# Impact of intensive care unit attending physician training background on outcomes in children undergoing heart operations

**Priya Bhaskar, Mallikarjuna Rettiganti[1], Jeffrey M Gossett[1], Punkaj Gupta**
Division of Pediatric Cardiology, Department of Pediatrics, University of Arkansas for Medical Sciences, Arkansas Children's Hospital, [1]Department of Pediatrics, University of Arkansas for Medical Sciences, Arkansas Children's Research Institute, Little Rock, Arkansas, USA

## ABSTRACT

**Background** : **The existing training pathways to become a pediatric cardiac intensivist are very variable with physicians coming from varied training backgrounds of pediatric critical care, pediatric cardiology, neonatology, or pediatric anesthesia.**

**Aim** : **To evaluate the impact of cardiac Intensive Care Unit (ICU) attending physician training background on outcomes in children undergoing heart operations.**

**Setting and Design** : **Patients in the age group from 1 day to 18 years undergoing heart operation at a Pediatric Health Information System database participating hospital were included (2010–2015).**

**Patients and Methods** : **Based on the training background of majority of attending physicians in an ICU, the participating ICUs were divided into three groups: critical care medicine (CCM), cardiology, and indeterminate.**

**Statistical Analysis** : **Multivariable logistic regression models were fitted to evaluate the association of ICU physician training background with study outcomes.**

**Results** : **A total of 54,935 patients from 42 ICUs were included. Of these, 31,815 patients (58%) were treated in the CCM group (26 ICUs), 19,340 patients (35%) were treated in the cardiology group (12 ICUs), and 3780 patients (7%) were treated in the indeterminate group (4 ICUs). In adjusted models, no specific group based on ICU attending physician training background was associated with lower mortality (CCM vs. cardiology, odds ratio: 0.75, 95% confidence interval: 0.48–1.18), or lower incidence of cardiac arrest, or prolonged hospital length of stay, or prolonged mechanical ventilation.**

**Conclusions** : **This large observational study did not demonstrate any impact of ICU attending training background on outcomes in children undergoing heart operations.**

**Keywords** : Cardiac intensive care, children, mortality, training background

## INTRODUCTION

Clinical practice variations are common in children undergoing heart operations.[1-5] It has been suggested that children with similar demographic patterns, comorbidities, and diagnoses receive different levels of care depending on when, where, or by whom they are treated.[1-5] Some variability may be justified by uncertainty in knowledge, differences in case mix, and need for individualized patient care. Unexplained variability in practice could lead to heterogeneous

**Access this article online**

**Quick Response Code:**

**Website:**
www.annalspc.com

**DOI:**
10.4103/apc.APC_99_17



**How to cite this article:** Bhaskar P, Rettiganti M, Gossett JM, Gupta P. Impact of intensive care unit attending physician training background on outcomes in children undergoing heart operations. Ann Pediatr Card 2018;11:48-55.

Address for correspondence: Dr. Punkaj Gupta, Department of Pediatrics, University of Arkansas for Medical Sciences, Arkansas Children's Hospital, One Children's Way, Slot 512-3, Little Rock, Arkansas, USA. E-mail: pgupta2@uams.edu

quality and poses safety risk in the care of patients. One of the postulated reasons for this variability is the varied training background of the attending cardiac intensive care physicians managing children after heart operations.

Pediatric cardiac intensive care is a relatively new frontier in cardiovascular medicine. As a subspecialty, this field demands expertise in pediatric cardiology, pediatric intensive care, pharmacology, cardiac surgery, cardiac anesthesia and to some extent in biomedical engineering and bioethics.[6] In addition, the care providers are required to have expertise in certain procedures such as intubation, insertion of central lines, arterial lines, and umbilical lines, echocardiography, cardioversion, and transcutaneous and transesophageal pacing.[6] The existing training pathways to become a pediatric cardiac intensivist are very variable as the physicians come from varied training backgrounds of pediatric critical care, pediatric cardiology, neonatology, or pediatric anesthesia. The variety brings forth its own unique strengths, but it also leaves much uncertainty among future trainees who want to pursue a career in cardiac intensive care.[7]

To address these knowledge gaps, we undertook this study to evaluate the impact of cardiac Intensive Care Unit (ICU) attending physician training background on outcomes in children undergoing heart operations using a national, multi-institutional database. The specific outcomes evaluated in our study included mortality at hospital discharge, postoperative use of extracorporeal membrane oxygenation (ECMO), incidence of cardiac arrest, mortality after cardiac arrest, prolonged mechanical ventilation, and prolonged hospital length of stay.

