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Article

Hospital Care for Adult Patients with Congenital Heart Diseases

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Abstract

Objective: The ideal type of hospital to care for adult congenital heart disease (ACHD) patients is not well known. Hospital competitiveness, clinical volume and market structure can influence clinical outcomes. We sought to understand how hospital competitiveness affects clinical outcomes in ACHD patients in the era prior to the Adult Congenital Heart Association accreditation program. **Methods**: Patient discharges with ACHD diagnosis codes were filtered between 2006–2011 from an all-payer inpatient healthcare database. Hospital-level data was linked to market structure patient flow. A common measure of market concentration used to determine market competitiveness—the Herfindahl-Hirschman Index (HHI)—was stratified into: more competitive (HHI $\leq$25th percentile), moderately competitive (HHI 25th to $<$75th percentile), and less competitive (HHI $\geq$75th percentile) hospital. Any complication, home discharge and mortality were analyzed with clustered mixed effects logistic regression. The combined impact of HHI and any complication on mortality by interaction was assessed. **Results**: A total of 67,434 patient discharges were isolated. More competitive hospitals discharged the least number of patients (N = 15,270, 22.6%) versus moderately competitive (N = 36,244, 53.7%) and less competitive (N = 15,920, 23.6%) hospitals. The adjusted odds of any complication or home discharge were not associated with hospital competitiveness strata. Compared to more competitive hospitals, mortality at moderately competitive hospitals (Adjusted Odds Ratio (AOR) 0.79, 95% CI: 0.66–0.94) and less competitive hospitals (AOR 0.79, 95% CI: 0.63–0.98) were lower (p = 0.025). Age, race, elective admission, transfer status, and payer mix were all significantly associated with adjusted odds of any complication, home discharge and mortality ($p \leq 0.05$). Having any complication independently increased the adjusted odds of mortality more than 6-fold ($p < 0.001$), and this trend was independent of HHI strata. Failure to rescue an ACHD patient from mortality after having any complication is highest at less competitive hospitals. Sensitivity analysis which excluded the transfer status variable, showed that any complication (p = 0.047) and mortality (p = 0.01) were independently associated with HHI strata. **Conclusions**: Whether lower competition allow hospitals to focus more on quality of care is unknown. Hospital competitiveness and outcome seem to have an inverse trend relationship among ACHD patients. Since medical care is frequently provided away from the home area, hospital selection is an important issue for ACHD patients. Further research is needed to determine why competitiveness is linked to surgical outcomes in this population.

Keywords

adult congenital heart disease; Herfindahl-Hirschman Index; mortality; complications; market economics

Introduction

One to the fastest growing segments in cardiovascular medicine are adult patients with congenital heart disease (ACHD) [1]. Most non-ACHD subspeciality clinicians treat these patients as either ‘big kids’ or base their clinical decisions for these patients on acquired heart disease criteria, which may be very different from ACHD guidelines. As such, quality of ACHD care is of major concern, since there can be wide variation [2,3]. Caring for ACHD patients is highly nuanced and requires multidisciplinary coordination [4,5]. This type of complex care is usually available at tertiary or quaternary centers only [6]. Research on hospital market competitiveness and quality outcomes and cost, has evaluated procedural subspecialties [7–10]. An evaluation of ACHD using a similar process has not been done for the United States (US) market. As an initial step and to glimpse the landscape of ACHD care in the US, we examined the risk of any complication, home discharge and mortality among patients based on hospital market structure. We hypothesized that increased competition would improve patient outcomes, and more competitive centers would provide better care.

Methods

Our work underwent expedited review and approved by the institutional review board (#IRB4463).

Data Source and Patient Population

Discharges with ACHD International Classification of Diseases–Ninth Revision, Clinical Modifications (ICD-9) diagnosis codes were filtered between 2006-2011 from Nationwide In-patient Sample (NIS) data (**Supplementary Table 1**). The NIS data represents the largest publicly available all-payer inpatient care database in the US, which is one of the Healthcare Cost and Utilization Project (HCUP) datasets sponsored by Agency for Healthcare Research and Quality (AHRQ). The data represent all discharges from a 20% random sample of community hospitals in the American Hospital Association (AHA) Annual Survey from 2006 to 2011. NIS hospital-level data was linked using a unique hospital identifier with Hospital Market Structure (HMS) data. HMS data was available from 2006 and 2009. NIS discharges from years 2006–2008 were linked with the 2006 HMS data, and NIS discharges from 2009–2011 were linked with the 2009 HMS data. Discharges from hospitals with HMS data were included. If a patient was missing one of the covariates of interest, they were excluded. However, if one was missing an outcome variable, they were not included in that analysis but were included in the other analyses. Comorbidities were assessed by components of the Charlson Comorbidities (**Supplementary Table 2**).

Definitions

To examine the effect of market concentration on outcomes, we used the HMS patient flow Herfindahl-Hirschman Index (HHI) variable, which uses hospital discharges and ZIP code data to quantify hospital market concentration. HHI ranges from 0 to 1, with lower numbers indicating lower concentration and higher competitiveness. Higher HHI values indicate higher concentration and lower levels of market competition. For example, an HHI of 1 indicates a monopoly, with no competition. We generated three HHI groups using quartile boundaries: $\leq$25th percentile (low concentration, more competitive), 25th to $<$75th percentile (moderate concentration), and $\geq$75th percentile (high concentration, less competitive). Quartile boundaries were calculated using HHI data from hospitals within the sample. Each hospital contributed one value for quartile calculation. Some hospitals had HHI values from both the 2006 and 2009 HMS data. For those institutions, the average of their two HHI values was taken for quartile calculations.

