Healthcare coordination and medical expenditures for Sickle Cell Disease patients with different levels of health utilization risk

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Abstract

Sickle Cell Disease (SCD) has a complex array of symptoms and is associated with high healthcare expenditures. A comprehensive care program may help to reduce expenditures of children with SCD. This research describes SCD comprehensive care program enrollees' expenditure patterns by level of hospitalization risk over a three-year period and estimates whether coordination of care services reduced costs for those with different risk levels. Medicaid claims data were collected for program patients with SCD. Data from the one year prior to program enrollment categorized patients as High, Medium, or Low risk for incurring inpatient expenditures. We compared utilization risk groups on inpatient expenditures by year after program enrollment. The trends in expenditures are shown in the subgroup analyses (descriptively). 361 program enrollees ages 1 to 27y had SCD; 8.9% were categorized as High risk of utilizing hospitalization services, 47.9% were at Medium risk, and 43.2% were at Low risk. The High Utilization and Medium Utilization Risk groups showed trends of expenditure reduction, but the trends may be due to regression of extreme group costs toward the mean. The lack of a statistically significant cost benefit might be due to small sample size, low engagement in the program services, short duration of intervention, and inability to distinguish the appropriateness of healthcare utilization for SCD.

INTRODUCTION

Sickle Cell Disease (SCD) affects an estimated 80,000 to 100,000 people in the US[1,2] and is associated with large healthcare expenditures [3-8]. In the United States, the disease predominantly affects African Americans, but SCD is the most common single-gene disease in the world and is a major global health concern[9,10]. SCD causes painful, debilitating, and life-threatening symptoms [11] and is known for considerable variation in symptom type and severity[12]. Health care for this complicated disease often requires multiple providers and treatment modalities[11,13]. Multiple studies have shown that the majority of SCD treatment expenditures come from hospitalizations[3-8,14,15], which can occur multiple times a year for each patient. This research examines SCD expenditures over time by disease severity.

SCD has a range of disease complications and severity, and multiple factors have been examined as predictors of SCD severity. Genetic variations in fetal hemoglobin gene expression and the co-inheritance of alpha thalassemia are linked to symptom severity[12,16,17]. Other genetic impacts on symptom severity are associated with blood chemistry biomarkers[18]. However, the literature indicates that not all symptom heterogeneity can be explained by genetic factors. Patients with SCD often have other chronic health conditions and comorbidities that can benefit from coordination of their health care services [13,19-23]. Asthma can especially exacerbate sickle cell disease complications[21], and asthma care is well-known to benefit from community health workers interventions (CHW) [24]. Other investigators have categorized acute ED and hospitalizations in SCD as unavoidable and avoidable. For example, an unavoidable hospitalization would be for SCD

with fever and acute chest syndrome; unavoidable hospitalizations are necessary. In contrast, an avoidable hospitalization would be for sickle cell pain triggered by over-exertion or forgetting to obtain refills of pain medications. Care coordination (from CHWs) might have guided different choices and prevented the avoidable hospitalization[13,19,20].

CHW may also be able to provide home assessments and education to ameliorate social and environmental factors that could reduce SCD severity. Exposure to tobacco smoke is associated with 73% more ED visits for acute chest syndrome[21]. Exposure to cold or wind increases the number of acute pain episodes that require hospitalization[25,26]. CHW can also assist with access to community resources, especially mental health services that could modulate SCD health care utilization [24,27,28].

In 2014, the Centers for Medicare and Medicaid awarded a grant to the University of Illinois at Chicago Pediatrics Department to fund the "Coordinated Healthcare for Complex Kids" (CHECK) program. The program was designed to provide comprehensive care coordination of services to Medicaid-enrolled children and young adults living in Chicago. The CHECK program enrolled patients with one or more chronic conditions, with the aim of determining whether health service coordination would reduce health care expenditures in patients with complex health needs[23,29-33].