## PATIENTS AND METHODS

### Data source

Data were obtained from Pediatric Health Information System (PHIS), a multicenter, administrative, national dataset. The PHIS database is powered by six million patient cases from freestanding children's hospitals across the United States with the aim to improve quality, enhance performance, and provide safe, effective, and efficient care.[8] The participating hospitals are affiliated with the Children's Hospital Association (Shawnee Mission, Kansas), a business alliance of children's hospitals, and account for 20% of all tertiary care children's hospitals. For 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).[9] Data are de-identified at the time of submission and are subjected to a number of reliability and validity checks before being processed into data quality reports.

### Study population

Patients in the age group from 1 day to 18 years undergoing heart operation at a PHIS participating hospital were included (2010–2015). The participating ICUs were divided into three groups: critical care medicine (CCM), cardiology, and indeterminate [Table 1]. Physicians with primary training in CCM (with or without an additional training in cardiac critical care) were classified as CCM physicians, physicians with primary training in pediatric cardiology (with or without an additional training in cardiac critical care) were classified as cardiology physicians, and physicians with dual training in both CCM and cardiology were classified as dual trained. An ICU was classified as the CCM group if majority of the attending physicians in that particular ICU were CCM physicians. In contrast, an ICU was classified as the cardiology group if majority of the attending physicians in that particular ICU were cardiology physicians or physicians with dual training. An ICU was classified as indeterminate if there were similar proportion of CCM and cardiology/dual training in that particular ICU. An ICU was also classified as indeterminate if majority of the attending physicians in that particular ICU came from other training backgrounds (such as anesthesia, cardiac surgery, and neonatology). 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.

### 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. Patients were identified for inclusion in the study population using ICD-9 codes for cardiac surgery (ICD-9, 35.xx, 36.xx, 37.3x, 39.0, 39.21, 39.23). We collected data on baseline characteristics including age, gender, developmental delay (ICD-9, 315.9), and congenital anomaly. Using an established and validated method assessed, the presence of concurrent chronic illnesses for characterizing ICD-9-based pediatric complex chronic conditions (CCCs) was determined by nine diagnostic categories: neuromuscular, cardiovascular, respiratory, renal, gastrointestinal, hematologic or immunologic, metabolic, malignancy, and genetic or other congenital defect conditions.[10]

The specific diagnoses collected in our study included sepsis (ICD-9, 995.91, 995.92,