Outcomes

This study focused on three main outcomes: any complication, discharge to home (in patients who survived to discharge), and mortality. To examine the relationship between complications and HHI on mortality, a fourth model was run with mortality as an outcome of an interaction term between HHI category and complication status. Complications were categorized in eight separate disease areas (**Supplementary Table 3**).

Statistical Analysis

Descriptive statistics such as counts and proportions, mean and standard deviation, or median and 25th/75th percentiles were calculated by hospital competitiveness. Outcomes were analyzed with clustered mixed effects logistic regression using the melogit command in Stata. Analyses included a random intercept for hospital to account for within-hospital correlation. To account for clinical and demographic factors, the model controlled for age, sex, race, weekend admissions, elective status, hospital bed size, rural status, hospital region, transfer status, hospital control, teaching hospital status, primary payer, median household income based on ZIP code, number of diagnoses, number of procedures, and comorbidities.

Because we were not interested in obtaining any national estimates and were instead using the NIS data to obtain a convenience sample of ACHD patients, we did not use survey weights in the analysis. Additionally, HCUP does not recommend using survey weights for clustered analyses, as the underlying model designs are based on conceptually infinite populations. Instead, as recommended by HCUP to us, we controlled for variables that were used to generate the weights by including those variables in our models. Model fit was assessed by calculating an area under the curve (AUC) with 95% Confidence Interval (CI). We also conducted sensitivity analyses by running the same models as described above, but omitting the transfer status variable. Transfer status was not collected prior to 2008. However, due to its potential important impact on outcomes, we included it in the primary analysis. All models fit well, with AUC ranging from 0.77 to 0.89. All lower bounds of the 95% CI were well above 0.5. Data management was conducted using SAS 9.4TS1M5 (SAS Institute Inc., Cary, NC, USA), and analysis was completed using Stata 16 (Stata Corp., College Station, TX, USA).

Results

There were 67,434 discharges eligible for analysis: 15,270 (22.6%) in the more competitive HHI category, 36,244 (53.7%) in the moderately competitive HHI category, and 15,920 (23.6%) in the less competitive HHI category. Mean age across groups was clinically similar be-

Table 1. Patient characteristics by hospital regional market competitiveness.

	More competitive (N = 15,270)	Moderately competitive (N = 36,244)	Less competitive (N = 15,920)
Age-Mean (SD)	55.2 (19.1)	57.8 (18.8)	59.4 (18.3)
Female-N (%)	7912 (51.8)	18,403 (50.8)	7891 (49.6)
Race-N (%)			
White	8500 (55.7)	22,656 (62.5)	10,509 (66.0)
Black	1819 (11.9)	2790 (7.7)	865 (5.4)
Hispanic	2439 (16.0)	1738 (4.8)	757 (4.8)
Asian or Pacific Islander	564 (3.7)	522 (1.4)	151 (0.9)
Weekend admission-N (%)	2672 (17.5)	6090 (16.8)	2828 (17.8)
Elective-N (%)	4345 (28.5)	11,054 (30.5)	4140 (26.0)
Hospital bed size-N (%)			
Small	1403 (9.2)	4410 (12.2)	931 (5.8)
Medium	2877 (18.8)	7351 (20.3)	3199 (20.1)
Large	10,990 (72.0)	24,483 (67.6)	11,790 (74.1)
Rural-N (%)	241 (1.6)	1453 (4.0)	2671 (16.8)
Hospital region-N (%)			
Northeast	216 (1.4)	4256 (11.7)	1799 (11.3)
Midwest	3776 (24.7)	12,448 (34.3)	4539 (28.5)
South	4113 (26.9)	12,673 (35.0)	6386 (40.1)
West	7165 (46.9)	6867 (18.9)	3196 (20.1)
Transfer-N (%)			
Not transferred in	13,766 (90.2)	32,165 (88.7)	14,454 (90.8)
Transferred in from a different acute care hospital	1196 (7.8)	3469 (9.6)	1173 (7.4)
Transferred in from another type of health facility	308 (2.0)	610 (1.7)	293 (1.8)
Hospital control-N (%)			
Government	10,281 (67.3)	26,984 (74.5)	8984 (56.4)
Government, nonfederal (public)	214 (1.4)	863 (2.4)	1305 (8.2)
Private, not-for-profit (voluntary)	2999 (19.6)	5629 (15.5)	3184 (20.0)
Private, investor-owned (proprietary)	1713 (11.2)	2261 (6.2)	940 (5.9)
Teaching hospital-N (%)	9335 (61.1)	22,714 (62.7)	7673 (48.2)
Primary payer-N (%)			
Medicare	5721 (37.5)	16,173 (44.6)	7676 (48.2)
Medicaid	2092 (13.7)	3598 (9.9)	1475 (9.3)
Private insurance	6054 (39.6)	13,711 (37.8)	5370 (33.7)
Self-pay	784 (5.1)	1514 (4.2)	798 (5.0)
No charge	148 (1.0)	232 (0.6)	63 (0.4)
Comorbidities-N (%)			
Acquired immune deficiency syndrome	35 (0.2)	49 (0.1)	11 (0.1)
Alcohol abuse	526 (3.4)	1215 (3.4)	518 (3.3)
Deficiency anemias	2978 (19.5)	6027 (16.6)	2543 (16.0)
Rheumatoid arthritis/collagen vascular diseases	433 (2.8)	981 (2.7)	467 (2.9)
Chronic blood loss anemia	295 (1.9)	614 (1.7)	242 (1.5)
Congestive heart failure	1394 (9.1)	3367 (9.3)	1455 (9.1)
Chronic pulmonary disease	2518 (16.5)	6701 (18.5)	3214 (20.2)
Coagulopathy	1445 (9.5)	2989 (8.2)	1101 (6.9)
Depression	1371 (9.0)	3843 (10.6)	1909 (12.0)
Diabetes, uncomplicated	2487 (16.3)	5986 (16.5)	2777 (17.4)
Diabetes with chronic complications	596 (3.9)	1320 (3.6)	655 (4.1)
Drug abuse	488 (3.2)	996 (2.7)	405 (2.5)
Hypertension	7650 (50.1)	19,038 (52.5)	8478 (53.3)
Hypothyroidism	1810 (11.9)	4186 (11.5)	1909 (12.0)
Liver disease	507 (3.3)	973 (2.7)	352 (2.2)
Lymphoma	92 (0.6)	275 (0.8)	89 (0.6)

