Journal of Critical Care 43 (2018) 207–213

Contents lists available at ScienceDirect

Journal of Critical Care

journal homepage: www.jccjournal.org

# Is Magnet® recognition associated with improved outcomes among critically ill children treated at freestanding children's hospitals?

Mallikarjuna Rettiganti [a,b], Kavisha M. Shah [b,c], Jeffrey M. Gossett [a,b], Joshua A. Daily [b,c], Paul M. Seib [b], Punkaj Gupta [b,c,*]

[a] Biostatistics Program, Department of Pediatrics, University of Arkansas for Medical Sciences, Little Rock, AR, United States
[b] Arkansas Children's Hospital, Little Rock, AR, United States
[c] Division of Pediatric Cardiology, Department of Pediatrics, University of Arkansas for Medical Sciences, Little Rock, AR, United States

ARTICLE INFO

*Keywords:*
Magnet recognition
In-hospital mortality
Children
Critical illness
Cardiac surgery
Outcomes

ABSTRACT

*Purpose:* With increasing emphasis on high-quality care, we designed this study to evaluate the relationship between Magnet® recognition and patient outcomes in pediatric critical care.
*Materials and methods:* Post hoc analysis of data from an existing administrative national database. We used inverse probability of treatment weighting and multivariate models to compare outcomes between two study groups after adjusting for confounding variables.
*Results:* A total of 823,634 pediatric patients from 41 centers were included. Of these, 454,616 patients (55.2%) were treated in 23 Magnet hospitals. The majority of baseline characteristics did not vary significantly among the two study groups. In adjusted models, there was no difference in mortality between the two groups (Magnet vs. non-Magnet; odds ratio: 0.92, 95% confidence interval: 0.77–1.11). When stratified by various subgroups, such as cardiac, non-cardiac, ECMO, cardiac arrest, respiratory failure, use of nitric oxide, genetic abnormality etc., Magnet status of the hospital did not confer a survival advantage. In a sensitivity analysis on patients from crossover hospitals only, attainment of magnet status was associated with increased hospital charges.
*Conclusions:* This large observational study calls into question the utility of the Magnet Recognition Program among children with critical illness, at least among the freestanding children's hospitals.


## 1. Introduction

Healthcare institutions in the United States (US) have placed increased emphasis on high-quality care, superior outcomes, staff retention, and program marketing. The Magnet Recognition Program® is an initiative that is propounded to be one solution for all these important facets required among high-performance hospitals [1-3]. Magnet hospitals are known for their high quality of patient care, excellence in nursing practices, high retention of well-qualified nurses, improved outcomes of care, and greater propensity to use evidence-based medicine [4-11]. To date, approximately 6% of US hospitals (~450) have achieved Magnet recognition [3].

The pediatric intensive care unit (PICU) is one of the most demanding settings for pediatric nurses. These nurses are on the frontline for assessing complex settings, implementing highly intensive therapies, making critical adjustments in patient's treatments to prevent adverse events, and providing the best possible outcomes. Magnet research has focused heavily on the work environment and nursing practice rather than measurements of patient outcomes, especially in pediatric critical care. It is unknown whether Magnet recognition leads to improved patient outcomes among children with critical illness. To address these knowledge gaps, we designed this study to evaluate the impact of Magnet recognition on patient outcomes among critically ill children treated at freestanding children's hospitals using a multicenter national database, the Pediatric Health Information System (PHIS). The specific outcomes evaluated in our study included in-hospital mortality, hospital length of stay (LOS), duration of mechanical ventilation (MV), and hospital charges.

## 2. Materials and methods

### 2.1. Data source

Data were obtained from the PHIS database, a multicenter, administrative, national dataset. The PHIS database is powered by 6 million patient cases from 47 children's hospitals across the US with the aim to improve quality, enhance performance, and provide safe, effective,

* Corresponding author at: University of Arkansas for Medical Sciences, College of Medicine, Section of Pediatric Cardiology, Arkansas Children's Hospital, 1 Children's Way, Slot 512-3, Little Rock, AR 72202, United States.
*E-mail address:* pgupta2@uams.edu (P. Gupta).

http://dx.doi.org/10.1016/j.jcrc.2017.09.004
0883-9441/

and efficient care [12]. The participating hospitals are affiliated with the Children's Hospital Association (Shawnee Mission, KS, USA), a business alliance of children's hospitals, and account for 20% of all tertiary care children's hospitals. Institutions are labeled within the database but cannot be identified in public reporting. For the purposes of external benchmarking, participating hospitals provide discharge data including demographic information, as well as diagnoses and procedures that are coded using the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) [13]. Billing data are also available detailing medications, imaging studies, laboratory tests, and supplies charged to each patient, and are coded under the Clinical Transaction Classification (CTC) system. Individual patient medical record numbers, billing numbers, and zip codes are encrypted. Data are de-identified at the time of submission and subjected to a number of reliability and validity checks before being processed into data quality reports.