**Table 1: Variation of attending training background across varied study centers**

| ICU number | Attending training background | | | | ECMO* volume | CPB* volume | Fellowship training | Study group |
|---|---|---|---|---|---|---|---|---|
| | Number of attending's | CCM trained | Cardiology trained | Dual trained | | | | |
| 1 | 9 | 9 | 0 | 0 | 1 | 43 | N | CCM |
| 2 | 10 | 10 | 0 | 0 | 5 | 56 | Y | CCM |
| 3 | 6 | 6 | 0 | 0 | 1 | 73 | N | CCM |
| 4 | 5 | 5 | 0 | 0 | 4 | 87 | N | CCM |
| 5 | 3 | 0 | 3 | 0 | 8 | 117 | N | Cardiology |
| 6 | 7 | 5 | 1 | 1 | 8 | 120 | Y | CCM |
| 7 | 6 | 6 | 0 | 0 | 15 | 141 | N | CCM |
| 8 | 6 | 3 | 2 | 1 | 16 | 151 | Y | Indeterminate |
| 9 | 15 | 15 | 0 | 0 | 2 | 151 | N | CCM |
| 10 | 6 | 4 | 1 | 1 | 15 | 156 | Y | CCM |
| 11 | 5 | 1 | 1 | 0 | 15 | 189 | N | Indeterminate |
| 12 | 9 | 9 | 0 | 0 | 13 | 201 | Y | CCM |
| 13 | 5 | 4 | 1 | 0 | 21 | 207 | N | CCM |
| 14 | 6 | 3 | 2 | 1 | 13 | 218 | Y | Indeterminate |
| 15 | 6 | 3 | 2 | 1 | 26 | 226 | Y | Indeterminate |
| 16 | 10 | 3 | 3 | 3 | 20 | 229 | Y | Cardiology |
| 17 | 14 | 14 | 0 | 0 | 29 | 232 | Y | CCM |
| 18 | 7 | 5 | 0 | 2 | 26 | 234 | Y | CCM |
| 19 | 3 | 1 | 1 | 1 | 21 | 236 | Y | Cardiology |
| 20 | 8 | 3 | 2 | 3 | 21 | 245 | Y | Cardiology |
| 21 | 8 | 2 | 1 | 5 | 15 | 267 | Y | Cardiology |
| 22 | 12 | 12 | 0 | 0 | 23 | 275 | Y | CCM |
| 23 | 17 | 15 | 0 | 2 | 30 | 279 | Y | CCM |
| 24 | 9 | 7 | 0 | 2 | 38 | 290 | Y | CCM |
| 25 | 8 | 7 | 0 | 1 | 38 | 290 | Y | CCM |
| 26 | 5 | 1 | 3 | 1 | 47 | 290 | Y | Cardiology |
| 27 | 6 | 2 | 0 | 4 | 25 | 292 | Y | Cardiology |
| 28 | 8 | 5 | 2 | 1 | 46 | 298 | Y | CCM |
| 29 | 5 | 2 | 1 | 2 | 41 | 299 | Y | Cardiology |
| 30 | 11 | 9 | 2 | 0 | 16 | 302 | N | CCM |
| 31 | 5 | 3 | 0 | 2 | 31 | 317 | Y | CCM |
| 32 | 8 | 8 | 0 | 0 | 34 | 346 | Y | CCM |
| 33 | 7 | 4 | 1 | 2 | 68 | 356 | Y | CCM |
| 34 | 10 | 1 | 4 | 5 | 26 | 359 | Y | Cardiology |
| 35 | 6 | 3 | 1 | 1 | 26 | 380 | Y | CCM |
| 36 | 10 | 6 | 1 | 3 | 43 | 381 | Y | CCM |
| 37 | 5 | 4 | 0 | 1 | 26 | 478 | Y | CCM |
| 38 | 9 | 3 | 0 | 6 | 53 | 517 | Y | Cardiology |
| 39 | 6 | 1 | 3 | 2 | 58 | 526 | Y | Cardiology |
| 40 | 8 | 7 | 0 | 1 | 45 | 540 | Y | CCM |
| 41 | 16 | 11 | 4 | 1 | 45 | 584 | Y | CCM |
| 42 | 12 | 1 | 7 | 4 | 55 | 726 | Y | Cardiology |

*ECMO volume and CPB volume represents the average annual volume for these two procedures for each center during the study period. Fellowship training represents training program for either Pediatric CCM or cardiology fellowship. CCM: Critical care medicine, CPB: Cardiopulmonary bypass, ECMO: Extracorporeal membrane oxygenation, ICU: Intensive Care Unit, Y: Yes N: No