Table 1. Continued.

	More competitive (N = 15,270)	Moderately competitive (N = 36,244)	Less competitive (N = 15,920)
Fluid and electrolyte disorders	3692 (24.2)	8539 (23.6)	3438 (21.6)
Metastatic cancer	136 (0.9)	376 (1.0)	138 (0.9)
Other neurological disorders	935 (6.1)	2367 (6.5)	1081 (6.8)
Obesity	1635 (10.7)	4051 (11.2)	1956 (12.3)
Paralysis	645 (4.2)	1458 (4.0)	649 (4.1)
Peripheral vascular disorders	1545 (10.1)	3909 (10.8)	1751 (11.0)
Psychoses	578 (3.8)	1207 (3.3)	528 (3.3)
Pulmonary circulation disorders	953 (6.2)	2164 (6.0)	909 (5.7)
Renal failure	1781 (11.7)	4013 (11.1)	1785 (11.2)
Solid tumor without metastasis	201 (1.3)	409 (1.1)	193 (1.2)
Peptic ulcer disease excluding bleeding	3 (0.0)	14 (0.0)	1 (0.0)
Valvular disease	1760 (11.5)	4648 (12.8)	2142 (13.5)
Weight loss	641 (4.2)	1330 (3.7)	613 (3.9)

tween 55.2 and 59.4 years. The lowest percentage of white patients and the highest percentage of black patients were treated at the more competitive hospitals. Less competitive hospitals were more likely to be identified in a rural area, and transfer rates were highest at the moderately competitive hospitals (Table 1).

Following multivariable adjustment, there was no significant relationship between HHI category and occurrence of any complication ($p = 0.27$). However, several variables including transfer in status, increasing age, non-white race, weekend admission and non-Medicare participants were all independently associated with increased presence of any complication after adjusting for market factors (Table 2).

Discharges to home, excluding inpatient deaths, had no significant independent association with HHI category following adjustment ($p = 0.86$). But multiple covariates such as older age, female gender, weekend admission, and transfer status were all independently associated with reduced odds of discharge to home after controlling for market structure (Table 3).

There was a significant relationship between HHI category and mortality after adjustment ($p = 0.025$). Compared with more competitive hospitals, discharges from moderately competitive hospitals had lower adjusted odds of death (AOR = 0.79, 95% CI: 0.66–0.94), and this was also seen in less competitive hospitals (aOR = 0.79, 95% CI: 0.63–0.98) (Table 4).

From a patient risk factor perspective—the risk of complication was higher in patients with metastatic cancer, paralysis, renal failure, pulmonary disorders, coagulopathy, heart failure, weight loss, and fluid/electrolyte disorders. Obesity, hypertension, liver disease and chronic anemia conferred an increased odds of home discharge.

While examining models further, the interaction between the risk of any complication and HHI category on mortality was significant ($p = 0.03$), indicating differential risk of mortality (Table 5). After accounting for the interaction term, the main effect of HHI category trended towards significance ($p = 0.06$), and there was a strong effect of complication on mortality ($p < 0.0001$). The interaction is driven by a difference between less competitive and moderately competitive hospitals. As seen in Fig. 1, complications increase mortality at all levels of hospital competitiveness. Within less competitive hospitals, patients who had a complication had 8.2 times the adjusted odds of dying compared with patients without a complication. This effect was smaller in moderately competitive hospitals, where the adjusted odds of dying with a complication was 4.6 times the adjusted odds of dying in patients without a complication. Comparing the aOR of 8.2 (95% CI: 5.0–11.3) in less competitive hospitals with the aOR of 4.6 (95% CI: 3.6–5.7) in moderate hospitals, we see that the effect of having a complication is associated with a significantly higher adjusted odds of death in the less competitive hospitals ($p = 0.01$). In more competitive hospitals, the odds of dying in patients with complication is 5.7 (95% CI: 3.8–7.6) times the adjusted odds in patients without complication.

Discussion

ACHD patients have high complexity and can require comprehensive supportive care which could be hard to deliver in a non-tertiary care system [6]. ACHD patients are more likely to have lower socioeconomic status, lower educational achievements, higher mental health and cognitive barriers, and tend to live further away from urban centers, placing them at higher risk of complications [6,11,12]. In this study, we learned that more competitive hospitals and less competitive hospitals collectively treated approximately the same number of patients compared to moderately competitive hospitals. Hospital competitiveness and risk of any complication may not be directly associated; however, several patient factors are all independently asso-

Table 2. Adjusted odds ratios of any complication following adjustments by various covariates.

