Pediatr Blood Cancer 2012;59:679–684

Shorter Hospitalization Trends Among Children With Sickle Cell Disease

Jean L. Raphael, MD, MPH,[1]* Brigitta U. Mueller, MD, MHCM,[1] Marc A. Kowalkowski, MS,[2] and Suzette O. Oyeku, MD, MPH[3]

Background. Vaso-occlusive crises (VOC) contribute to frequent hospitalizations among children with sickle cell disease (SCD). The objective of this study was to determine whether length of stay (LOS) has decreased for VOC hospitalizations between 1997 and 2009. ***Procedure.*** We analyzed pediatric discharges (aged 0–18) with a primary or secondary diagnosis of SCD with crisis from the Kid's Inpatient Database (years 1997, 2003, and 2009), a nationally representative sample of pediatric hospital discharges. We conducted bivariate and multivariate, sample-weighted linear regression analyses to determine associations between independent variables (patient demographics, hospital characteristics, co-diagnoses, and procedures) and LOS. ***Results.*** Both the number (22,661–21,741) and proportion of VOC hospitalizations (0.34–0.29%) among all pediatric hospitalizations marginally decreased between 1997 and 2009 ($P < 0.01$). Mean LOS decreased from 4.59 to 4.21 days ($P < 0.01$). For all study years, older age was the only socio-demographic variable associated with longer LOS, controlling for other factors. Between 1997 and 2009, LOS decreased for all age categories, with the largest statistically significant reduction occurring among adolescents (5.69–4.76 days). ***Conclusions.*** Nationally representative hospital data indicate modest but meaningful reductions in LOS for children with VOC over a 12-year period. Adolescents who typically have the greatest disease severity showed the largest reduction in LOS. However, adolescents continue to account for a large proportion of inpatient stays for VOC. These findings illustrate that the adolescent period is a critical time in the lifespan for targeted intervention. Pediatr Blood Cancer 2012;59:679–684. © 2012 Wiley Periodicals, Inc.

Key words: health care utilization; sickle cell disease

INTRODUCTION

Vaso-occlusive crises (VOC) are the most common reason for hospitalization and the most common cause of acute morbidity in pediatric sickle cell disease (SCD) [1]. A large body of research has documented inpatient hospitalizations as a major driver of SCD associated health care utilization and costs [1–8]. One study demonstrated that 81% of SCD-related costs were associated with inpatient hospital care [9]. In 2004, SCD was listed as the discharge diagnosis for over 113,000 admissions to U.S. hospitals, incurring aggregate charges exceeding $1 billion and estimated costs of $500 million [10].

Over the past several decades, survival of young children with SCD has improved dramatically with innovations in basic science and clinical care [11–15]. Historically, interventions such as newborn screening, prophylactic penicillin, and immunization against invasive bacteria played a significant role in decreasing childhood mortality [16–18]. Other advances in preventive care such as hydroxyurea therapy and comprehensive care have been increasingly postulated as the next line of innovations to improve outcomes for children with SCD, particularly with respect to VOC [19–21].

Hospital length of stay (LOS) represents a universal metric for gauging the success of these efforts, assuming that overall health care costs are reduced when patients are discharged more quickly [22]. While ample research shows current patterns and characteristics of hospital admissions for VOC [2,4,6–8,20,23,24], little epidemiologic data exist to document changes in LOS over time. Previous studies suggest older age as a proxy for disease severity, and consequently a significant factor influencing LOS [25,26]. Since innovative therapies such as hydroxyurea are more likely to be beneficial among those with the highest disease severity, the largest anticipated change in LOS may be observed in the adolescent population.

The primary aim of this study was to examine the differences in LOS among VOC-related hospitalizations according to age between 1997 and 2009 using data from the Kids' Inpatient Database (KID). We hypothesized that (i) there would be an overall reduction in LOS from 1997 to 2009 and (ii) the largest decrease would occur among adolescents.