771.81, 038.9, 785.52, 790.7, 771.83, 038.xx, 998.59, 38.xx), renal insufficiency (ICD-9, 584.70, 584.90, 586.00, 584.50, 593.90), bloodstream 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), and cardiac arrest (ICD-9, 427.5, 779.85, 770.87, 99.6x). Data were also collected on procedures performed during the hospital stay, including placement of central venous catheter (ICD-9, 38.92, 38.93, 38.94, 38.95, and 38.97), arterial line (ICD-9, 38.91), chest tube (ICD-9, 34.0), need for dialysis (ICD-9, 39.95, 54.98), use of ECMO (ICD-9, 39.65 and/or CTC code, 521181), and use of invasive mechanical ventilation (ICD-9, 96.70, 96.71, 96.72). Other risk factors evaluated included need for inotropes (epinephrine, dopamine, norepinephrine, milrinone, vasopressin), need for antiepileptics (fosphenytoin, phenytoin, phenobarbital, lamotrigine, levetiracetam), and need for nitric oxide (ICD-9, 00.12 and/or CTC code, 521173). All drugs were identified using first six-digit root codes in the 13-digit CTC codes defined in the PHIS database. Center data collected included average annual inpatient admissions per center, average annual use of mechanical ventilators per center, and average annual use of ECMO per center. The average annual center volume was calculated by dividing the number of patients for the particular center variable (inpatient admissions, mechanical ventilators, and ECMO) by the number of months that the center participated in the database and multiplying the result by 12.

### Statistical analysis

Data were summarized using medians and interquartile ranges (IQRs) for continuous variables and frequencies for categorical variables. Unadjusted demographic variables and outcomes were compared between groups using a Wilcoxon rank-sum test for continuous variables or a Chi-squared test for categorical variables. Analysis was aimed at comparing outcomes between the three major groups; the patients were classified into based on predominantly attending physicians: cardiology, pediatric ICU (PICU), and indeterminate. The following binary outcomes were compared between the three groups using unadjusted and adjusted models: use of ECMO, incidence of cardiac arrest, mortality, mortality after cardiac arrest, prolonged hospital length of stay (>21 days), and prolonged mechanical ventilation (>7 days). Prolonged hospital length of stay and prolonged mechanical ventilation were defined as true or false based on whether the patients' outcome exceeded the 75$^{th}$ percentile of the entire patient population among all groups combined. We used mixed effects logistic regression model to compare the binary outcomes between the three groups after adjusting for the following patient and center level factors: gender, age at hospital admission (months), and indicators (yes/no) for prematurity, developmental delay, genetic abnormality, bacteremia, renal problem, bloodstream infection, urinary tract infection, seizures, brain damage, surgery complexity (RACHS 4–6), use of anti-arrhythmics, use of antiepileptics, use of dialysis, use of inotropes, >1 CCC, pneumonia, pulmonary hypertension, use of mechanical ventilation, use of inhaled nitric oxide, use of invasive intubation, shock, pediatric charge weight, use of steroids, average annual cardiopulmonary bypass (CPB) cases (center level), and average annual ECMO counts (center level). We included a random intercept for each hospital to account for clustering of patients within each hospital. The analysis was repeated after stratifying patients based on the complexity of operations performed (RACHS 1–3, RACHS 4–6). Effects from the logistic regression models were presented using odds ratios (ORs) and 95% confidence intervals (CIs). All data analyses were done using SAS software version 9.4, (Cary, North Carolina, USA) Copyright © 2012 of SAS Institute Inc. $P \leq 0.05$ was considered to be statistically significant.

## RESULTS

A total of 54,935 patients from 42 ICUs were included. Of these, 31,815 patients (58%) were treated in the CCM group (26 ICUs), 19,340 patients (35%) were treated in the cardiology group (12 ICUs), and 3780 patients (7%) were treated in the indeterminate group (4 ICUs) [Table 1]. The median age of the study patients was 7.2 months. Majority of the study patients were males (55%). Approximately 13% of the study patients underwent high complexity operations, and ~42% patients underwent reoperation during their same hospital stay. Cardiac arrest was noted among 2090 (3.8%) patients. ECMO was deployed among 2043 (3.7%) patients. Overall mortality was noted among 1183 (3.1%) patients.

### Physicians characteristics

Our study included 337 attending physicians from 42 ICUs. Of these, 223 (66.2%) physicians were primarily trained in CCM (with or without an additional training in cardiac critical care), 49 (14.5%) physicians were primarily trained in cardiology (with or without an additional training in cardiac critical care), and 60 (17.8%) physicians were dual-trained in both CCM and pediatric cardiology. Of the physicians with CCM training background, 52 (23.3%) physicians received an additional year of formal training in cardiac critical care. In contrast, more than one-third of the attending with pediatric cardiology background (19 physicians, 38.7%) received additional year of formal training in cardiac critical care.