### 2.2. Study population

Patients who were ≤18 years old admitted to a pediatric intensive care unit at a PHIS hospital were included (2004–2015). The study population was divided in two groups: Magnet hospitals included patients who were treated in Magnet-recognized hospitals, whereas non-Magnet hospitals included patients who were not treated in Magnet-recognized hospitals. There was no crossover among the participating hospitals in the two groups. During the study period, if a particular hospital was a non-Magnet hospital prior to gaining Magnet recognition, the patients contributed by that hospital prior to Magnet recognition were excluded from the study population (N = 81,223). The University of Arkansas for Medical Sciences Institutional Review Board for the protection of human subjects reviewed the study protocol and determined that querying de-identified patient data does not fall under the jurisdiction of the Institutional Review Board oversight process.

### 2.3. Data collection

Data collected included demographic information, baseline characteristics, patient diagnoses, interventions (procedures and/or medications) performed, and center data. Study variables were identified using codes from the ICD-9-CM and/or CTC system as defined in the PHIS database. We collected data on baseline characteristics including age, gender, developmental delay (ICD-9, 315.9), and congenital anomaly. The presence of concurrent chronic illnesses was assessed by using an established and validated method for characterizing ICD-9-based pediatric complex chronic conditions, determined by nine diagnostic categories: neuromuscular, cardiovascular, respiratory, renal, gastrointestinal, hematologic or immunologic, metabolic, malignancy, and genetic or other congenital defect conditions. In addition, we collected data on the case-mix index, a widely used surrogate for severity of illness and risk of mortality from the PHIS database [14-16].

The specific diagnoses collected in our study included shock (ICD-9, 785.50, 785.51, 785.52), renal insufficiency (ICD-9, 584.70, 584.90, 586.00, 584.50, 593.90), blood stream infection (ICD-9, 999.31, 999.32), urinary tract infection (ICD-9, 599.0, 112.2, 760.1), seizures (ICD-9, 345.xx, 780.31–39, 779.0), pneumonia (ICD-9, 480.xx–486.xx, 770.xx), pulmonary hypertension (ICD-9, 416.0), cardiac surgery (ICD-9, 35.xx, 36.xx, 37.3x, 39.0, 39.21, 39.23), cardiomyopathy (ICD-9, 425.xx), and cardiac arrest (ICD-9, 427.5, 779.85, 770.87, 99.6x,). Data were also collected on the procedures performed during the hospital stay, including use of extracorporeal membrane oxygenation (ECMO) (ICD-9, 39.65 and/or CTC code, 521181), need for nitric oxide (ICD-9, 00.12 and/or CTC code, 521173), and use of invasive MV (ICD-9, 96.70, 96.71, 96.72). Other risk factors evaluated included: need for inotropes (epinephrine, dopamine, norepinephrine, milrinone, and vasopressin), need for anti-epileptics (fosphenytoin, phenytoin, phenobarbital, lamotrigine, and levetiracetam), and need for anti-arrhythmics (amiodarone, lidocaine, flecainide, quinidine, propranolol, and digoxin). All drugs were identified using the first six-digit root codes in the 13-digit CTC codes defined in the PHIS database. Center data collected included the average annual discharges per center, average annual ECMO per center, and average annual cardiopulmonary bypass (CPB) cases per center. The average annual center volume was calculated by dividing the number of patients for each variable by the number of months that the center participated in the database and multiplying the result by 12.

### 2.4. Statistical analysis

We aimed to compare outcomes among patients who were seen in Magnet hospitals compared to non-Magnet hospitals. All baseline characteristics, diagnoses, procedures and interventions, and center-level variables were summarized and compared between the two groups using appropriate summary statistics, such as frequency and percentages for categorical variables and mean and standard deviation for continuous variables. We used standardized difference as a measure of balance between the two comparison groups and an absolute standardized difference ≤0.10 was used to indicate sufficient balance. We used the inverse probability of treatment weighting method (IPTW) to balance the Magnet and non-Magnet groups on several patient and center level characteristics. IPTW using the propensity score is a method to estimate causal treatment effects when the subjects are not randomized between the comparison groups. Weighting each subject due to the inverse of the probability of treatment balances the two groups with respect to the variables used in calculating the probability thereby providing unbiased estimates of the average treatment effect [17]. In the IPTW method, we first fit a mixed-effects logistic regression model to predict the probability ($p$) that a patient was seen in a Magnet hospital.

The following patient and center level factors were included as predictors in the logistic regression model: age (years), gender, year of admission, and indicators of prematurity, congenital anomaly, chronic lung disease, genetic abnormality, developmental delay, number of complex chronic conditions (0, 1, ≥ 2), cardiac arrest, seizures, cardiomyopathy, respiratory insufficiency, renal insufficiency, shock, pulmonary hypertension, immunodeficiency, pneumonia, bacteremia, urinary tract infection, oncology diagnosis, has organ transplant, number of cardiac surgeries, use of nitric oxide, use of inotropes, use of anti-arrhythmics, use of anti-epileptics, use of steroids, chest tube, arterial line, central venous line, use of dialysis, use of mechanical ventilation, use of ECMO, high complexity case (Risk adjustment for congenital heart surgery, RACHS categories 4–6) [18], average annual discharges per center, average annual mechanical ventilators per center, average annual ECMO cases per center, and average annual CPB cases per center. Generalized linear mixed models were used to compare outcomes between the Magnet and non-Magnet groups after weighting each observation by either $1/p$ or $1/(1\text{-}p)$ depending on whether the patient was seen in the Magnet or non-Magnet hospital, respectively. The distribution and the link function were chosen based on the type of outcome variable. Mortality (yes/no) was compared using a mixed-effects logistic regression model, whereas hospital LOS (days), duration of MV, and hospital charges were analyzed using a lognormal distribution with an identity link.