Covariates, any complication	Adjusted odds ratio	95% CI	*p* value
Herfindahl-Hirschman Index category			0.271
More competitive	Ref.		
Moderately competitive	1.042	(0.962, 1.129)	
Less competitive	0.980	(0.889, 1.081)	
Age	1.013	(1.011, 1.014)	<0.001
Female	0.848	(0.818, 0.880)	<0.001
Race			<0.001
White	Ref.		
Black	1.159	(1.079, 1.245)	
Hispanic	1.059	(0.980, 1.145)	
Asian or Pacific Islander	1.145	(0.998, 1.314)	
Weekend admission	1.155	(1.102, 1.210)	<0.001
Elective	0.520	(0.497, 0.544)	<0.001
Hospital bedsize			0.710
Small	Ref.		
Medium	1.032	(0.935, 1.138)	
Large	1.002	(0.916, 1.097)	
Rural	1.133	(0.980, 1.309)	0.090
Hospital region			0.697
Northeast	Ref.		
Midwest	0.923	(0.805, 1.058)	
South	0.926	(0.800, 1.071)	
West	0.925	(0.794, 1.078)	
Transfer			<0.001
Not transferred in	Ref.		
Transferred in from a different acute care hospital	1.242	(1.166, 1.323)	
Transferred in from another type of health facility	1.127	(0.988, 1.285)	
Hospital control			0.249
Government	Ref.		
Government, nonfederal (public)	0.871	(0.719, 1.054)	
Private, not-for-profit (voluntary)	0.942	(0.821, 1.080)	
Private, investor-owned (proprietary)	0.856	(0.735, 0.997)	
Teaching hospital	0.942	(0.849, 1.046)	0.262
Primary payer			<0.001
Medicare	Ref.		
Medicaid	1.102	(1.025, 1.184)	
Private insurance	1.138	(1.084, 1.195)	
Self-pay	1.312	(1.195, 1.441)	
No charge	1.064	(0.849, 1.334)	
Comorbidities			
Acquired immune deficiency syndrome	0.893	(0.568, 1.405)	0.625
Alcohol abuse	0.948	(0.859, 1.046)	0.284
Deficiency anemias	0.754	(0.718, 0.792)	<0.001
Rheumatoid arthritis/collagen vascular diseases	0.757	(0.681, 0.841)	<0.001
Chronic blood loss anemia	0.753	(0.655, 0.866)	<0.001
Congestive heart failure	1.445	(1.354, 1.543)	<0.001
Chronic pulmonary disease	1.025	(0.979, 1.074)	0.291
Coagulopathy	1.432	(1.339, 1.531)	<0.001
Depression	0.743	(0.700, 0.788)	<0.001
Diabetes, uncomplicated	0.945	(0.900, 0.992)	0.022
Diabetes with chronic complications	0.965	(0.878, 1.060)	0.456
Drug abuse	0.974	(0.873, 1.087)	0.643
Hypertension	0.811	(0.780, 0.844)	<0.001

Table 2. Continued.

Covariates, any complication	Adjusted odds ratio	95% CI	*p* value
Hypothyroidism	0.811	(0.767, 0.857)	<0.001
Liver disease	0.660	(0.591, 0.737)	<0.001
Lymphoma	1.052	(0.855, 1.295)	0.630
Fluid and electrolyte disorders	1.665	(1.594, 1.739)	<0.001
Metastatic cancer	1.271	(1.065, 1.516)	0.008
Other neurological disorders	0.748	(0.696, 0.805)	<0.001
Obesity	0.865	(0.816, 0.916)	<0.001
Paralysis	1.309	(1.199, 1.431)	<0.001
Peripheral vascular disorders	0.937	(0.884, 0.992)	0.026
Psychoses	0.781	(0.709, 0.861)	<0.001
Pulmonary circulation disorders	1.426	(1.320, 1.540)	<0.001
Renal failure	1.358	(1.279, 1.441)	<0.001
Solid tumor without metastasis	0.983	(0.840, 1.151)	0.835
Peptic ulcer disease excluding bleeding	0.424	(0.141, 1.274)	0.126
Valvular disease	0.944	(0.893, 0.998)	0.041
Weight loss	1.456	(1.317, 1.610)	<0.001

ciated with increased risk of any complication. Similarly, hospital competitiveness and discharge to home may not be directly associated, but again many patient factors independently associate with discharge to home. Less competitive hospitals had lower mortality versus more competitive hospitals, and age, race, elective admissions, and transfer status were all associated with higher mortality. But less competitive hospitals were associated with greater mortality compared to more competitive hospitals when there was a complication, suggesting their reduced ability to recognize and rescue a clinically decompensating ACHD patient.

Insomuch as ACHD care is multidisciplinary, a clear relationship between hospital competitiveness and any complication or discharge to home were not seen, and were unexpected. This lack of association between complications and outcomes by HHI among ACHD centers has been reported previously [13]. Given that ACHD patients require complex care, we anticipated higher complications and lower home discharge at less competitive hospitals. Our ACHD cohort is not a procedural subset only, and therefore may account for our findings, compared to other series where volume, care and cost differences trend by HHI strata [7–9,14]. ACHD patients are frequently misdiagnosed and receive inadequate, late, or inappropriate care [15,16]. They are also at high risk of being transferred out to a tertiary center.