### Clinical characteristics

Patients in the cardiology group were younger in age as compared to the other two groups. Patients treated in the CCM group were more commonly associated with comorbidities such as genetic abnormality and CCCs [Table 2]. In addition, certain diagnoses such as pulmonary hypertension, shock, and renal insufficiency were more commonly noted among the patients treated in the CCM group. High complexity operations were more commonly performed in the cardiology group. Reoperations (>1 heart operation) during the same hospital stay were also more commonly performed in the cardiology group. Surprisingly, use of nitric oxide and use of inotropes were lowest among the patients being treated in the cardiology group.

Not surprisingly, the ICUs with cardiology-predominant attending physicians were higher volume centers. The median annual ECMO volume in the ICUs with cardiology-predominant attending physicians was 48 (IQR: 25, 55), as compared to annual ECMO volume of 30 (IQR: 21, 43) in the ICUs with CCM-predominant attending physicians and 15 (IQR: 13, 16) in the indeterminate group. Similar trends of center volume were noted when center volume was stratified by annual CPB cases, annual mechanical ventilators, and annual discharges [Table 3].

### Study outcomes

Unadjusted mortality was similar in three groups (cardiology: 3.2%, CCM: 3.0%, and indeterminate: 3.0%, $P = 0.19$) [Table 3]. There was no difference in ECMO deployment after heart operations in the three study groups. However, the incidence of cardiac arrest

**Table 2: Patient characteristics**

| | All patients (*n*=54,935) ICUs=42, *n* (%) | Cardiology (*n*=19,340) ICUs=12, *n* (%) | CCM (*n*=31,815) ICUs=26, *n* (%) | Indeterminate (*n*=3780) ICUs=4, *n* (%) | *P* |
|---|---|---|---|---|---|
| Baseline characteristics | | | | | |
| Male gender | 30,030 (55) | 10,479 (54) | 17,496 (55) | 2055 (54) | 0.19 |
| Age (months) | 7.2 (2.1-45.5) | 6.7 (1.9-44.2) | 7.4 (2.2-45.9) | 7.7 (2.2-49) | <0.001 |
| Birth weight (g) | 3070 (2665-3444) | 3055 (2640-3430) | 3095 (2693-3460) | 2980 (2550-3374) | <0.001 |
| Genetic abnormality | 11,138 (20) | 3871 (20) | 6539 (21) | 728 (19) | 0.09 |
| Down syndrome | 5379 (10) | 1826 (9) | 3179 (10) | 374 (10) | 0.12 |
| Prematurity | 2332 (4) | 873 (4) | 1310 (4) | 149 (4) | 0.06 |
| Developmental delay | 1807 (3) | 786 (4) | 874 (3) | 147 (4) | <0.001 |
| Congenital heart defect | 52,894 (96) | 18,623 (96) | 30,640 (96) | 3631 (96) | 0.74 |
| Complex chronic conditions | | | | | |
| 1 | 30,874 (56) | 10,983 (57) | 17,769 (56) | 2122 (56) | <0.001 |
| ≥2 | 20,674 (38) | 7175 (37) | 12,164 (38) | 1335 (35) | |
| Diagnoses | | | | | |
| Pediatric charge weight | 9.7 (7.3-22.0) | 9.7 (7.3-22.0) | 9.7 (7.3-22.0) | 9.7 (6.3-16.7) | <0.001 |
| Pulmonary hypertension | 4505 (8) | 1491 (8) | 2794 (9) | 220 (6) | <0.001 |
| Shock | 2124 (4) | 428 (2) | 1623 (5) | 73 (2) | <0.001 |
| Sepsis | 4477 (8) | 1438 (7) | 2707 (8) | 332 (9) | <0.001 |
| Renal insufficiency | 5215 (9) | 1844 (9) | 3142 (10) | 229 (6) | <0.001 |
| Pneumonia | 2222 (4) | 725 (4) | 1410 (4) | 87 (2) | <0.001 |
| Seizures | 1750 (3) | 562 (3) | 1112 (3) | 76 (2) | <0.001 |
| Intracranial complications | 1494 (3) | 518 (3) | 886 (3) | 90 (2) | 0.32 |
| Oncology diagnosis | 364 (1) | 115 (1) | 230 (1) | 19 (0.5) | 0.10 |
| Procedures and interventions | | | | | |
| High complexity surgery | 7121 (13) | 2596 (14) | 4074 (13) | 451 (12) | 0.03 |
| Number of heart operations | | | | | |
| 1 | 25,917 (48) | 7912 (41) | 16,130 (51) | 1875 (50) | <0.001 |
| 2 | 9601 (18) | 3700 (19) | 5159 (16) | 742 (20) | |
| ≥3 | 19,096 (35) | 7647 (40) | 10,327 (33) | 1122 (30) | |
| Use of MV | 43,034 (78) | 16,383 (85) | 23,369 (74) | 3282 (87) | <0.001 |
| Use of nitric oxide | 8980 (16) | 2876 (15) | 5159 (16) | 945 (25) | <0.001 |
| Dialysis | 1220 (2) | 337 (2) | 778 (2) | 105 (3) | <0.001 |
| Use of inotropes | 52,032 (95) | 17,983 (93) | 30,314 (95) | 3735 (99) | <0.001 |
| Days of inotropes | 4 (3-8) | 4 (3-8) | 4 (3-8) | 4 (3-9) | <0.001 |
| Use of anti-arrhythmics | 33,497 (61) | 11,264 (58) | 19,550 (61) | 2683 (71) | <0.001 |
| Use of anti-epileptics | 3397 (6) | 878 (4) | 2375 (7) | 144 (4) | <0.001 |
| Use of steroids | 33,676 (61) | 10,846 (56) | 20,947 (66) | 1883 (50) | <0.001 |