METHODS

Data Source and Case Selection

We performed a retrospective analysis using administrative data, as described below. The project was reviewed and approved by the Baylor College of Medicine Institutional Review Board. The Healthcare Cost and Utilization Project (HCUP), sponsored by the Agency for Healthcare Research and Quality, is a group of health care databases including the Nationwide Inpatient Sample, State Inpatient Database, and KID. Collectively, HCUP is the largest collection of multiyear, all-payer, encounter-level, health care data available in the U.S. This study was a retrospective analysis of the HCUP KID 1997, 2003, and 2009 (the most recent available). These years were chosen to assess data for the first and most recent datasets for HCUP KID with 2003 providing a midpoint dataset. The KID 1997 included 2,521 hospitals in 22 states. In 2003, there were 3,438 hospitals in 36 states. The KID 2009 was comprised of 4,121 hospitals in 44 states.

The KID, available every 3 years since1997, was designed to report hospital use and outcomes for children and is the only all-payer inpatient discharge database for children in the U.S. The KID sampling frame was constructed using all U.S. short-term,

[1]Department of Pediatrics, Baylor College of Medicine, Texas Children's Cancer Center, Houston, Texas; [2]Department of Medicine, Baylor College of Medicine, Houston, Texas; [3]Department of Pediatrics, Albert Einstein College of Medicine at Yeshiva University, Bronx, New York

Conflict of Interest:

*Correspondence to: Jean L. Raphael, MD, MPH, Suite D.1540.00, Texas Children's Hospital, 6701 Fannin Street Houston, TX 77030. E-mail: Raphael@bcm.edu

Received 3 October 2011; Accepted 5 December 2011

DOI 10.1002/pbc.24065
Published online 4 January 2012 in Wiley Online Library (wileyonlinelibrary.com).

non-federal, general, and specialty hospitals that had pediatric discharges defined as less than age 20 years from states participating in HCUP. The database does not include all discharges from participating institutions but instead a 10% sample of uncomplicated in-hospital births and an 80% sample of other pediatric discharges. The database contains more than 100 clinical and non-clinical variables included in hospital abstracts of all hospitalizations. The KID database is designed to provide national estimates for pediatric hospitalizations for both common and rare conditions. The database contains weighted discharge data for use in generating national estimates of total U.S. discharges for specific diagnoses and procedures. These weights are configured to produce rates that are comparable across years despite variation in the number of participating states. In order to protect hospital and patient confidentiality, identifying information on hospitals or patients are omitted in the database.

Pediatric hospitalizations for patients $\leq$18 years of age with an *International Classification of Diseases, Ninth Revision, Clinical Modification* (ICD-9-CM) code for SCD with crisis (282.62, 282.42, 282.64, or 282.69) were selected for analysis. VOC-related hospitalizations were defined as hospitalizations with a primary or secondary diagnosis of VOC according to KID.

Measures

Patient characteristics. Independent child variables examined included demographic information (age, gender), insurance status, income category, and U.S. region. Age at the time of discharge was categorized into 5-year age increments except for the final age group [15–18]. Insurance type was grouped into the following payers: private, public, and other. Income was divided by the KID into four groups based on the median household income for the child's zip code of residence: first quartile ($0–25,000), second quartile ($25,001–30,000), third quartile ($30,001–35,000), and fourth quartile (>$35,000). Because of the relative homogeneity of race/ethnicity for SCD and the high percentage of missing values for race/ethnicity in the dataset (approximately 20%), this variable was not examined. U.S. region was grouped into four categories (Northeast, Midwest, South, and West).

Hospital characteristics. Independent hospital variables as defined by the dataset included hospital bed size (small, medium, large), teaching status (teaching, non-teaching), hospital type (not children's hospital, children's unit in a general hospital, children's hospital), and location (urban, rural).

Co-diagnoses and procedures. To account for co-morbidities and illness severity, we assessed variables for co-diagnoses and procedures. Co-diagnoses were determined by assessing the ICD-9 codes listed for co-diagnoses in the discharge abstract in addition to ICD-9 282.62, 282.42, 282.64, or 282.69. In accordance with prior studies, we included all secondary diagnoses that occurred in at least 2% of hospitalizations [25]. In 2004, an ICD-9 code for acute chest syndrome (517.3) was introduced. Therefore, its occurrence was determined for the 2009 KID, the only one of our study years in which acute chest syndrome would be coded. Procedures occurring in at least 2% of hospitalizations were also considered. We also specifically assessed surgical procedures associated with SCD (e.g., cholecystectomy, splenectomy) and non-SCD-related procedures (e.g., appendectomy) likely to require elective blood transfusion.