We are not aware of literature addressing hospital competitiveness and outcomes in ACHD patients. In non-ACHD patients, Sethi *et al*. [9] studied Endovascular aortic aneurysm repair (EVAR) versus open infra-renal Abdominal aortic aneurysm (AAA) management and postulated that hospitals in competitive markets were early EVAR adopters and had improved AAA outcomes. They found that neither complications nor in-hospital mortality were associated with HHI and that EVAR adoption as a technology was not solely driven by clinical indication but also by market forces [9]. We know that from a cohort of >200,000 patients who underwent prostatectomy, nephrectomy, hysterectomy or oophorectomy across 13,170 hospitals in the US, hospital competitiveness drove the choice towards a robotic assisted procedure [14]. Taken together, procedural based subspecialties are influenced by timing of adoption, surgical volume and purportedly better outcomes in more competitive hospitals and markets. ACHD patients require dynamic and advanced medical management and do not share volume-outcome relationships.

Our mortality analysis findings suggests three major themes: (i) less competitive hospitals have lower ACHD mortality suggesting earlier transfer out, or earlier disposition to other centers or home, (ii) mortality event rate is high after a complication in ACHD patients in less competitive hospitals, and (iii) once there is a complication, less competitive hospitals have reduced ability to avoid a mortality in ACHD patients. This may be due to lack of recognition, resources, inability to transfer out at late stage or other reasons (i.e., clinical failure to rescue). More competitive hospitals tend to hire competitive physicians who seek to distinguish themselves through innovation and adoption [13]. Competitive hospitals could arguably have higher volumes which could reflect having expertise and better resources. Hall and colleagues examined National Surgical Quality Improvement Program (NSQIP) data between 2002 and 2005 and found that surgeon specialization was inversely related to mortality rates after adjusting for case volume when using medium HHI procedural aggregation, suggesting that surgical specialization is correlated with improved mortality [17]. We have learned that TAVR adoption by physician groups in concentrated markets was impacted by regulations around reimbursement favoring more adoption in less competitive markets [18]. These data sug-

Table 3. Adjusted odds ratios of discharge to home following adjustments by various covariates.

Covariates, discharge to home	Adjusted odds ratio	95% CI	*p* value
Herfindahl-Hirschman Index category			0.861
More competitive	Ref.		
Moderately competitive	1.023	(0.928, 1.127)	
Less competitive	1.001	(0.889, 1.128)	
Age	0.969	(0.967, 0.970)	<0.001
Female	0.868	(0.835, 0.904)	<0.001
Race			<0.001
White	Ref.		
Black	0.838	(0.776, 0.906)	
Hispanic	1.000	(0.916, 1.093)	
Asian or Pacific Islander	1.084	(0.930, 1.265)	
Weekend admission	0.926	(0.880, 0.974)	0.003
Elective	0.855	(0.815, 0.897)	<0.001
Hospital bedsize			0.080
Small	Ref.		
Medium	0.994	(0.885, 1.116)	
Large	1.088	(0.978, 1.211)	
Rural	1.038	(0.879, 1.226)	0.658
Hospital region			<0.001
Northeast	Ref.		
Midwest	1.885	(1.594, 2.230)	
South	2.365	(1.974, 2.834)	
West	2.742	(2.268, 3.314)	
Transfer			<0.001
Not transferred in	Ref.		
Transferred in from a different acute care hospital	0.673	(0.628, 0.721)	
Transferred in from another type of health facility	0.365	(0.316, 0.423)	
Hospital control			0.043
Government			
Government, nonfederal (public)	0.770	(0.615, 0.963)	
Private, not-for-profit (voluntary)	0.882	(0.747, 1.042)	
Private, investor-owned (proprietary)	0.851	(0.708, 1.023)	
Teaching hospital	1.127	(0.994, 1.277)	0.062
Primary payer			<0.001
Medicare	Ref.		
Medicaid	1.067	(0.986, 1.154)	
Private insurance	1.307	(1.241, 1.376)	
Self-pay	1.853	(1.647, 2.086)	
No charge	2.241	(1.661, 3.024)	
Comorbidities			
Acquired immune deficiency syndrome	0.889	(0.555, 1.423)	0.623
Alcohol abuse	1.019	(0.915, 1.135)	0.732
Deficiency anemias	0.864	(0.821, 0.910)	<0.001
Rheumatoid arthritis/collagen vascular diseases	1.051	(0.942, 1.173)	0.373
Chronic blood loss anemia	1.220	(1.051, 1.417)	0.009
Congestive heart failure	0.710	(0.663, 0.761)	<0.001
Chronic pulmonary disease	1.033	(0.983, 1.085)	0.197
Coagulopathy	0.748	(0.698, 0.803)	<0.001
Depression	0.953	(0.896, 1.014)	0.129
Diabetes, uncomplicated	0.979	(0.930, 1.030)	0.405
Diabetes with chronic complications	0.843	(0.766, 0.928)	0.001
Drug abuse	0.753	(0.667, 0.850)	<0.001
Hypertension	1.107	(1.061, 1.155)	<0.001

Table 3. Continued.