Continuous variables are summarized by IQR, IQR as median (25th percentile–75th percentile). Categorical variables are summarized as *n* (%). CCM: Critical care medicine, MV: Mechanical ventilation, ICUs: Intensive Care Units, IQR: Interquartile range

**Table 3: Center data and unadjusted study outcomes**

| | All patients (*n*=54,935) ICUs=42, *n* (%) | Cardiology (*n*=19,340) ICUs=12, *n* (%) | CCM (*n*=31,815) ICUs=26, *n* (%) | Indeterminate (*n*=3780) ICUs=4, *n* (%) | *P* |
|---|---|---|---|---|---|
| Center data | | | | | |
| Annual CPB cases per center | 298 (229-484) | 359 (291-527) | 298 (220-357) | 189 (151-219) | <0.001 |
| Annual ECMO cases per center | 30 (21-45) | 48 (25-55) | 30 (21-43) | 15 (13-16) | <0.001 |
| Annual MV per center | 1400 (989-1660) | 1660 (1298-1726) | 1237 (989-1515) | 620 (620-924) | <0.001 |
| Annual discharges per center | 10,123 (8074-12,992) | 12,020 (10,562-15,400) | 9928 (8069-10,833) | 7969 (7969-9665) | <0.001 |
| Training program | 52,580 (96) | 19,340 (100) | 29,460 (93) | 3780 (100) | <0.001 |
| Study outcomes | | | | | |
| Mortality | 1683 (3.1) | 627 (3.2) | 941 (3.0) | 115 (3.0) | 0.19 |
| Use of ECMO | 2043 (3.7) | 732 (3.8) | 1156 (3.6) | 155 (4.1) | 0.30 |
| Incidence of cardiac arrest | 2090 (3.8) | 828 (4.3) | 1144 (3.6) | 118 (3.1) | <0.001 |
| Mortality after cardiac arrest | 620 (30) | 251 (30) | 325 (28) | 44 (37) | 0.12 |
| Prolonged MV | 10,225 (18.6) | 3483 (18.0) | 6007 (18.8) | 735 (19.4) | |
| Prolonged hospital LOS | 13,173 (23.9) | 4240 (21.9) | 8011 (25.1) | 922 (24.3) | <0.001 |