Length of stay outcome. In KID, LOS was calculated by subtracting the admission date from the discharge date. Same day admissions were given a value of "0." Hospital charges in KID represent the total amount charged by the hospital for the entire hospital stay including procedures.

Data Analysis

Statistical analyses were performed using SAS® 9.2 (SAS Institute Inc, Cary, NC). We applied sampling weights derived from hospital discharges and provided by the KID to generate nationally representative estimates. The results represent weighted analyses unless otherwise indicated. Weighted linear regression was performed to evaluate the independent association between patient and hospital characteristics with LOS, while controlling for other co-variables. For the region category, the West is used as the reference. The choice of West region is arbitrary as there is no clear standard for which region of the country should serve as the reference. Results are reported as parameter estimates and least square means with 95% confidence intervals (95% CI). Parameter estimates represent number of days relative to the reference variable. Positive estimates indicate increased hospital days relative to the reference. Negative estimates indicate decreased hospital days relative to the reference. Records with missing data accounted for approximately 10% of the data and were excluded from the multivariate analyses.

RESULTS

Demographics, Co-Diagnoses, and Procedures

Patient and hospital characteristics are demonstrated in Table I. In 1997, a weighted total of 22,791 hospital discharges (0.34% of all pediatric discharges) were documented for children with VOC. In 2003, 21,087 (0.28% of all pediatric discharges) such discharges occurred. In 2009, there were 21,741 such discharges (0.29% of all pediatric discharges). The mean LOS for VOC-related hospitalizations was 4.21 days in 2009 compared with 4.59 days in 1997 ($P < 0.01$). In 2003, the mean LOS was 4.46 days. Children ages 15–18 years comprised the largest proportion of VOC-related hospitalizations for all 3 years. The proportion of children ages 15–18 years of age increased from 30.8% to 35.4% ($P < 0.001$) during the study period.

The proportion of hospitalizations with co-diagnoses and procedures occurring in at least 2% of hospitalizations are shown in Table II. Among co-diagnoses, asthma and constipation showed the most dramatic increases between 1997 and 2009. Acute chest syndrome was a co-diagnosis in 18.6% of VOC-related hospitalizations in 2009. Among procedures, the proportion of hospitalizations in which red blood cell transfusion occurred increased twofold higher from 1997 to 2009. Surgical procedures occurred in less than 1% of VOC-related hospitalizations for all study years.

Mean LOS According to Age

Table III demonstrates mean LOS according to age for 1997, 2003, and 2009. All differences were statistically significant between and within years. For all years, LOS was longer in the older age groups. In 1997, mean LOS was 3.7 days for children 0–4 years of age and 5.69 days for children ages 15–18, reflecting a

TABLE I. Patient and Hospital Characteristics for VOC-related Hospitalizations in KID 1997, 2003, and 2009