Covariates, discharge to home	Adjusted odds ratio	95% CI	*p* value
Hypothyroidism	1.153	(1.088, 1.223)	<0.001
Liver disease	1.140	(1.014, 1.282)	0.028
Lymphoma	0.755	(0.608, 0.938)	0.011
Fluid and electrolyte disorders	0.725	(0.692, 0.760)	<0.001
Metastatic cancer	0.829	(0.688, 0.998)	0.048
Other neurological disorders	0.722	(0.669, 0.778)	<0.001
Obesity	1.062	(0.999, 1.130)	0.053
Paralysis	0.286	(0.260, 0.315)	<0.001
Peripheral vascular disorders	1.026	(0.966, 1.089)	0.405
Psychoses	0.669	(0.605, 0.740)	<0.001
Pulmonary circulation disorders	0.727	(0.670, 0.789)	<0.001
Renal failure	1.021	(0.960, 1.086)	0.509
Solid tumor without metastasis	1.117	(0.947, 1.319)	0.189
Peptic ulcer disease excluding bleeding	1.843	(0.578, 5.871)	0.301
Valvular disease	1.045	(0.984, 1.109)	0.151
Weight loss	0.468	(0.422, 0.520)	<0.001

Table 4. Adjusted odds ratios of mortality following adjustments by various covariates.

Covariates, mortality	Adjusted odds ratio	95% CI	*p* value
Herfindahl-Hirschman Index category			0.025
More competitive	Ref.		
Moderately competitive	0.786	(0.655, 0.942)	
Less competitive	0.785	(0.629, 0.979)	
Age	1.016	(1.011, 1.020)	<0.001
Female	0.972	(0.868, 1.089)	0.629
Race			0.006
White	Ref.		
Black	1.250	(1.018, 1.534)	
Hispanic	0.958	(0.747, 1.228)	
Asian or Pacific Islander	0.867	(0.565, 1.331)	
Weekend admission	1.113	(0.973, 1.274)	0.118
Elective	0.600	(0.516, 0.696)	<0.001
Hospital bedsize			0.087
Small	Ref.		
Medium	0.886	(0.694, 1.131)	
Large	0.793	(0.637, 0.988)	
Rural	0.889	(0.615, 1.286)	0.533
Hospital region			<0.001
Northeast	Ref.		
Midwest	0.535	(0.394, 0.727)	
South	0.758	(0.554, 1.039)	
West	0.720	(0.516, 1.005)	
Transfer			<0.001
Not transferred in	Ref.		
Transferred in from a different acute care hospital	1.791	(1.535, 2.090)	
Transferred in from another type of health facility	1.958	(1.475, 2.599)	
Hospital control			0.227
Government	Ref.		
Government, nonfederal (public)	1.342	(0.852, 2.114)	
Private, not-for-profit (voluntary)	0.870	(0.629, 1.202)	
Private, investor-owned (proprietary)	1.042	(0.728, 1.491)	
Teaching hospital	0.943	(0.732, 1.214)	0.648

Table 4. Continued.

Covariates, mortality	Adjusted odds ratio	95% CI	*p* value
Primary payer			0.050
Medicare	Ref.		
Medicaid	0.901	(0.719, 1.130)	
Private insurance	0.789	(0.676, 0.922)	
Self-pay	1.053	(0.774, 1.433)	
No charge	0.750	(0.316, 1.777)	
Comorbidities			
Acquired immune deficiency syndrome	0.649	(0.151, 2.794)	0.562
Alcohol abuse	0.925	(0.691, 1.238)	0.600
Deficiency anemias	0.688	(0.600, 0.789)	<0.001
Rheumatoid arthritis/collagen vascular diseases	1.064	(0.798, 1.418)	0.673
Chronic blood loss anemia	0.652	(0.436, 0.974)	0.037
Congestive heart failure	1.765	(1.529, 2.037)	<0.001
Chronic pulmonary disease	0.978	(0.859, 1.115)	0.743
Coagulopathy	1.520	(1.316, 1.755)	<0.001
Depression	0.624	(0.509, 0.764)	<0.001
Diabetes, uncomplicated	0.868	(0.750, 1.004)	0.057
Diabetes with chronic complications	0.545	(0.409, 0.725)	<0.001
Drug abuse	0.730	(0.499, 1.068)	0.105
Hypertension	0.498	(0.442, 0.561)	<0.001
Hypothyroidism	1.000	(0.851, 1.175)	>0.999
Liver disease	1.084	(0.835, 1.407)	0.545
Lymphoma	1.530	(0.998, 2.348)	0.051
Fluid and electrolyte disorders	1.816	(1.611, 2.047)	<0.001
Metastatic cancer	2.627	(1.921, 3.590)	<0.001
Other neurological disorders	1.247	(1.045, 1.489)	0.014
Obesity	0.671	(0.554, 0.814)	<0.001
Paralysis	0.997	(0.794, 1.253)	0.981
Peripheral vascular disorders	0.793	(0.672, 0.936)	0.006
Psychoses	0.548	(0.385, 0.780)	0.001
Pulmonary circulation disorders	1.886	(1.607, 2.213)	<0.001
Renal failure	1.388	(1.203, 1.601)	<0.001
Solid tumor without metastasis	1.370	(0.956, 1.965)	0.087
Peptic ulcer disease excluding bleeding	0.934	(0.092, 9.452)	0.954
Valvular disease	0.750	(0.637, 0.882)	0.001
Weight loss	1.110	(0.930, 1.325)	0.247

gest that market competitiveness can drive clinical care, and higher managed care markets have greater adoption. In general, there is no conceivable way to expect all ACHD patients in the US to have access to similar care [4,5]. The less competitive markets have fewer ACHD trained physicians caring for these patients, with a relatively bigger catchment. Consolidation of ACHD services maybe an ideal advocacy position (based on low prevalence and need) for special expertise to provide high quality care for this heterogeneous and challenging patient cohort. As more centers get accredited by the Adult Congenital Heart Disease Association (ACHA), insurers may regard all accredited centers as equal and limit patient choice. Should ACHD care be stratified into comprehensive and basic models, may be intriguing to consider.