Continuous variables are summarized by IQR, IQR as median (25th percentile–75th percentile). Categorical variables are summarized as *n* (%). CPB: Cardiopulmonary bypass, ECMO: Extracorporeal membrane oxygenation, MV: Mechanical ventilation, LOS: Length of stay, CCM: Critical care medicine, ICUs: Intensive Care Units, IQR: Interquartile range

was higher in the cardiology group (cardiology: 4.3%, PICU: 3.6%, indeterminate: 3.1%, $P \leq 0.001$). In spite of performing of multiple, high complexity operations, surprisingly, the unadjusted duration of mechanical ventilation and hospital length of stay were lowest among the patients treated in the cardiology group.

In adjusted models, no specific group based on ICU attending physician training background was associated with lower mortality (CCM vs. cardiology, OR: 0.75, 95% CI: 0.48–1.18; indeterminate vs. cardiology, OR: 0.86, 95% CI: 0.42–1.78), or lower incidence of cardiac arrest (CCM vs. cardiology, OR: 0.71, 95% CI: 0.47–1.06; indeterminate vs. cardiology, OR: 0.61, 95% CI: 0.32–1.18), or prolonged hospital length of stay (PICU vs. cardiology, OR: 1.39, 95% CI: 0.83–2.31; indeterminate vs. cardiology, OR: 1.76, 95% CI: 0.80–3.84), or prolonged mechanical ventilation (CCM vs. cardiology, OR: 0.86, 95% CI: 0.24–3.04; indeterminate vs. cardiology, OR: 1.34, 95% CI: 0.19–9.57). To our surprise, we found that use of ECMO after heart operation was higher in the indeterminate group as compared to cardiology group (indeterminate vs. cardiology, OR: 2.96, 95% CI: 1.12–7.83). There was no difference in the use of ECMO in the CCM group as compared to the cardiology group (OR: 1.12, 95% CI: 0.60–2.08) [Table 4].

### Outcomes stratified by complexity of heart operations

Among the patients undergoing high complexity operations, the CCM group was associated with lower mortality as compared to the cardiology group (CCM vs. cardiology, OR: 0.60, 95% CI: 0.39–0.92). There was no difference in other outcomes (such as use of ECMO, incidence of cardiac arrest, mortality after cardiac arrest, prolonged hospital LOS, and prolonged mechanical ventilation) in any comparisons among the patients undergoing high complexity operations [Table 5]. Among the patients undergoing low complexity operations, no specific group based on ICU attending physician training background was associated with lower mortality, or lower incidence of cardiac arrest, or lower deployment of ECMO after heart operation, or prolonged hospital length of stay, or prolonged mechanical ventilation.

**Table 4: Adjusted study outcomes among all patients**

| Study outcomes | CCM versus cardiology | | Indeterminate versus cardiology | |
|---|---|---|---|---|
| | OR (95% CI) | *P* | OR (95% CI) | *P* |
| All patients | | | | |
| Use of ECMO | 1.12 (0.60-2.08) | 0.72 | 2.96 (1.12-7.83) | 0.03 |
| Incidence of cardiac arrest | 0.71 (0.47-1.06) | 0.09 | 0.61 (0.32-1.18) | 0.14 |
| Mortality | 0.75 (0.48-1.18) | 0.22 | 0.86 (0.42-1.78) | 0.69 |
| Mortality after cardiac arrest | 0.92 (0.63-1.34) | 0.66 | 1.70 (0.85-3.37) | 0.13 |
| Prolonged hospital LOS | 1.39 (0.83-2.31) | 0.21 | 1.76 (0.80-3.84) | 0.16 |
| Prolonged MV | 0.86 (0.24-3.04) | 0.81 | 1.34 (0.19-9.57) | 0.77 |

CI: Confidence interval, ECMO: Extracorporeal membrane oxygenation, LOS: Length of stay, CCM: Critical care medicine, MV: Mechanical ventilation, OR: Odds ratio

## DISCUSSION

Data from this large, multicenter observational study did not demonstrate a significant impact of ICU attending physician training background on mortality among children undergoing heart operations. Irrespective of physician training background, there was no difference in duration of mechanical ventilation, duration of hospital stay, incidence of cardiac arrest, or deployment of ECMO among patients undergoing heart surgeries of all complexities. However, among patients undergoing high complexity heart operations, we noted higher mortality in the cardiology-predominant attending group compared to the CCM-predominant attending group.