We also performed a sensitivity analysis by comparing outcomes between Magnet and non-Magnet hospitals using mixed-effects regression models after adjusting for all variables used in the IPTW method. We further compared outcomes between Magnet and non-Magnet groups by stratifying patients according to certain diagnoses, procedures, and center volume categories. A separate analysis was performed on patients including hospitals that crossover from Magnet to non-Magnet hospitals during the study period. Outcomes were compared among patients who were seen

in hospitals prior to and after attaining Magnet status. All models included a center-level random effect to adjust for hospital-level clustering. All analyses were generated using SAS/STAT software, Version 9.4 of the SAS System for Windows (SAS Institute Inc., Cary, NC, USA). All tests were two-sided assuming a significance level of 5%.

## 3. Results

A total of 823,634 patients from 41 hospitals were included. Of these, 454,616 patients (55.2%) from 23 hospitals were treated at a Magnet hospital. The remaining 369,018 patients (44.8%) from 18 hospitals were treated at a non-Magnet hospital. In the study cohort, 455,695 patients were male (55.3%), 85,512 patients (10.4%) were associated with genetic abnormality, and 95,044 patients (11.5%) underwent cardiac surgery during their hospital stay. Overall mortality was among 26,113 patients (3.2%) and the median hospital LOS was 5 days (IQR: 3, 11). A majority of the study hospitals were associated with a residency or fellowship training program.

### 3.1. Patient characteristics

The majority of baseline characteristics including age and other comorbidities (prematurity, chronic lung disease, genetic abnormality, and complex chronic conditions) were similar in the two study groups (Table 1). The Magnet hospitals had a higher proportion of patients with renal insufficiency, shock, pulmonary hypertension, immunodeficiency, pneumonia, bacteremia, urinary tract infection, and cardiac diagnoses. Resource utilization (such as cardiac surgery, MV, nitric oxide, inotropes, and ECMO) was higher in the Magnet hospitals compared to non-Magnet hospitals. A majority of the center volume characteristics (such as annual MVs, annual hospital inpatient discharges, annual ECMO use, and annual CPB cases) were higher in Magnet hospitals compared to non-Magnet hospitals.