Patients with SCD were included in the CHECK program because their large treatment expenditures and disease complexities. A prior randomized trial of the CHECK program including patients with a range of diseases found no difference in health care expenditures between a CHECK treatment group (N=3126) and a Usual Care control group (N=3128) but this study could not account for heterogeneity within the small subgroup with SCD (n=12 received CHECK and n=21 received Usual Care)[33]. Therefore, additional analyses were needed to understand the specific experience of children with SCD using a larger sample. The aim was to describe expenditure patterns of patients with SCD enrolled in the CHECK program by level of hospitalization risk over a three-year period (baseline year, and one-and-two years after enrollment).

PATIENTS AND METHODS

Study design and patients

The CHECK patients used for this analysis were between ages 1-27y and had a Medicaid diagnosis of SCD. In some cases, SCD was among multiple chronic disease diagnoses (most commonly asthma, diabetes mellitus, or epilepsy).

Procedures

The CHECK program served families throughout the Chicago area. Initial eligibility was based on Medicaid claims data and is described extensively elsewhere [23]. Patients were passively selected into the CHECK programs and CHECK program data were collected from January 1, 2015, through January 12, 2018. All patients were sent a letter stating that they were enrolled. CHECK CHWs attempted to contact a subset of patients (based on risk and diagnosis) either by mail, phone, or household visit[31]. Patients who completed the CHW-administered interview were considered as '*engaged'* in the CHECK program. Those who did not complete the intake assessment were considered '*enrolled'* but not 'engaged'. Engaged patients were connected to CHWs who provided consultation, care coordination, education, and social support services as needed[33]. Patients were enrolled and participated in the CHECK program on a rolling basis over time. The CHECK data collection was approved by The University of Illinois at Chicago Institutional Review Board (protocol #2017-0604) [34].

Assessment and criteria

Inclusion criteria were Medicaid insurance, CHECK enrollment, and sickle cell disease diagnostic ICD9 or ICD10 code. Retrospective data for this study were extracted from Illinois Medicaid paid claims for a three-year period per participant: one year prior to CHECK enrollment (Baseline Year) and the following two years during CHECK enrollment. Exclusion criterion was diagnostic code for sickle cell trait. Based on Baseline Year Medicaid claims, patients were categorized as High, Medium, or Low risk for incurring

inpatient expenditures during the CHECK enrollment period. High risk patients were those having more than 3 emergency department (ED) visits or were hospitalized more than once during the Baseline year. Medium risk patients were those who had 1 to 3 ED visits or 1 hospitalization during the Baseline year and Low risk patients were those who had no ED visits and no hospitalizations during the Baseline year[33]. Outliers with inpatient expenditures more than $100,000 per year in any CHECK year were excluded from analyses because such patients were expected to have unique medical problems beyond their SCD [5,33].

Statistical analysis

The analytic plan was developed to handle skewed data with outliers of high expenditures and individual heterogeneity over time, which are seen in all studies of SCD. Expenditure data were analyzed across three years for everyone, based on each individual's enrollment in CHECK: a Baseline year preceding enrollment, then one year and two years after CHECK enrollment. Analyses were conducted using the R program, version 4.0. Outliers with inpatient expenditures more than $100,000 per year were already excluded from analyses [5,33]. Because the overall distribution of expenditures was highly skewed, data were transformed by taking the natural logarithm of each patient's expenditures to reduce the distortion caused by the high values. To account for the zero expenditure cases, the number one was added to every expenditure value to enable the logarithmic transformation. 11Geometric means were calculated as the nth root of the product of n logarithmically transformed expenditure values. They were used instead of arithmetic means because geometric means are appropriate summary statistics to report log-transformed data. It is the average of log-transformed value converted to the original expenditure scale. Geometric means of the log transformed data were calculated.

Baseline distributions of demographics and medical conditions were compared by enrollment risk using Pearson's chi-square test or Fisher's exact test. Analyses were conducted using the R program Version 0.7.15.

Because many SCD patients had no inpatient expenditures, a two-part expenditure analysis based on a statistical decomposition of the distribution of the outcome into a process that generates zeros and a process that generates non-zero positive values [35] was conducted using the GLMMadaptive (v0.7.15) R package. The analysis accommodates the semi-continuous expenditure data; that is, a continuous model allowing for data with excess zeros was fitted to the data[36,37].