	KID 1997 (N = 8,998; weighted = 22,791)	KID 2003 (N = 12,102; weighted = 21,087)	KID 2009 (N = 14,468; weighted = 21,741)
	Weighted n (%)	Weighted n (%)	Weighted n (%)
Patient characteristics			
Age			
0–4	4,309 (18.9)	3,364 (16.0)	3,940 (18.1)
5–9	5,281 (23.2)	4,242 (20.1)	4,536 (20.9)
10–14	6,173 (27.1)	6,494 (30.8)	5,570 (25.6)
15–18	7,028 (30.8)	6,987 (33.1)	7,694 (35.4)
Gender			
Male	11,281 (49.5)	10,857 (51.9)	10,924 (50.4)
Female	11,510 (50.5)	10,073 (48.1)	10,755 (49.6)
Insurance			
Private	6,834 (30.0)	6,042 (28.7)	5,600 (25.8)
Public	14,432 (63.4)	14,447 (68.6)	15,497 (71.3)
Other	1,495 (6.6)	565 (2.7)	621 (2.9)
Median zip code income			
First quartile	11,292 (51.4)	9,593 (46.3)	10,494 (49.4)
Second quartile	4,573 (20.8)	5,541 (26.7)	4,896 (23.1)
Third quartile	2,794 (12.7)	3,663 (17.7)	3,544 (16.7)
Fourth quartile	3,310 (15.1)	1,941 (9.4)	2,300 (10.8)
Hospital characteristics			
Region			
Northeast	5,875 (25.8)	4,951 (23.5)	5,411 (24.9)
Midwest	3,340 (14.6)	4,556 (21.6)	4,653 (21.4)
South	11,112 (48.8)	9,570 (45.4)	10,048 (46.2)
West	2,465 (10.8)	2,010 (9.5)	1,628 (7.5)
Bed size			
Small	4,083 (17.9)	3,847 (18.9)	2,014 (10.6)
Medium	5,566 (24.4)	4,196 (20.6)	3,948 (20.9)
Large	13,143 (57.7)	12,309 (60.5)	12,944 (68.5)
Teaching status			
Non-teaching	7,385 (32.4)	3,539 (17.4)	3,021 (16.0)
Teaching	15,407 (67.6)	16,813 (82.6)	15,884 (84.0)
Location			
Rural	1,694 (7.4)	1,079 (5.3)	780 (4.1)
Urban	21,097 (92.6)	11,180 (94.7)	18,125 (95.9)
Hospital type			
Not children's hospital	9,036 (39.6)	7,426 (38.3)	5,458 (30.0)
Children's general hospital	4,319 (19.0)	4,866 (25.1)	4,661 (25.7)
Children's unit in general hospital	9,436 (41.4)	7,087 (36.6)	8,049 (44.3)

nearly 2-day difference. In 2009, the differences between age groups narrowed. The mean LOS for children ages 0–4 years of age was 3.1 days compared with 4.76 days for children 15–18 years of age. Overall, LOS decreased for all age categories between 1997 and 2009. The largest decrease occurred for children 15–18 years of age with approximately a 1 day decrease in LOS.

Linear Regression Analysis for Age and LOS

Further analyses were conducted to specifically assess the relationship between age and LOS, while accounting for other variables. The linear regression analysis for LOS is shown in Table IV. Only variables significantly associated with LOS in bi-variate analyses were included. Several patterns were similar across study years. Age was the only socio-demographic variable to demonstrate a statistically significant relationship with LOS while controlling for other factors. Increasing age group was associated with a longer LOS. Compared to being 0–4 years of age, being 15–18 years was associated with an additional 1.79 days to hospitalization in 1997 and 1.66 days in 2009.

In addition to age, co-diagnoses and procedures also demonstrated relationships with LOS. Hospitalizations with either pneumonia or constipation as co-diagnoses were associated with longer LOS. Receipt of red blood cell transfusion was associated with an additional 1.50 days to hospitalization in 1997 and 1.40 days in 2009.

DISCUSSION

The findings of this epidemiologic study suggest that LOS for VOC-related hospitalizations among children with SCD has modestly decreased over time, with the most significant decrease occurring in adolescents. This represents a notable result given

TABLE II. Co-diagnoses and Procedure for VOC-related Hospitalizations in KID 1997, 2003, and 2009[a]

	KID 1997 (N = 8,998; weighted = 22,791)	KID 2003 (N = 12,102; weighted = 21,087)	KID 2009 (N = 14,468; weighted = 21,741)
	Weighted n (%)	Weighted n (%)	Weighted n (%)
Co-diagnoses			
Fever	1,646 (7.2)	1,947 (9.2)	3,317 (15.3)
Asthma	898 (3.9)	1,885 (8.9)	3,308 (15.2)
Constipation	870 (3.8)	1,430 (6.8)	2,436 (11.2)
Pneumonia	2,720 (11.9)	2,789 (13.2)	2,734 (12.6)
Volume depletion[b]	837 (3.7)	826 (3.9)	—
Acute chest syndrome[c]	—	—	10,924 (50.4)
Procedures			
Red blood cell transfusion	2,531 (11.1)	3,712 (17.6)	5,826 (26.8)
Exchange transfusion[d]	483 (2.1)	—	—

[a]Greater than 2% prevalence. [b]Greater than 2% prevalence in 1997 and 2003 only. [c]ICD-9 code for acute chest syndrome introduced in 2004. [d]Greater than 2% prevalence in 1997 only.

efforts to shift SCD care away from costly and lengthy inpatient stays to toward less expensive outpatient treatment [27,28]. Even a reduction of 1 day in LOS represents a significant amount in potential cost savings for VOC-related hospitalizations. In addition to cost containment, a decrease in LOS further mitigates against risks associated with hospitalizations, including medical complications and acquired infections in a population susceptible to invasive bacterial organisms. The findings according to age demonstrate that the changing epidemiology of VOC hospitalizations are well distributed across different groups but may be especially beneficial for older children who typically have worse disease.