**Table 1**
Patient and center characteristics.

| Variable | Total N = 823,634 | Magnet N = 454,616 | Not Magnet N = 369,018 | Std. Diff. |
|---|---|---|---|---|
| Number of hospitals | 41 | 23 | 18 | |
| Baseline characteristics | | | | |
| Male gender | 455,695 (55.3%) | 253,434 (55.8%) | 202,261 (54.8%) | 0.019 |
| Age (years) | 5.8 (5.8) | 5.7 (5.7) | 5.9 (5.8) | −0.048 |
| Prematurity | 23,456 (2.8%) | 13,257 (2.9%) | 10,199 (2.8%) | 0.009 |
| Congenital anomaly | 183,529 (22.3%) | 107,196 (23.6%) | 76,333 (20.7%) | 0.070 |
| Chronic lung disease | 22,731 (2.8%) | 13,172 (2.9%) | 9559 (2.6%) | 0.019 |
| Genetic abnormality | 85,512 (10.4%) | 50,000 (11.0%) | 35,512 (9.6%) | 0.045 |
| Developmental delay | 49,722 (6.0%) | 28,421 (6.3%) | 21,301 (5.8%) | 0.020 |
| Complex chronic conditions | | | | 0.083 |
| 0 | 286,215 (34.8%) | 151,228 (33.3%) | 134,987 (36.6%) | |
| 1 | 275,982 (33.5%) | 152,129 (33.5%) | 123,853 (33.6%) | |
| ≥2 | 261,437 (31.7%) | 151,259 (33.3%) | 110,178 (29.9%) | |
| Diagnoses | | | | |
| Cardiac arrest | 16,542 (2.0%) | 9745 (2.1%) | 6797 (1.8%) | 0.022 |
| Seizures | 133,181 (16.2%) | 74,049 (16.3%) | 59,132 (16.0%) | 0.007 |
| Cardiac patient | 195,498 (23.7%) | 113,651 (25.0%) | 81,847 (22.2%) | 0.067 |
| Cardiomyopathy | 13,004 (1.6%) | 7422 (1.6%) | 5582 (1.5%) | 0.010 |
| Respiratory insufficiency | 56,082 (6.8%) | 31,817 (7%) | 24,265 (6.6%) | 0.017 |
| Renal insufficiency | 40,748 (4.9%) | 23,254 (5.1%) | 17,494 (4.7%) | 0.017 |
| Shock | 33,467 (4.1%) | 19,598 (4.3%) | 13,869 (3.8%) | 0.028 |
| Pulmonary hypertension | 26,088 (3.2%) | 15,773 (3.5%) | 10,315 (2.8%) | 0.039 |
| Immunodeficiency | 17,161 (2.1%) | 10,043 (2.2%) | 7118 (1.9%) | 0.020 |
| Pneumonia | 95,750 (11.6%) | 56,909 (12.5%) | 38,841 (10.5%) | 0.062 |
| Bacteremia | 70,793 (8.6%) | 39,829 (8.8%) | 30,964 (8.4%) | 0.013 |
| Urinary tract infection | 28,232 (3.4%) | 15,710 (3.5%) | 12,522 (3.4%) | 0.003 |
| Oncology diagnosis | 46,564 (5.7%) | 26,076 (5.7%) | 20,488 (5.6%) | 0.008 |
| Organ transplant | 10,104 (1.2%) | 5546 (1.2%) | 4558 (1.2%) | −0.001 |
| Procedures and interventions | | | | |
| Cardiac surgery | 95,044 (11.5%) | 56,370 (12.4%) | 38,674 (10.5%) | 0.060 |
| Use of nitric oxide | 33,043 (4.0%) | 18,852 (4.1%) | 14,191 (3.8%) | 0.015 |
| Use of inotropes | 236,200 (28.7%) | 136,059 (29.9%) | 100,141 (27.1%) | 0.062 |
| Use of anti-arrhythmics | 305,518 (37.1%) | 175,975 (38.7%) | 129,543 (35.1%) | 0.075 |
| Use of anti-epileptics | 132,395 (16.1%) | 72,274 (15.9%) | 60,121 (16.3%) | −0.011 |
| Use of steroids | 221,595 (26.9%) | 126,893 (27.9%) | 94,702 (25.7%) | 0.051 |
| Chest tube | 31,652 (3.8%) | 18,250 (4.0%) | 13,402 (3.6%) | 0.020 |
| Arterial line | 55,718 (6.8%) | 33,451 (7.4%) | 22,267 (6.0%) | 0.053 |
| Central venous line | 160,791 (19.5%) | 95,048 (20.9%) | 65,743 (17.8%) | 0.078 |
| Dialysis | 12,187 (1.5%) | 7089 (1.6%) | 5098 (1.4%) | 0.015 |
| Use of mechanical ventilation | 317,548 (38.6%) | 176,095 (38.7%) | 141,453 (38.3%) | 0.008 |
| Use of ECMO | 7774 (0.9%) | 4457 (1.0%) | 3317 (0.9%) | 0.008 |
| Center variables | | | | |
| Average annual discharges per center | 10,717 (3471) | 10,903 (3069) | 10,484 (3904) | 0.119 |
| Average annual mechanical ventilators per center | 1333 (540) | 1381 (444) | 1274 (635) | 0.195 |
| Average annual ECMO per center | 30 (17) | 32 (17) | 28 (16) | 0.273 |
| Average annual CPB cases per center | 302 (151) | 322 (143) | 276 (157) | 0.306 |
| Residency training | 792,432 (96.2%) | 423,414 (93.1%) | 369,018 (100.0%) | −0.384 |
| Fellowship training | 723,647 (87.9%) | 397,504 (87.4%) | 326,143 (88.4%) | −0.029 |

Categorical variables are summarized as N (percent). Continuous variables are summarized by mean (standard deviation). An absolute standardized difference (Std. Diff.) of <0.10 indicates sufficient balance, while a standardized difference ≥0.10 indicates imbalance between the two study groups. Abbreviations: ECMO: extracorporeal membrane oxygenation; CPB: cardiopulmonary bypass.

**Table 2**
Unadjusted study outcomes.

| Variable | Total N = 823,634 | Magnet N = 454,616 | Not Magnet N = 369,018 | *P* |
|---|---|---|---|---|
| | | **Mortality** | | |
| Overall | 26,113 (3.2%) | 14,125 (3.1%) | 11,988 (3.2%) | 0.0003 |
| Cardiac | 8796 (4.5%) | 4974 (4.4%) | 3822 (4.7%) | 0.02 |
| Non-cardiac | 17,317 (2.8%) | 9151 (2.7%) | 8166 (2.8%) | <0.0001 |
| | | **Days of hospital stay** | | |
| Overall | 5 (3, 11) | 5 (3, 12) | 5 (3, 11) | <0.0001 |
| Cardiac | 8 (4, 20) | 8 (4, 21) | 8 (4, 19) | <0.0001 |
| Non-cardiac | 4 (2, 9) | 4 (2, 10) | 4 (2, 9) | <0.0001 |
| | | **Days of mechanical ventilation** | | |
| Overall | 3 (1, 7) | 3 (2, 8) | 3 (1, 7) | <0.0001 |
| Cardiac | 3 (2, 9) | 3 (2, 10) | 3 (1, 8) | <0.0001 |
| Non-cardiac | 3 (1, 7) | 3 (1, 7) | 3 (1, 6) | <0.0001 |
| | | **Hospital charges** | | |
| Overall | 57,409 (25,606, 134,802) | 62,059 (28,487, 140,905) | 51,631 (22,516, 126,924) | <0.0001 |
| Cardiac | 122,132 (63,689, 266,476) | 123,894 (67,166, 269,745) | 119,189 (58,677, 261,995) | <0.0001 |
| Non-cardiac | 44,105 (21,637, 101,414) | 47,583 (23,940, 106,779) | 39,721 (19,346, 94,970) | <0.0001 |

Continuous variables are summarized by interquartile range, IQR as Median (25th percentile, 75th percentile). Categorical variables are summarized as N (percent).