Using this approach, excess zeros were accounted for in an analytically appropriate way, so that better estimates of effects were produced. The model consisted of a logistic regression for the binary indicator that inpatient expenditures were zero or not and a standard linear mixed model for the log transformed non-zero inpatient expenditures. Interactions between utilization risk group and CHECK year were examined in both parts of the model. (Table 3). The first part of the analysis estimated the percent expenditure differences between utilization risk groups for each CHECK year while the second part estimated ratios of the odds of having zero expenditures between utilization groups for each CHECK year. For subgroup analysis, Wilcoxon pairwise tests were performed to compare mean inpatient expenditures over CHECK years (Baseline year, first year in CHECK, and second year in CHECK) within each utilization risk group. Multiple comparisons were accounted for by using the Bonferroni correction[38].

RESULTS

Patient and clinical characteristics

Of the more than 20,000 patients enrolled in the CHECK program, 373 had SCD. Twelve outliers with inpatient expenditures more than $100,000 in any CHECK year were excluded from analyses because such patients were expected to have unique medical problems beyond their SCD[5,33]. Therefore, the analytic sample included 361 cases. Fifty-two percent of these 361 SCD patients were "engaged" for CHECK services, which were tailored to their individual needs. Table 1 shows the demographics and comorbidities in these 361 participants stratified by High utilization (n=32), Medium utilization (n=173) and Low utilization (n=156) groups. Statistical tests were conducted across risk utilization groups at baseline. Age and percent male

did not differ significantly across the three risk groups, nor did the percentage of patients who were engaged versus enrolled in the CHECK program. Splenic sequestration history was not significantly different across the three risk groups. Only stroke and respiratory disease varied significantly across the SCD hospitalization utilization risk groups: (Stroke, High utilization risk group= 15.6%, Medium utilization risk group=4.6%, and Low utilization risk group= 1.9%, p=.0007; Respiratory Disease High utilization risk group= 81.2%, Medium utilization risk group=60.7%, and Low utilization risk group= 46.2%, p<.001). For all the comorbidities, symptoms were significantly highest in the High risk group and lowest in the Low risk group

Analysis of inpatient expenditures

The utilization of acute care services was predicted to be associated with total expenditures because published studies show that acute inpatient expenditures are the dominant cost in SCD[39,40]. As expected, inpatient expenditures mirrored the trends of total expenditures across the three risk group categories (see Table 2). Many SCD patients had no inpatient expenditures. A two-part analysis accommodated the semi-continuous expenditure data - fitting a continuous model allowing for data with excess zeros. The results suggested that the effect of utilization risk group on inpatient expenditure varied by CHECK year. For utilization risk group comparisons, the first part of the analysis estimated the percent expenditure reduction for each CHECK year while the second part estimated the odds of having zero expenditures for each CHECK year (see Table 3).

The results suggested that the effect of utilization risk on expenditure varied by CHECK year. In the Baseline year, both Medium and Low utilization risk groups had lower expenditures compared to High utilization risk groups. During the first year in CHECK, the odds of having zero inpatient expenditures for patients in the Low risk group was 7.34 times those in the High risk group and the odds of having zero inpatient expenditure for patients in the Medium risk group was 3.54 times those in the High risk group. At baseline, 95% of patients in the low risk utilization group had zero expenditure compared to 22% in the high risk group.

Looking at expenses a different way, Figure 1 shows the frequency distribution of logarithm transformed expenditures for children in the three tiers of utilization. High utilizers (n=32; Panel A) began with a broad range of expenditures, then all but a few had reduced expenditures over the next two years, ending with a bimodal distribution. Wilcoxon pairwise tests suggested that inpatient expenditures during the second year in CHECK were significantly lower compared to Baseline year (adjusted p-value = 0.02). The other two comparisons (Year 1 compared to Baseline year (p=0.209) and Year 2 compared to Year 1 (p=0.42)) were not significantly different because the small sample size of high utilization risk group limits statistical power.