The relationship between age and VOC among children is well documented with an underlying assumption that age acts a surrogate for disease severity and progression [7,25,26]. Multiple studies document that VOCs increase in accordance to age [25,26,29]. More directly related to this work, several studies have demonstrated a positive relationship between older age and LOS. In a study of the 2000 HCUP KID, LOS was longer in the older age groups [25]. Mean LOS was 3.5 days for children 0–4 years of age and increased by nearly 2–5.4 days for children 15–18 years of age. In our study, the difference in mean LOS during 2009 was smaller, with 3.1 days for children 0–4 years and 4.76 days for children 15–18 years. Since age may act as a proxy for disease severity and progression, these trends may reflect the impact of newer SCD therapies and management which have in turn resulted in better LOS outcomes according to age.

Such trends in the epidemiology of SCD may be catalyzed by numerous innovations in SCD management. Specific reasons include more widespread use of hydroxyurea and blood transfusions. Among children, hydroxyurea treatment has been associated with a significant decrease in pain, hospitalizations, and LOS [19,30]. Hydroxyurea may particularly impact adolescents where disease severity is often greater relative to younger age groups. Although still underutilized among pediatric patients [31,32], more standard use of hydroxyurea in the future may further decrease LOS for VOC hospitalizations. While HCUP KID provides valuable data on age categories and LOS, it does not contain information on patient medications. Therefore, we could not specifically test whether the reduction in LOS among adolescents was attributable to hydroxyurea use.

Increasing use of blood transfusion has also potentially contributed to the reduction in LOS. With decreasing concerns regarding safety and expanding clinical benefit (e.g., reduction of acute chest syndrome [33] decrease in acute pain hospitalizations [34], stroke prevention [35]), red blood cell transfusion usage may be increasing [36]. A recent study in an adult sickle cell center demonstrated a substantial increase in both the mean units

TABLE III. Length of Stay for VOC-related Hospitalizations in KID 1997, 2003, and 2009, Stratified by Age Group

	KID 1997	KID 2003	KID 2009	
	Mean LOS in days (95% CI)	Mean LOS in days (95% CI)	Mean LOS in days (95% CI)	*P*-value
Overall	4.59 (4.49–4.69)	4.46 (4.26–4.67)	4.21 (4.15–4.27)	<0.01
Age[a]				<0.01
0–4	3.78 (3.43–4.13)	3.30 (2.96–3.64)	3.11 (2.82–3.39)	
5–9	3.92 (3.60–4.25)	3.54 (3.21–3.86)	3.41 (3.13–3.68)	
10–14	4.76 (4.44–5.08)	4.45 (4.14–4.75)	4.17 (3.90–4.44)	
15–18	5.57 (5.26–5.87)	5.24 (4.94–5.55)	4.77 (4.51–5.02)	

[a]Age-group specific LOS adjusted for additional covariates including: hospital region, hospital type, pneumonia, constipation, and red blood cell transfusion.

TABLE IV. Linear Regression Analysis of Length of Stay for VOC-related Hospitalizations in KID 1997, 2003, and 2009