### 3.2. Study Outcomes

The unadjusted and adjusted models are depicted in Tables 2 and 3. The unadjusted in-hospital mortality was higher in non-Magnet hospitals (Magnet vs. non-Magnet; 3.2% vs. 3.1%, $p = 0.0003$). However, in adjusted IPTW models, there was no difference in mortality between the two groups (Magnet vs. non-Magnet; odds ratio [OR]: 0.92, 95% confidence interval [CI]: 0.77–1.11). Furthermore, in adjusted IPTW models, we did not find any difference in hospital LOS (mean ratio: 1.01, 95% CI: 0.91–1.12), duration of MV (mean ratio: 1.03, 95% CI: 0.92–1.15), or hospital charges (mean ratio: 1.10, 95% CI: 0.90–1.34). The sensitivity analysis using multivariable models demonstrated similar results among all study patients pooled together (cardiac and non-cardiac). Fig. 1 depicts the predicted mortality at each study hospital after adjusting for patient and center characteristics. Fig. 2 depicts the predicted mortality among the magnet hospitals over time among the study hospitals.

### 3.3. Stratified analysis

In adjusted IPTW models, there was no difference in mortality among the cardiac and non-cardiac patients (Magnet vs. non-Magnet, cardiac, OR: 0.89, 95% CI: 0.74–1.08; non-cardiac, OR: 0.90, 95% CI: 0.73–1.10) (Table 3). We found similar results for mortality outcome among the cardiac and non-cardiac patients when the analysis was repeated using multivariable models. We did not find any difference in the other study outcomes (hospital LOS, duration of MV, and hospital charges) among both cardiac and non-cardiac patients in the two study groups utilizing either IPTW models or multivariable models. We, then, evaluated risk-adjusted mortality between the two study groups for commonly encountered conditions in pediatric critical care (Table 4). The Magnet status of the hospital did not affect mortality rate among any of these commonly encountered conditions.

### 3.4. Sensitivity analysis from crossover hospitals

Finally, we performed sensitivity analysis on patients from crossover hospitals only (Table 3). These hospitals' Magnet status changed (from non-Magnet to Magnet) during the study period. This analysis included 81,223 patients in the non-Magnet group, and 358,444 patients in the Magnet group (19 hospitals). In adjusted models, there was no difference in mortality, hospital LOS, or duration of MV after magnet recognition. However, attainment of magnet status was associated with increased hospital charges (Magnet vs. non-Magnet, all patients, OR: 1.40, 95% CI: 1.22–1.63; cardiac, OR: 1.28, 95% CI: 1.16–1.42; non-cardiac, OR: 1.43, 95% CI: 1.21–1.69).

## 4. Discussion

This large, observational study from a multi-center database calls into question the utility of the Magnet-recognition program among

**Table 3**
Adjusted study outcomes (Magnet vs. non Magnet).

| | [a]Main sample | | | | [a]Excluded sample | |
|---|---|---|---|---|---|---|
| **Study outcome** | **IPTW models** | | **Multivariable models** | | **Multivariable models** | |
| **Mortality** | Odds Ratio (95% CI) | *P* | Odds Ratio (95% CI) | *P* | Odds Ratio (95% CI) | *P* |
| All patients | 0.92 (0.77, 1.11) | 0.40 | 0.91 (0.74, 1.11) | 0.35 | 1.00 (0.90, 1.13) | 0.93 |
| Cardiac | 0.89 (0.74, 1.08) | 0.24 | 0.86 (0.72, 1.03) | 0.11 | 0.86 (0.71, 1.03) | 0.10 |
| Non-cardiac | 0.90 (0.73, 1.10) | 0.31 | 0.91 (0.72, 1.14) | 0.42 | 1.09 (0.94, 1.26) | 0.26 |
| [b]**Hospital length of stay** | Mean Ratio (95% CI) | *P* | Mean Ratio (95% CI) | *P* | Mean ratio (95% CI) | *P* |
| All patients | 1.01 (0.91, 1.12) | 0.87 | 0.97 (0.90, 1.03) | 0.32 | 1.00 (0.92, 1.08) | 0.95 |
| Cardiac | 1.05 (0.91, 1.20) | 0.52 | 0.99 (0.89, 1.10) | 0.84 | 0.98 (0.93, 1.04) | 0.48 |
| Non-cardiac | 0.98 (0.89, 1.08) | 0.74 | 0.96 (0.90, 1.02) | 0.22 | 0.93 (0.84, 1.02) | 0.12 |
| [b]**Duration of MV** | Mean Ratio (95% CI) | *P* | Mean Ratio (95% CI) | *P* | Mean Ratio (95% CI) | *P* |
| All patients | 1.03 (0.92, 1.15) | 0.60 | 1.01 (0.96, 1.07) | 0.65 | 1.02 (0.97, 1.06) | 0.52 |
| Cardiac | 1.06 (0.89, 1.27) | 0.51 | 1.04 (0.94, 1.15) | 0.49 | 0.97 (0.91, 1.03) | 0.27 |
| Non-cardiac | 1.01 (0.92, 1.10) | 0.91 | 1.00 (0.96, 1.04) | 0.89 | 0.97 (0.93, 1.02) | 0.27 |
| [b]**Hospital charges** | Mean Ratio (95% CI) | *P* | Mean Ratio (95% CI) | *P* | Mean Ratio (95% CI) | *P* |
| All patients | 1.10 (0.90, 1.34) | 0.35 | 1.05 (0.93, 1.18) | 0.45 | 1.40 (1.22, 1.63) | <0.001 |
| Cardiac | 1.11 (0.91, 1.34) | 0.30 | 1.05 (0.92, 1.20) | 0.48 | 1.28 (1.16, 1.42) | <0.001 |
| Non-cardiac | 1.08 (0.89, 1.30) | 0.45 | 1.05 (0.93, 1.18) | 0.47 | 1.43 (1.21, 1.69) | <0.001 |