While our work has several strengths, there are some notable limitations. First, by using an administrative database, we are unable to account for potential unmeasured confounders, and patient level specific data including severity of presenting illness, medications, and social determinants of health. It is possible that there may be bias toward sicker patients in competitive markets that may not be realized in administrative data and might confound the effects of market concentration. The temporal relationship of ACHD care and complication are not discreet nor related in this dataset and cannot be fully evaluated. Second, the NIS is limited to a sampling of only 20% of hospitals in the United States. Random sampling may have affected our results if hospitals selected in a particular market were biased toward frequent care of ACHD patients, although our sen-

Table 5. Adjusted odds ratios of mortality and complications following adjustments by various covariates.

Covariates, mortality with complication	Adjusted odds ratio	95% CI	*p* value
Interaction			0.033
Complication * more competitive	Ref.		
Complication * moderately competitive	0.794	(0.527, 1.196)	
Complication * less competitive	1.434	(0.850, 2.420)	
Herfindahl-Hirschman Index category			0.064
More competitive	Ref.		
Moderately competitive	0.949	(0.636, 1.416)	
Less competitive	0.576	(0.344, 0.964)	
Any complication	6.409	(4.514, 9.099)	<0.001
Age	1.013	(1.009, 1.017)	<0.001
Female	1.007	(0.898, 1.128)	0.911
Race			0.035
White	Ref.		
Black	1.222	(0.995, 1.500)	
Hispanic	0.952	(0.743, 1.221)	
Asian or Pacific Islander	0.872	(0.570, 1.334)	
Weekend admission	1.085	(0.948, 1.242)	0.234
Elective	0.678	(0.583, 0.788)	<0.001
Hospital bedsize			0.103
Small	Ref.		
Medium	0.880	(0.692, 1.119)	
Large	0.800	(0.645, 0.992)	
Rural	0.847	(0.587, 1.221)	0.373
Hospital region			<0.001
Northeast	Ref.		
Midwest	0.557	(0.414, 0.749)	
South	0.780	(0.575, 1.057)	
West	0.736	(0.533, 1.015)	
Transfer			<0.001
Not transferred in	Ref.		
Transferred in from a different acute care hospital	1.687	(1.446, 1.970)	
Transferred in from another type of health facility	1.873	(1.410, 2.489)	
Hospital control			0.117
Government			
Government, nonfederal (public)	1.427	(0.913, 2.229)	
Private, not-for-profit (voluntary)	0.871	(0.635, 1.193)	
Private, investor-owned (proprietary)	1.060	(0.747, 1.505)	
Teaching hospital	0.943	(0.737, 1.206)	0.638
Primary payer			0.058
Medicare	Ref.		
Medicaid	0.888	(0.708, 1.113)	
Private insurance	0.786	(0.673, 0.918)	
Self-pay	0.995	(0.731, 1.356)	
No charge	0.739	(0.310, 1.763)	
Comorbidities			
Acquired immune deficiency syndrome	0.617	(0.142, 2.686)	0.520
Alcohol abuse	0.931	(0.695, 1.246)	0.629
Deficiency anemias	0.730	(0.636, 0.837)	<0.001
Rheumatoid arthritis/collagen vascular diseases	1.131	(0.847, 1.510)	0.406
Chronic blood loss anemia	0.720	(0.482, 1.077)	0.110
Congestive heart failure	1.614	(1.400, 1.861)	<0.001
Chronic pulmonary disease	0.961	(0.843, 1.095)	0.548
Coagulopathy	1.427	(1.237, 1.647)	<0.001

Table 5. Continued.

Covariates, mortality with complication	Adjusted odds ratio	95% CI	*p* value
Depression	0.681	(0.555, 0.835)	<0.001
Diabetes, uncomplicated	0.878	(0.758, 1.016)	0.080
Diabetes with chronic complications	0.544	(0.409, 0.723)	<0.001
Drug abuse	0.729	(0.498, 1.068)	0.105
Hypertension	0.534	(0.474, 0.602)	<0.001
Hypothyroidism	1.037	(0.882, 1.219)	0.662
Liver disease	1.193	(0.917, 1.551)	0.189
Lymphoma	1.483	(0.968, 2.273)	0.070
Fluid and electrolyte disorders	1.571	(1.394, 1.771)	<0.001
Metastatic cancer	2.530	(1.849, 3.462)	<0.001
Other neurological disorders	1.312	(1.098, 1.568)	0.003
Obesity	0.698	(0.576, 0.847)	<0.001
Paralysis	0.924	(0.736, 1.159)	0.494
Peripheral vascular disorders	0.821	(0.696, 0.969)	0.020
Psychoses	0.583	(0.409, 0.831)	0.003
Pulmonary circulation disorders	1.775	(1.514, 2.081)	<0.001
Renal failure	1.302	(1.130, 1.501)	<0.001
Solid tumor without metastasis	1.397	(0.973, 2.007)	0.070
Peptic ulcer disease excluding bleeding	1.341	(0.126, 14.321)	0.808
Valvular disease	0.771	(0.656, 0.907)	0.002
Weight loss	1.070	(0.899, 1.274)	0.446