Figure 1, Panel B shows that Medium utilizers (n=173) began with a bimodal distribution. Inpatient expenditures during the second year in CHECK were significantly reduced compared to the first year (p = 0.004) and Baseline year (p = 0.002). The first year vs. baseline year was not significant (p=0.675). Figure 1, Panel C shows that Low utilizers (n=156) also began with a bimodal distribution of expenditures. Expenditures for the low utilizer tier increased over time. As expected, higher expenditures were associated with more hospital days; some were elective hospitalizations such as tonsillectomy and others were hospitalizations for unpredictable sickle cell complications. Using pairwise comparisons, inpatient expenditures for the second and first years in CHECK were significantly increased compared to the Baseline year (p < 0.001). The second compared to the first-year expenditures were not significantly different (p = 0.672).

DISCUSSION

The present descriptive study demonstrated that expenditures for patients with SCD in the CHECK High and Medium utilizer tiers decreased over time. However, the small size of the High utilizer group (n=32) may have reduced the statistical power to detect a true effect. The SCD patients in the Low utilizer tier showed significant rise in expenditure levels over time. The Low utilizer tier group increase in expenditures after the second year of CHECK may have been due to receiving appropriate, but formerly unused, services introduced by the CHECK CHWs.

Chronic health conditions effect an estimated 25% of children and adolescents in the United States and account for a disproportionate share of pediatric healthcare utilization and expenditures, with the majority of the $110 billion annual expenditures attributed to hospital care[34]. Similarly, while comprising a small proportion of children and adolescents with chronic diseases, those with SCD have a disproportionately large effect on health care expenditures[41].

In developing the CHECK program, the hope was that a comprehensive health care coordination program would reduce health care expenditures. We did not expect this program would impact all patients equally. While the overall analysis of the CHECK program showed no change in costs related to the program[33], this exploration specific to the children with SCD demonstrated a likely impact on healthcare costs for SCD children.

The comparisons between Low and High, Medium and High utilization risk groups support the expectation that the odds of zero expenditures were significantly different from Baseline Year in the predicted direction. We can speculate that care coordination was associated with some of these changes, but the study was designed as a demonstration project and has limitations (discussed below) that preclude definitive conclusion. A null hypothesis that High and Low utilization are simply exhibiting regression to the mean cannot be completely excluded. The high odds ratio of 240.54 for the comparison at Baseline year is likely due to cells with few patients. Finally, the bimodal distributions of utilization for all the risk groups (Figure 1) show striking similarity in Year 2. This longitudinal pattern suggests that one year of utilization data was not enough to stratification patients for utilization.

A longitudinal study of 101 children with SCD in Houston in 2011-2013 found that 25% of parents reported receiving care coordination help and another 20% reported a need for extra care coordination[42]. However, multivariate regression did not detect an association between care coordination and acute care utilization. The Houston findings are consistent with the stratification we used. Together, the CHECK program data and Houston data suggest that much a larger sample size and a rigorous study design might be required to determine a benefit of care coordination for children with SCD. This is difficult to do because SCD is a rare disease.

The longitudinal pattern of acute care utilization highlights that some SCD patients have complications that vary from year to year. These data suggest that future stratification by utilization risk groups should use baseline data that spans at least 3 years, and the intervention period probably should also span multiple years.

Limitations

This study has several limitations. First, because the CHECK program was designed as a healthcare demonstration project and not as a randomized clinical trial, there is no control group; patients receiving CHECK services were targeted for services for specific reasons. The SCD sample is small, illustrating the small proportion of chronically ill patients with the disorder but also limiting the statistical power necessary for introducing other variables in the analyses. Using these heterogeneous cost data, a sample size estimate for 3 utilization categories with repeated differences in expenditures across time and 2-3 covariates, alpha=.05 and power=.80 would require n=3800 SCD patients in each utilization category to detect a 10% cost difference. The SCD patients in this study were not selected using randomized sampling procedures and outliers were removed, which weakens the ability to generalize findings to the wider SCD population.