Mean ratio depicts mean duration in Magnet hospitals divided by duration in non-Magnet hospitals. Abbreviations: IPTW: inverse probability treatment weighting; CI: confidence interval; MV: mechanical ventilation.

[a] Main sample included patients from Magnet and non-Magnet hospitals (hospitals were exclusive and did not overlap in the two groups), while excluded sample included patients from the hospitals that changed their Magnet status (non-Magnet to magnet) during the study period.

[b] For continuous outcomes, log normal distribution were used to compare means in the two groups.

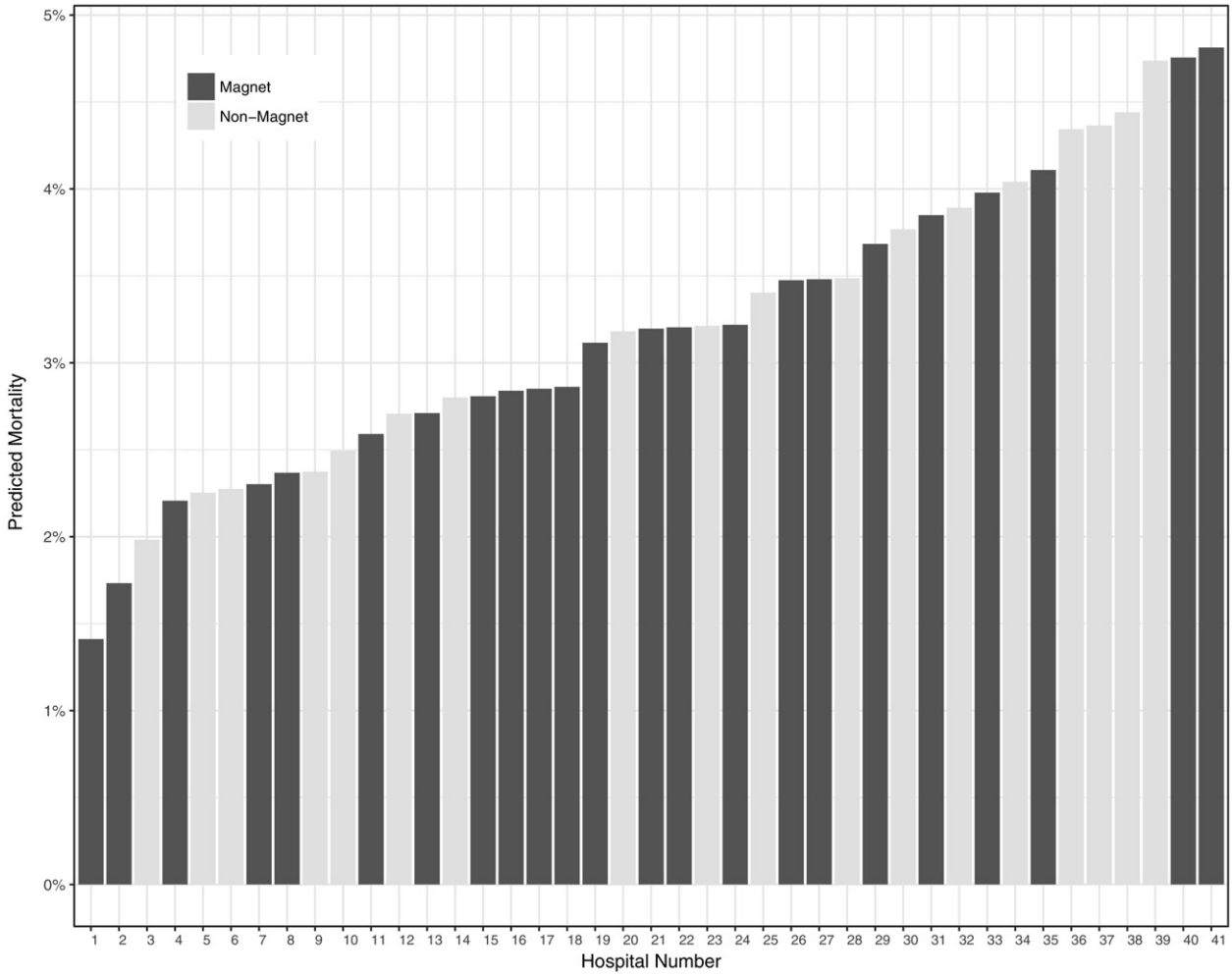


**Fig. 1.** Predicted Mortality at each study hospital after adjusting for patient and center characteristics.

children with critical illness, at least among the freestanding children's hospitals. In our study, Magnet hospitals were associated with higher resource utilization (such as cardiac surgery, MV, nitric oxide, inotropes, and ECMO), and were larger in center volume measured by varied metrics (such as annual MVs, annual hospital inpatient discharges, annual ECMO use, etc.). Despite higher resource utilization, our study demonstrated that Magnet hospitals were not associated with improved outcomes (such as, mortality, hospital length of stay, or duration of MV). In fact, one of the sensitivity analyses demonstrated that attainment of Magnet status might have been associated with increased hospital charges.