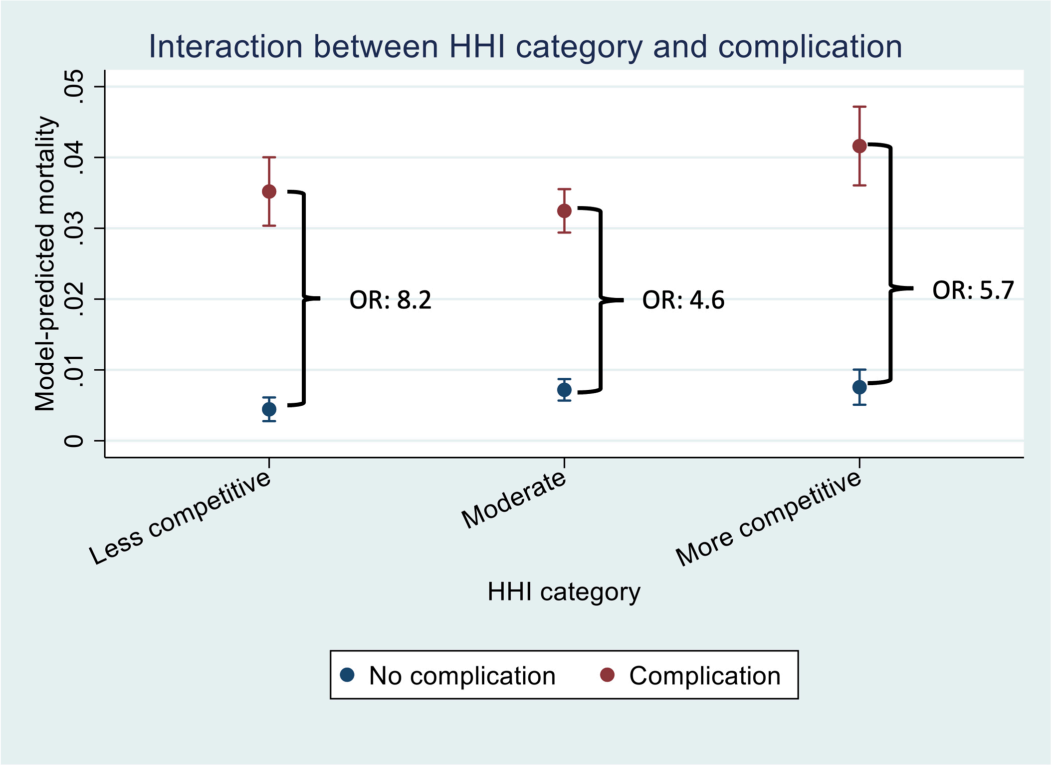

Fig. 1. The odds of having a mortality with a complication at less competitive hospitals is approximately 8× than without a complication. The odds of having a mortality with a complication at moderate competitiveness hospitals is approximately 5× than without a complication. The odds of having a mortality with a complication at more competitive hospitals is approximately 6× than without a complication.

sitivity analysis in part addresses this bias. Third, there is variation in defining the ACHD patient, and use of diagnosis codes to isolate patients from an administrative dataset is challenging. Fourth, we used hospital market structure files that are from two different time points and the latest available information, but may not be current nor accurate and may not fully reflect the contemporary state. Lastly, HHI was used as an indicator for market concentration, and while HHI is a validated metric to evaluate market concentration, it may not fully capture other important market factors, including hospital affiliations, mergers and consolidations, local payor, and referral patterns.

Conclusions

To our knowledge, we are the first to explore and report a relationship between market structure and outcomes among ACHD patients. Our data shows that not all hospitals caring for ACHD patients are the same. These data are important to policy makers and patients alike. Hospital competitiveness is associated with differential mortality outcomes among ACHD patients, and once there is a complication the ability to rescue and avoid mortality is lower at less competitive hospitals. These data require additional validation and cross examination. However, there is a clear signal that ACHD care is highly nuanced, multi-factorial and requires mindful consideration at the market structure level especially when regionalization and accreditation are being considered.

Availability of Data and Materials

Datasets used and/or analyzed for this study are available from https://hcup-us.ahrq.gov/nisoverview.jsp upon appropriate request.

Author Contributions

AJJ, LBM, AMK, CSB, YO, IS, AM, CMB: Study design, developed initial concepts, data analysis, and interpretation. AJJ, LBM, AMK, CSB, YO, IS, AM, CMB: Contributed to editorial changes, and revised the manuscript critically for intellectual content. AJJ, LBM, AMK, CSB, YO, IS, AM, CMB: Participated sufficiently in the work and are accountable for all aspects of the research. AJJ, LBM, AMK, CSB, YO, IS, AM, CMB: Read and approved the final manuscript. CMB: Data acquisition, Corresponding author.

Ethics Approval and Consent to Participate

Our work underwent expedited review and approved by the Oregon Health and Science University review board (#IRB4463). No informed consent was needed to use this publicly available data.

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Conflict of Interest

The authors declare no conflict of interest. CMB is a member of the editorial board of this journal. CMB declares that he was not involved in the processing of this article and has no access to information regarding its processing.

Supplementary Material

Supplementary material associated with this article can be found, in the online version, at https://doi.org/10.59958/hsf.6833.

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