Only 52% of SCD patients were fully "engaged" in the CHECK program, meaning they received full CHECK services tailored to individual needs. This means our analysis does include some who may have needed services but did not choose to participate or could not be reached. Some acute hospitalizations in SCD are avoidable (e.g., hospitalization for sickle cell pain that was triggered by bad behavioral choices or failure to fill prescriptions for home pain medications), but other hospitalizations are unavoidable (e.g., fever or Acute chest syndrome). This makes determination of the appropriateness of hospitalizations difficult. New guidelines recommending pediatric use of the disease-modifying therapy hydroxyurea were released in 2014 during the CHECK study period and could have reduced the acute care utilization with or without CHECK

services[43]. CHECK SCD patients received medical services, care coordination, or education from other programs, confounding the coordinated care in CHECK. Most of the CHECK SCD patients were outside of UI Health, receiving a variety of services in other pediatric SCD programs in the Chicago region. The study design does not allow untangling a CHECK treatment effect from these other services. Finally, the longitudinal observational study design leaves open the possibility that the pattern simply represents the phenomenon that data at the extremes of a distribution might show "regression toward the mean" through random changes.

Conclusion

In conclusion, this analysis provides lessons regarding care coordination service needs for children. The heterogeneity of SCD care utilization was revealed in the skewed bimodal distribution of expenditures that emerged in each tier over the three years of data. Stratification showed a trend of reduced expenditures in the High risk and Medium risk groups. The CHECK care coordination intervention was a tailored "precision medicine" approach delivered by CHWs. With this, the care coordination tried to match the intensity of intervention to the multiple modifiers and barriers to SCD acute and chronic care. The benefit of CHECK might have been obscured by low sample size, uneven intensity of care coordination intervention, duration of intervention shorter than the natural variability of SCD expenditures (possibly 3 years), and the inability to distinguish the appropriateness of healthcare utilization for SCD. Future studies of care coordination in SCD should build upon these lessons learned in CHECK: stratify by tiers of healthcare utilization, focus on the highest utilizers, design more than three years of data collection, and add outcomes for appropriateness of healthcare utilization.

Table 1: SCD patients (N=361) by characteristics and SCD-related chronic diseases for High, Medium, and low utilization groups

	High	**High**	**Medium**	**Medium**	**Low**	**Low**	**p-value**
	N	**%**	**N**	**%**	**N**	**%**	
Total N=361	32	8.9	173	47.9	156	43.2	
Male	18	56.2	83	48.0	73	46.8	0.62
Age group Adolescents/young adults (11-18)	19	59.4	78	45.1	79	50.6	0.273
Engaged N (%)	16	50.0	83	48.0	84	53.8	0.566
Mood Disorders N (%)	9	28.1	26	15.0	17	10.9	0.039
Cognitive Deficit N (%)	5	15.6	8	4.6	9	5.8	0.073
Stroke N (%)	5	15.6	8	4.6	3	1.9	0.007
Splenic Sequestration N (%)	5	9.4	12	6.9	5	3.2	0.155

	High	High	Medium	Medium	Low	Low	p-value
Acute Chest Syndrome N (%)	15	46.9	45	26.0	46	29.5	0.059
Behavioral Health Needs (%)	8	25.0	32	18.5	37	23.7	0.446
Respiratory Disease N (%)	26	81.2	105	60.7	72	46.2	<0.001

Table 2: Arithmetic and geometric means and percent zero expenditures for SCD patients (N=361) in the High, Medium, and Low risk utilization groups, by time period

Utilization Risk	Time Period	Arithmetic means (SD)	Geometric means and significant differences	Geometric means and significant differences	Lower and upper confidence intervals for geometric means	Lower and upper confidence intervals for geometric means	Percent zero expenditures
					95%LCL	95%UCL	
High	Baseline year	17,371 (22,522)	987.11	**a**	219.46	4439.89	21.9
	1st year in CHECK	7,196 (12,816)	138.80		28.6	674.38	40.6
	2nd year in CHECK	4,971 (11,643)	15.45	**a**	3.33	71.65	68.8
Medium	Baseline year	3,685 (7,889)	38.10	a	20.49	70.81	53.2
	1st year in CHECK	3,529 (8,977)	18.85	b	10.28	34.55	63.0
	2nd year in CHECK	1,877 (6,189)	5.85	**a,b**	3.5	9.78	77.5
Low	Baseline year	101 (949)	1.36	**a,b**	1.09	1.69	94.9
	1st year in CHECK	2,406 (8,373)	7.24	**a**	4.12	12.7	74.4
	2nd year in CHECK	3,135 (8,687)	7.43	**b**	4.12	13.41	76.3