Existing literature demonstrates conflicting results for outcomes among Magnet and non-Magnet hospitals [19-27]. Some studies demonstrate improved outcomes (including mortality) among Magnet hospitals [1,8,9,10,19,20,21], whereas others demonstrate no difference in outcomes among the Magnet and non-Magnet hospitals [22-27]. Some studies even found that outcomes were better at non-Magnet hospitals than Magnet hospitals [22]. As researchers expanded their investigations to include sepsis, pressure ulcers, urinary tract infections, failure to rescue, pediatric traumatic brain injury, and other clinical end points, they found no differences in outcomes between the two types of hospitals [23-27]. The improved outcomes in Magnet hospitals are postulated to be associated with lower patient-to-nurse ratios, a more educated nurse workforce, more specialty-certified nurses, and better nurse work environments [1-4].

It has also been postulated that the Magnet hospitals may be surrogates for pre-existing quality with higher participation in quality-related programs [22]. This commitment for organizational innovation could possibly lead to improved outcomes in Magnet hospitals. In our study, all participating centers (Magnet and non-Magnet hospitals) were freestanding children's hospitals. In a recent study from our group, it was demonstrated that freestanding children's hospitals are associated with improved outcomes compared to non-freestanding children's hospitals [28]. It is possible that the complex organizational structure, commitment to excellence, and willingness to undertake organizational innovation among freestanding children's hospitals could have led to improved outcomes in our current study, irrespective of Magnet status. This calls into question the need for Magnet status among freestanding children's hospitals.

The impact of Magnet recognition on hospital costs/charges remains debatable. Though the main analyses did not demonstrate any difference in hospital charges between the Magnet and non-Magnet hospitals, one of the sensitivity analyses demonstrated higher hospital charges in Magnet hospitals. It is possible that higher resource utilization among the Magnet hospitals may have contributed to higher hospital charges. In a recent study, Jayawardhana et al. demonstrated a higher utilization of diagnostic imaging services among Magnet hospitals than non-Magnet hospitals [29]. However, the authors' demonstrated cost efficiency at Magnet hospitals with lower costs per procedure at Magnet hospitals compared to non-Magnet hospitals. It is further suggested that the process of attaining Magnet status takes 4.25 years to complete with an average total investment of $2,125,000 [30]. This cost includes the application fees, appraiser fees, site cost visits, and document preparation.