	KID 1997 (N = 8,998; weighted = 22,791)		KID 2003 (N = 12,102; weighted = 21,087)		KID 2009 weighted = 14,468; 21,741)	
Variables	Estimate[a] (SE)	*P*-value	Estimate (SE)	*P*-value	Estimate (SE)	*P*-value
Age						
0–4 (Ref)	0.00	—	0.00	—	0.00	—
5–9	0.15 (0.15)	0.35	0.24 (0.13)	0.07	0.30 (0.10)	<0.01
10–14	0.98 (0.15)	0.01	1.15 (0.12)	<0.01	1.06 (0.10)	<0.01
15–18	1.79 (0.15)	<0.01	1.94 (0.12)	<0.01	1.66 (0.09)	<0.01
Region						
West (Ref)	0.00	—	0.00	—	0.00	—
Northeast	−0.19 (0.20)	0.34	0.05 (0.16)	0.75	−0.36 (0.13)	<0.01
Midwest	−1.11 (0.20)	<0.01	−0.31 (0.16)	0.05	−0.35 (0.13)	<0.01
South	−1.12 (0.19)	<0.01	−0.41 (0.15)	<0.01	−0.20 (0.12)	0.11
Hospital type						
Not children's hospital (Ref)	0.00	—	0.00	—	0.00	—
Children's general hospital	0.34 (0.17)	0.04	0.21 (0.11)	0.07	0.41 (0.11)	<0.01
Children's unit in general hospital	0.75 (0.15)	<0.01	0.60 (0.16)	<0.01	0.20 (0.09)	0.03
Prevalent co-diagnoses						
Pneumonia	1.73 (0.16)	<0.01	1.30 (0.12)	<0.01	0.94 (0.10)	<0.01
Constipation	1.62 (0.26)	<0.01	1.40 (0.16)	<0.01	1.12 (0.10)	<0.01
Volume depletion disorder[b]	0.96 (0.27)	<0.01	0.03 (0.21)	0.88	—	—
Acute chest syndrome[c]	—	—	—	—	0.39 (0.09)	<0.01
Prevalent procedures						
RBC transfusion	1.50 (0.16)	<0.01	1.80 (0.11)	<0.01	1.40 (0.07)	<0.01
Fxrhflnpp transfusion[d]	2.82 (0.37)	<0.01	—	—	—	—

[a]Interpreted as number of increased days (negative values indicate number of decreased days). [b]Greater than 2% prevalence in KID 1997 and 2003 only. [c]ICD-9 code for acute chest syndrome introduced in 2004. [d]Greater than 2% prevalence in KID 1997 only.

transfused per patient and percentage of patients transfused over a 10-year period [36]. The results from our study demonstrate similar findings. Over a 12-year period, the percentage of VOC hospitalizations in which transfusion were administered increased from one-tenth to over a quarter. Although it was possible that blood transfusions were administered electively for surgical procedures, this was of little relevance in our study where selected surgical procedures occurred in less than 1% of VOC-related hospitalizations.

While there are clear benefits to transfusion, it was difficult to determine whether receipt of a red blood cell transfusion reduced LOS in this study. In our multivariate linear regression, transfusion was associated with increased LOS in both 1997 and 2009. This result may be misleading since the transfusion may be indicative of underlying illness severity and not directly influencing LOS. Further studies are needed to determine the impact of transfusion on LOS, controlling for illness severity as well as the number and volume of transfusions.

There were methodological limitations to our study. Although the HCUP KID is considered to provide a representative sample of pediatric hospitalizations, discharge information originates from a limited number of states and is only released every 3 years. Data are not available for interval years. The HCUP KID data set does not contain unique patient identifiers or record linkages, thereby preventing analysis of utilization according to detailed patient characteristics and assessment of multiple hospitalizations of the same patient. Prior studies have demonstrated that a small subset of individuals account for frequent and resource-intensive hospitalizations [4,37].

Additionally, the HCUP KID database lacks data on patient medications, illness severity, and disease severity. For understanding trends in LOS among children with SCD, the lack of data on medications is particularly limiting in national administrative datasets such as HCUP KID. Insurance plan data, either private or public, offer the best options to assess the relationships between hydroxyurea or other treatment interventions and trends in LOS. While we were able to extract data on secondary diagnoses at discharge, we could not determine whether they were present at admission since KID only records the discharge abstract. The ICD-9 code for acute chest syndrome was not introduced until 2004 so we were not able to assess trends over time using this dataset. Our data only reflect trends up to 2009, the most recent year available.

Lastly, it is possible that the observed decreases in LOS in our study reflect global managerial and financial incentives within the health care system to reduce LOS rather than innovations in care. Payer and health care system policy imperatives to reduce LOS may potentially have negative impact on children with SCD, especially adolescents who already are at risk as their disease worsens and they transition to adult care. Theoretical concerns regarding financially driven reductions in LOS include an increase in the number of high intensity days of hospital care, re-hospitalization, and cost shifting to outpatient care [38]. We were unable to test these hypotheses with our dataset. Future studies should assess the influence of policy changes regarding LOS on children with SCD.

