massachusetts, and 3485 from the United Kingdom (excluding 86 infants who died before hospital discharge). Table 1 summarises the infant characteristics across the three areas. Similar proportions of infants received antenatal steroids and were delivered by caesarean section. Otherwise, no clear pattern in the characteristics of infants was found. Although the median gestational age at delivery was similar, Apgar scores were higher in the United Kingdom and birth weights were higher in Massachusetts compared with the other two areas. A lower proportion of infants in California received mechanical ventilation than infants in the other two areas.

Within the United States, a significantly ($p < 0.001$) greater proportion of infants were coded as white in Massachusetts

(73.1%) than in California (26.9%), annual family income was significantly ($p < 0.001$) higher in Massachusetts (85.7% income above \$50 000 per annum) than in California (66.7% income above \$50 000 per annum), and maternal education was significantly ($p = 0.002$) higher in Massachusetts (84.6% graduated from high school) than in California (75.1% graduated from high school). Within the United Kingdom, 1896 of the 3485 infants were successfully

Figure 1 Mean adjusted postmenstrual age at discharge (PMAD) for each neonatal intensive care unit by number of admissions. The horizontal line indicates the overall mean PMAD of 36.2 weeks. The dashed lines indicate 99.9% control limits, where units above the upper control limit have an unexpectedly high and units below the lower control limit have an unexpectedly low average PMAD. The funnel between the dashed lines gets smaller as the number of admissions increases because of the associated decrease in standard error on discharge timing. Notice that three out of five Californian units have an unexpectedly low mean PMAD.

matched to the 2000 IMD. The overall median IMD was 36.9 (interquartile range 10.7, 50.7).

In the United States, severe morbidity including intraventricular haemorrhage (grades 3 or 4), periventricular leucomalacia, and retinopathy of prematurity (stage 3 or higher) occurred in less than 0.6% of patients. In the United Kingdom, cerebral abnormality of probable postnatal origin (cystic leucomalacia and porencephalic cyst on cranial ultrasound arising more than 10 days after birth) occurred in 0.7% of infants. Table 1 also shows that the unadjusted mean (SD) PMAD of the infants in California, Massachusetts, and the United Kingdom were 35.9 (1.3), 36.3 (1.3), and 36.3 (1.9) weeks respectively.

Adjusted PMAD by region

Table 2 shows the results of the multiple linear regression model, showing the relation between PMAD in weeks and region of care, adjusted for size for gestation, sex, Apgar score at five minutes, antenatal steroids, mechanical ventilation, and clustering on unit of care. The adjusted difference in PMAD between infants in the United Kingdom and Massachusetts of -0.13 (95% CI -0.43 to 0.17) weeks was not significant ($p = 0.385$). However, compared with the United Kingdom, infants in California had a significantly lower PMAD of -0.56 weeks (95% CI -0.93 to -0.19) ($p = 0.003$), equivalent to a difference of -3.9 (95% CI -6.5 to -1.4) days. Infants in California also had a lower PMAD than in Massachusetts of -0.43 (95% CI -0.89 to 0.03), equivalent to -3.0 (95% CI -6.2 to 0.2) days; however, this was not statistically significant ($p = 0.068$). Gestational age, birth weight z-score (an indicator of size for gestation, the number of standard deviations from the mean birth weight for gestation), whether the infant received mechanical ventilation, and sex of the infant were all significant predictors of PMAD.

Figure 1 summarises the overall results, displaying mean PMAD by unit. It illustrates that three out of five California units compared with three out of 54 United Kingdom units discharge more readily. It also shows that discharge at six out of 54 units in the United Kingdom occurred at higher than expected gestational age. It is of note is that the California unit with a mixed payer population was among those discharging within the expected range.

Potential bias: socioeconomic status

Lower PMAD was associated with non-white race (-0.37 , 95% CI -0.69 to -0.04 , $p = 0.026$), income $<\$50\,000$ (-0.23 , 95% CI -0.41 to -0.05 , $p = 0.014$), and lower maternal education (-0.32 , 95% CI -0.58 to -0.07 , $p = 0.012$). After adjustment for socioeconomic status, PMAD was lower in California than Massachusetts by -0.36 (95% CI -0.79 to 0.07) $p = 0.104$ weeks, equivalent to -2.5 (95% CI -5.5 to 0.5) days. Adjusting for the available socioeconomic factors reduced the difference in PMAD between California and Massachusetts by the equivalent of 0.5 days. In both cases however, the difference between PMAD in California and Massachusetts was not significant.

Within the United Kingdom, the median NICU level IMD was 22.3 (quartiles 14.6, 34.4) and ranged from 9.3 in the least deprived NICU to 55.7 in the most deprived NICU. After adjustment for the case mix variables, IMD within the United Kingdom was significantly related to PMAD, where an increase in deprivation was associated with lower PMAD (-0.07 per 10 point increase in IMD; 95% CI -0.12 to -0.02).

Potential bias: transferred infants

To assess the potential bias of excluding transferred infants from the UKNSS data set, we repeated the above analysis

including the 516 UKNSS infants transferred before discharge. This analysis revealed that a predicted PMAD for infants transferred compared with those not transferred was 0.25 (95% CI 0.19 to 0.32) weeks higher. Therefore our results may represent an underestimate of the true gap between the length of stay in California and the United Kingdom.