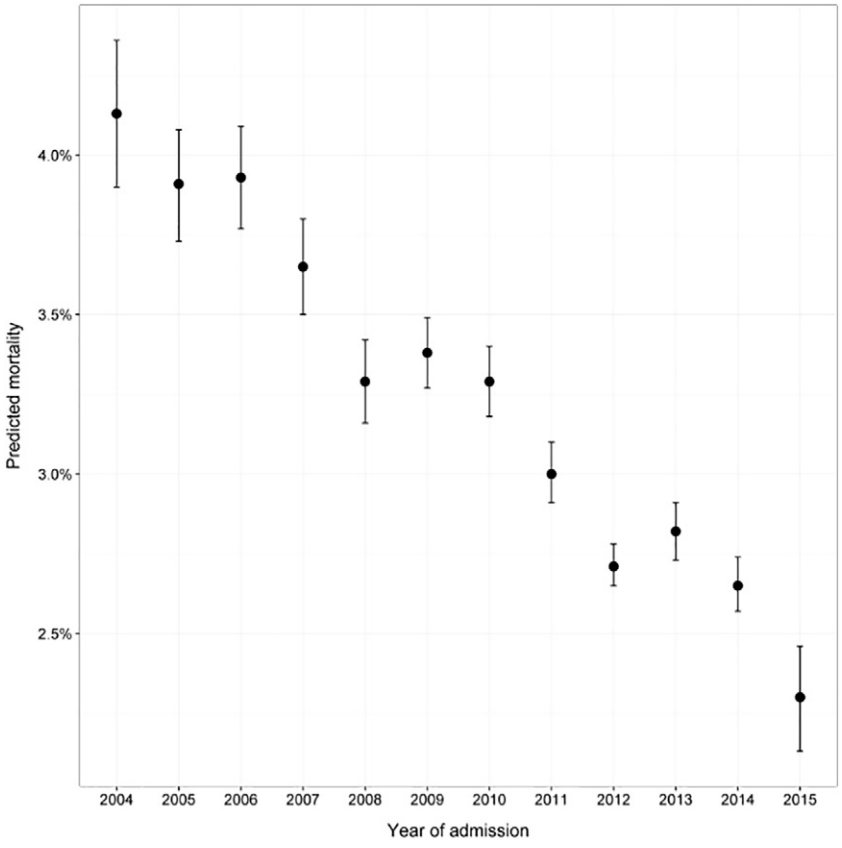


**Fig. 2.** Trends of predicted mortality among Magnet hospitals for the study period (2004–2015).

Our study has several limitations. The retrospective nature of our study renders it susceptible to study design flaws and bias. Although we attempted to adjust for important patient- and center-level variables, it is possible that our dataset lacked important confounders that could have impacted our analysis. Another limitation of this study is the use of an administrative database for case ascertainment. One of the challenges for research in this area is the low sensitivity of administrative data for correctly identifying patient characteristics, patient comorbidities, appropriate case-mix adjustment, and accurate assessment of complication rates. We were unable to finely adjust for severity of illness with respect to progressive organ failure not captured by diagnosis coding. Our dataset also lacked important severity of illness scores, such as the pediatric index of mortality (PIM) score and the pediatric risk of mortality (PRISM) score.

Misclassification bias may have been introduced because many ICD-9-related conditions lack explicit definitions. They are also subject to errors at multiple points including diagnostic errors, communication errors, and transcription errors. The ICD-9 codes may be limited by the level of detail they provide, thus resulting in a lack of granularity. Our study utilized a database that contains data from only freestanding children's hospitals. It is possible that the results would have been different if we had also included non-freestanding children's hospitals in our study. An ideal solution to overcome some of these limitations would be to use other clinical databases such as Collaborative Pediatric Critical Care Research Network (CPCCRN), Pediatric Emergency Care Applied Research Network (PECARN), Virtual Pediatric Systems (VPS, LLC; Los Angeles, CA, USA) or link a clinical database, such as the VPS, LLC database,

**Table 4**
Risk adjusted mortality across varied subgroups (Magnet vs. non-Magnet).

| Study patients | Magnet | Non-magnet | | |
|---|---|---|---|---|
| | Adjusted mortality (95% CI) | Adjusted mortality (95%CI) | Odds ratio (95% CI) | *P* |
| CCC > 1 | 2.0% (0.5%, 8.6%) | 2.3% (0.5%, 8.9%) | 0.91 (0.77, 1.07) | 0.27 |
| Genetic abnormality | 1.0% (0.6%, 1.7%) | 1.1% (0.7%, 1.8%) | 0.88 (0.71, 1.08) | 0.23 |
| Respiratory failure | 1.5% (0.0%, 6.9%) | 1.6% (0.0%, 7.6%) | 0.94 (0.70, 1.27) | 0.70 |
| Cardiac arrest | 46.1% (16.2%, 79.1%) | 47.0% (17.3%, 79.0%) | 0.96 (0.80, 1.15) | 0.68 |
| Renal insufficiency | 8.7% (0.3%, 76.2%) | 9.2% (0.3%, 76.6%) | 0.94 (0.81, 1.10) | 0.43 |
| ECMO | 42.6% (5.7%, 90.1%) | 42.0% (5.2%, 90.5%) | 1.02 (0.86, 1.22) | 0.80 |
| Use of nitric oxide | 15.6% (8.0%, 28.0%) | 16.6% (9.0%, 28.6%) | 0.93 (0.79, 1.08) | 0.32 |
| Cardiac surgery | 0.7% (0.0%, 19.6%) | 0.8% (0.0%, 24.1%) | 0.81 (0.63, 1.04) | 0.10 |
| Low-volume centers[a] | 0.5% (0.3%, 0.6%) | 0.6% (0.5%, 0.7%) | 0.82 (0.59, 1.14) | 0.23 |
| Medium-volume centers[a] | 0.5% (0.0%, 0.7%) | 0.6% (0.0%, 0.8%) | 0.92 (0.67, 1.25) | 0.58 |
| High-volume centers[a] | 0.6% (0.5%, 0.7%) | 0.7% (0.5%, 0.9%) | 0.88 (0.68, 1.15) | 0.34 |

Abbreviations: CCC: complex chronic conditions; ECMO: extracorporeal membrane oxygenation.

[a] Center volume was defined based on the tertiles of average annual mechanical ventilators used. Low volume centers utilized < 1000 annual mechanical ventilators, Medium volume centers utilized 1000–1500 annual mechanical ventilators, and high volume centers utilized > 1500 annual mechanical ventilators.

with an administrative database, such as the PHIS database [31]. Clinical databases (such as the VPS) provide granular information on patient characteristics, comorbidities, case-mix adjustment, and administrative databases (like the PHIS database) provide granular information on data related to resource utilization and hospital costs [32].

## 5. Conclusions

This large, observational study from a multi-center database calls into question the utility of the Magnet-recognition program among children with critical illness, at least among the freestanding children's hospitals. Despite higher resource utilization, our study demonstrated that Magnet hospitals were not associated with improved outcomes (such as, mortality, hospital length of stay, or duration of MV). This study lays the foundation for future more accurate studies by linking clinical and administrative databases.

## Conflict of interests

None, no potential conflicts for any authors.

## Funding source

None.

## Financial disclosure

The authors have no financial relationships relevant to this article to disclose.

## Acknowledgements

None.

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