As previous studies document, the burden of mortality in SCD has shifted to young adults with the transition from pediatric to

adult care representing a vulnerable period [13]. While the literature on health care utilization among children with SCD has expanded dramatically in the past several years [2,4,6–8,20,23,39,40], few data existed on national trends according to age, particularly at a time of continued innovation in SCD care. Although the magnitude of trends varied among descriptive factors, we observed a downward trend in LOS for VOC among all age groups. Furthermore, we documented the greatest gain to occur in adolescents who typically have greater disease severity. While such modest improvements are encouraging, they continue to highlight the young adult period as a critical point for intervention and quality improvement.

REFERENCES

1. Yang YM, Shah AK, Watson M, et al. Comparison of costs to the health sector of comprehensive and episodic health care for sickle cell disease patients. Public Health Rep 1995;110:80–86.
2. Amendah DD, Mvundura M, Kavanagh PL, et al. Sickle cell disease-related pediatric medical expenditures in the U.S. Am J Prev Med 2010;38:S550–S556.
3. Ballas SK. The cost of health care for patients with sickle cell disease. Am J Hematol 2009;84:320–322.
4. Carroll CP, Haywood C Jr, Fagan P, et al. The course and correlates of high hospital utilization in sickle cell disease: Evidence from a large, urban Medicaid managed care organization. Am J Hematol 2009;84:666–670.
5. Davis H, Moore RM Jr, Gergen PJ. Cost of hospitalizations associated with sickle cell disease in the United States. Public Health Rep 1997;112:40–43.
6. Raphael JL, Dietrich CL, Whitmire D, et al. Healthcare utilization and expenditures for low income children with sickle cell disease. Pediatr Blood Cancer 2009;52:263–267.
7. Raphael JL, Mei M, Mueller BU, et al. High resource hospitalizations among children with vaso-occlusive crises in sickle cell disease. Pediatr Blood Cancer (in press).
8. Mvundura M, Amendah D, Kavanagh PL, et al. Health care utilization and expenditures for privately and publicly insured children with sickle cell disease in the United States. Pediatr Blood Cancer 2009;53:642–646.
9. Kauf TL, Coates TD, Huazhi L, et al. The cost of health care for children and adults with sickle cell disease. Am J Hematol 2009;84:323–327.
10. Steiner CA, Miller JL. Sickle cell disease patients in U.S. hospitals; 2004; Report No.: HCUP statistical brief #21.
11. Powars DR, Hiti A, Ramicone E, et al. Outcome in hemoglobin SC disease: A four-decade observational study of clinical, hematologic, and genetic factors. Am J Hematol 2002;70:206–215.
12. Quinn CT, Rogers ZR, Buchanan GR. Survival of children with sickle cell disease. Blood 2004;103:4023–4027.
13. Quinn CT, Rogers ZR, McCavit TL, et al. Improved survival of children and adolescents with sickle cell disease. Blood 2010;115:3447–3452.
14. Lee A, Thomas P, Cupidore L, et al. Improved survival in homozygous sickle cell disease: Lessons from a cohort study. BMJ 1995;311:1600–1602.
15. Prabhakar H, Haywood C Jr, Molokie R. Sickle cell disease in the United States: Looking back and forward at 100 years of progress in management and survival. Am J Hematol 2010;85:346–353.
16. Gaston MH, Verter JI, Woods G, et al. Prophylaxis with oral penicillin in children with sickle cell anemia. A randomized trial. N Engl J Med 1986;314:1593–1599.
17. Vichinsky E, Hurst D, Earles A, et al. Newborn screening for sickle cell disease: Effect on mortality. Pediatrics 1988;81:749–755.
18. Vichinsky EP. Comprehensive care in sickle cell disease: Its impact on morbidity and mortality. Semin Hematol 1991;28:220–226.
19. McGann PT, Ware RE. Hydroxyurea for sickle cell anemia: What have we learned and what questions still remain? Curr Opin Hematol 2011;18:158–165.