DISCUSSION

This is the first study to compare the gestational age at discharge of premature neonates across health systems. We show that moderately premature infants are discharged home earlier if they receive care under the KPMCP system in California compared with the United Kingdom.

Our findings appear to support and expand previous research indicating that a managed care model can expedite patient care. Ham *et al*¹ highlighted the differences in acute bed utilisation at KPMCP in California and in the NHS. They found lower rates of bed utilisation at KPMCP and attributed this to integration of patient care, active management of patients, the use of intermediate care, self care, and medical leadership. Feachem *et al*² showed superior access to primary and hospital level care at KPMCP at comparable per capita cost.

This study found that PMAD in California is four days lower than in the United Kingdom, which represents an 18% (mean length of stay 25 days) reduction in total length of stay. Decreasing length of stay has important cost advantages, as moderately premature infants comprise such a large proportion of the total NICU population. However, this cost advantage will only be realised if earlier discharge does not lead to a subsequent increase in medical resource consumption. The literature on downstream resource use is inconsistent. Eichenwald *et al*¹² showed equivalent numbers of readmission and emergency room and office visits for infants in California and Massachusetts. In contrast, within the state of California, Escobar *et al*²⁵ showed considerable variation in both hospital readmission and short term follow up rates. Until more data from multiple systems are available, it is not clear whether the shorter length of stay in KPMCP units is being attained at the expense of later healthcare resource use.

The descriptive nature of this study does not allow us to infer causality. However, as our patient population is not only clinically homogeneous but also case-mix adjusted, we suggest that our results reflect differences in health delivery systems. Previously suggested contributors to efficient care include implementation of care guidelines, quality improvement methods, positive incentives, and care integration.^{1 2 26-28} In particular, the Kaiser effect may rely on quality improvement efforts, which decrease inter-institutional and inter-provider variability. Given the excellent outcomes in this population, decreasing the overall variability by instituting integrated care and clinical guidelines may lead to efficiency gains.

Comparisons of outcomes and practices between institutions, states, and countries are subject to certain limitations.^{3 4 29-36} One common criticism of such benchmarking relates to the incompatibility of patient populations. There are, however, a number of studies that appear to demonstrate both the utility of case mix adjustment and persistent variability in outcomes after such adjustment.^{6 11 18 19 37-45}

Our data must be interpreted in the context of this particular study design. All chart reviews are subjected to biases. We minimised this bias by using a previously validated chart abstraction protocol.¹⁴ Because we based our analysis on the combination of two data sets from two countries, the depth of our analysis was limited to variables common to both studies. In contrast, the homogeneity and low illness severity of our population favours the generalisability of our results. Finally, the possibility remains that our

What is already known on this topic

- Managed care arrangements may improve quality and efficiency of care
- Previous comparisons between the Kaiser Permanente in the United States and the NHS in the United Kingdom have supported this theory, but differences in efficiency found in previous research may have been attributable to case mix

observations might be explained by an unobserved variable. Our analysis did not have a measure of socioeconomic status across all regions. However, our subanalysis between California and Massachusetts showed that not all the variation in PMAD could be explained by socioeconomic factors, at least for infants in these two regions. Moreover, the direction of the association between socioeconomic status and PMAD was similar in the United Kingdom. Therefore, in order to negate the difference between the United Kingdom and California, this would imply that infants in California are on average associated with deprivation levels similar to the most deprived areas of the United Kingdom. Given the similar purchasing power adjusted per capita income between the countries, this is unlikely.⁴⁶

In conclusion, we show that moderately premature infants within the KPMCP system are likely to be discharged home at an earlier gestational age than similar infants in the United Kingdom. We speculate that this may be the result of care policies within KPMCP's managed care system. Further research should attempt to verify and then identify specifically which factors of healthcare systems are responsible for such differences and to identify the barriers or facilitators to altering them in order to improve the efficiency of healthcare provision.

ACKNOWLEDGEMENTS

Contributors: JP and GP planned and performed the analyses. JZ advised on clinical analysis and interpretation. JP wrote the paper under guidance from GP and JZ. MM, GE, and DR are MPIP principal investigators. GP, JT and WTM are UKNSS principal investigators. DR, MM, GE, GP, and WTM are grant holders. MM, GE, JT, and WTM all acted as senior advisors and editors of the paper. All authors are guarantors of the paper.

We thank all staff who participated in the studies for their support and dedication, and John Orav for his comments.

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What this study adds

- In a clinically homogeneous sample, we found a significantly shorter hospital stay for moderately premature infants cared for under the Kaiser Permanente Medical Care Program in Northern California than in the United Kingdom
- These results may be due to the integrated model of healthcare delivery provided by Kaiser Permanente

Funding: The Agency for Healthcare Research and Quality supported JP with a training grant (T32 HS000063). The MPIP study was funded by a grant from the same organisation (R01 HS10131). The Commonwealth Fund, a national, private foundation based in New York City that supports independent research on health and social issues, supported GP in writing this paper. The views presented here are those of the authors and not necessarily those of The Commonwealth Fund, its director, officers, or staff. GJP is a member of the UKNSS group, which was funded by the NHS R&D Executive, Mother and Child Health Programme (MCH: 6–7).

Competing interests: none declared

Dr Richardson is deceased

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