Note: Within each utilization risk category, geometric means that share a subscripted letter

are significantly different at p <.05. 95%LCL = Lower Confidence Limit. 95%UCL = Upper Confidence Limit

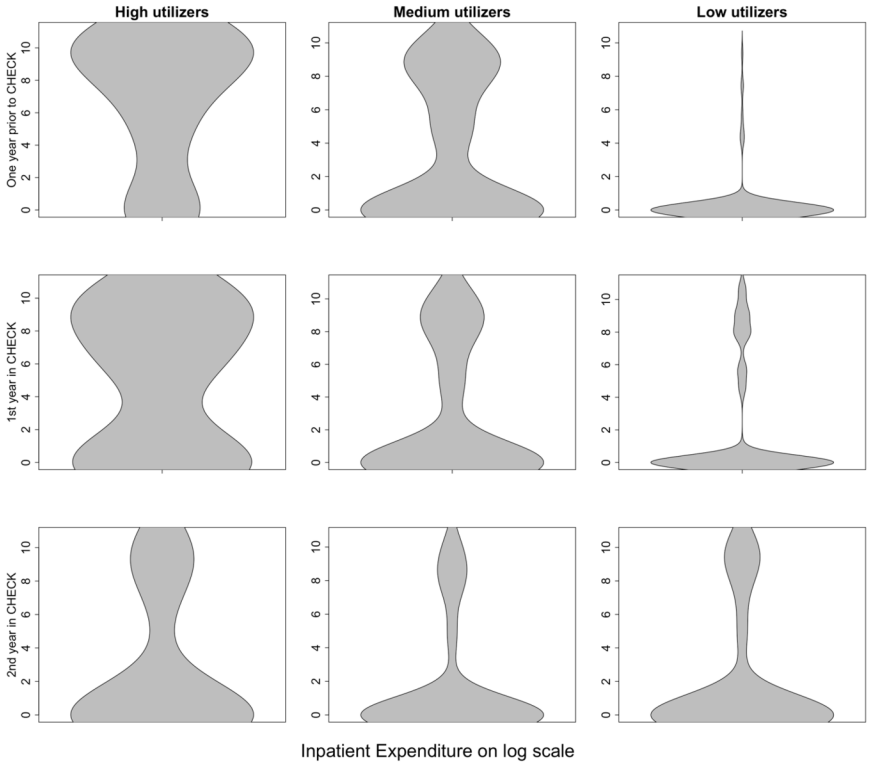
Table 3: Inpatient expenditures by utilization risk and CHECK year

Part 1: Association of utilization risk with non-zero inpatient expenditures Baseline Year and during CHECK

Utilization Risk	**CHEC**
Medium vs. High	Baselin
	1st yea
	2nd yea
Low vs. High	Baselin
	1st yea
	2nd yea
Part 2: Association of utilization risk with probability of zero inpatient expenditures prior to and during CHECK	Part 2:
Utilization Risk	**CHEC**
Medium vs. High	Baselin
	1st yea
	2nd yea
Low vs. High	Baselin
	1st yea
	2nd yea

Figure 1 – Bean plots of inpatient expenditures for High, Medium, and low utilization risk patients. To accommodate zero expenditures, the Y-axis shows Logarithmic transform of the inpatient expenditures using the term [expenditure + $1]. Thus, 0 on the Y-axis corresponds to zero expenditures in that year. The width of the plot indicates the frequency of patients with the level of expenditure.

Panel A Panel B Panel C



Pediatric Blood and Cancer submission requirements

* data availability statement. – data are available

* permission to reproduce material from other sources – N/A

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Ethics approval statement

The University of Illinois at Chicago Institutional Review Board approved this study (protocol # 2019-1164.)

Informed consent

Informed consent was not necessary for this study. The patient data were de-identified and no new clinical information was collected.

Clinical trials registration

Not applicable. This was a demonstration project for CMS, not a clinical trial.

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