20. Shankar SM, Arbogast PG, Mitchel E, et al. Impact of proximity to comprehensive sickle cell center on utilization of healthcare services among children with sickle cell disease. Pediatr Blood Cancer 2008;50:66–71.
21. Raphael JL, Kavanagh PL, Wang CJ, et al. Translating scientific advances to improved outcomes for children with sickle cell disease: A timely opportunity. Pediatr Blood Cancer 2011;56:1005–1008.
22. Schwartz WB, Mendelson DN. Hospital cost containment in the1980s. Hard lessons learned and prospects for the 1990s. N Engl J Med 1991;324:1037–1042.
23. McCavit TL, Lin H, Zhang S, et al. Hospital volume, hospital teaching status, patient socioeconomic status, and outcomes in patients hospitalized with sickle cell disease. Am J Hematol 2011;86:377–380.
24. Brousseau DC, Owens PL, Mosso AL, et al. Acute care utilization and rehospitalizations for sickle cell disease. JAMA 2010;303:1288–1294.
25. Panepinto JA, Brousseau DC, Hillery CA, et al. Variation in hospitalizations and hospital length of stay in children with vaso-occlusive crises in sickle cell disease. Pediatr Blood Cancer 2005;44:182–186.
26. Ellison AM, Bauchner H. Socioeconomic status and length of hospital stay in children with vaso-occlusive crises of sickle cell disease. J Natl Med Assoc 2007;99:192–196.
27. Raphael JL, Kamdar A, Beavers MB, et al. Treatment of uncomplicated vaso-occlusive crises in children with sickle cell disease in a day hospital. Pediatr Blood Cancer 2008;51:82–85.
28. Raphael JL, Kamdar A, Wang T, et al. Day hospital versus inpatient management of uncomplicated vaso-occlusive crises in children with sickle cell disease. Pediatr Blood Cancer 2008;51:398–401.
29. Platt OS, Brambilla DJ, Rosse WF, et al. Mortality in sickle cell disease. Life expectancy and risk factors for early death. N Engl J Med 1994;330:1639–1644.
30. Wang WC, Ware RE, Miller ST, et al. Hydroxycarbamide in very young children with sickle-cell anaemia: A multicentre, randomised, controlled trial (BABY HUG). Lancet 2011;377:1663–1672.
31. Candrilli SD, O'Brien SH, Ware RE, et al. Hydroxyurea adherence and associated outcomes among Medicaid enrollees with sickle cell disease. Am J Hematol 2011;86:273–277.
32. Stallworth JR, Jerrell JM, Tripathi A. Cost-effectiveness of hydroxyurea in reducing the frequency of pain episodes and hospitalization in pediatric sickle cell disease. Am J Hematol 2010;85:795–797.
33. Vichinsky EP, Neumayr LD, Earles AN, et al. Causes and outcomes of the acute chest syndrome in sickle cell disease. National Acute Chest Syndrome Study Group. N Engl J Med 2000;342:1855–1865.
34. Miller ST, Wright E, Abboud M, et al. Impact of chronic transfusion on incidence of pain and acute chest syndrome during the Stroke Prevention Trial (STOP) in sickle-cell anemia. J Pediatr 2001;139:785–789.
35. Adams RJ, McKie VC, Hsu L, et al. Prevention of a first stroke by transfusions in children with sickle cell anemia and abnormal results on transcranial Doppler ultrasonography. N Engl J Med 1998;339:5–11.
36. Drasar E, Igbineweka N, Vasavda N, et al. Blood transfusion usage among adults with sickle cell disease—A single institution experience over ten years. Br J Haematol 2011;152:766–770.
37. Nietert PJ, Abboud MR, Zoller JS, et al. Costs, charges, and reimbursements for persons with sickle cell disease. J Pediatr Hematol Oncol 1999;21:389–396.
38. Clarke A, Rosen R. Length of stay. How short should hospital care be? Eur J Public Health 2001;11:166–170.
39. Yusuf HR, Atrash HK, Grosse SD, et al. Emergency department visits made by patients with sickle cell disease: A descriptive study, 1999–2007. Am J Prev Med 2010;38:S536–S541.
40. Grosse SD, Boulet SL, Amendah DD, et al. Administrative data sets and health services research on hemoglobinopathies: A review of the literature. Am J Prev Med 2010;38:S557–S567.