Based on a survey conducted in 2003, Stromberg uncovered a great discrepancy between the growing need for trained cardiac intensivists and the graduation rate of the trained professionals to fulfill that need.[11] The reason for this discrepancy could be multifactorial; however, nevertheless, the discrepancy emphasized the fact that the academic preparation to pursue a career in cardiac intensive care should be clearly defined. To address this need, a taskforce was established to clearly delineate a pathway designed for cardiology fellows to train in cardiac intensive care.[12] However, this taskforce did not address the cardiac intensive care training pathway for physicians from other backgrounds such as CCM, anesthesia, or neonatology.

There is a general consensus that physicians from varied backgrounds (CCM, cardiology, pediatric anesthesia, and neonatology) should undergo additional training in cardiac intensive care to practice as cardiac intensivists. One step further, a subset of pediatricians have also obtained dual certification in both pediatric cardiology and critical care as this pathway allows them to have increased exposure to complex care of all organ systems. Given the acute shortage of cardiology trained or dual-trained cardiac intensive care physicians, a few larger cardiac ICUs that were previously staffed with cardiology-trained cardiac intensive care physicians have undergone a paradigm shift and are now staffed with more CCM-trained cardiac intensive care physicians.

Given the variable options to procure the necessary knowledge and skills to care for patients with complex congenital heart diseases, there remains a debate as to which group of physicians is better equipped to provide the optimal care that this population demands.[13-15] In 2006, Baden *et al.* recommended that CCM-trained physicians should be the leaders of a multidisciplinary team taking care of children with heart disease.[13] The guidelines published by the American College of CCM also emphasized the same recommendations.[14] Baden *et al.* emphasized that 9 months of additional clinical training beyond a standard cardiology fellowship is

**Table 5: Adjusted study outcomes stratified by complexity of operations performed**

| Study outcomes | CCM versus cardiology | | Indeterminate versus cardiology | |
|---|---|---|---|---|
| | OR (95% CI) | *P* | OR (95% CI) | *P* |
| High complexity | | | | |
| Use of ECMO | 0.85 (0.38-1.88) | 0.68 | 2.87 (0.81-10.19) | 0.10 |
| Incidence of cardiac arrest | 0.69 (0.41-1.15) | 0.16 | 0.69 (0.30-1.62) | 0.40 |
| Mortality | 0.60 (0.39-0.92) | 0.02 | 1.01 (0.50-2.06) | 0.97 |
| Mortality after cardiac arrest | 0.75 (0.37-1.55) | 0.44 | 1.49 (0.40-5.54) | 0.55 |
| Prolonged hospital LOS | 1.42 (0.83-2.41) | 0.20 | 1.30 (0.55-3.04) | 0.55 |
| Prolonged MV | 0.82 (0.24-2.79) | 0.75 | 1.27 (0.19-8.53) | 0.80 |
| Low complexity | | | | |
| Use of ECMO | 1.22 (0.64-2.36) | 0.54 | 3.54 (1.24-10.11) | 0.02 |
| Incidence of cardiac arrest | 0.77 (0.52-1.15) | 0.20 | 0.68 (0.35-1.32) | 0.25 |
| Mortality | 0.82 (0.50-1.35) | 0.44 | 0.85 (0.38-1.93) | 0.70 |
| Mortality after cardiac arrest | 0.99 (0.66-1.49) | 0.96 | 1.92 (0.90-4.13) | 0.09 |
| Prolonged hospital LOS | 1.36 (0.82-2.25) | 0.23 | 1.93 (0.88-4.20) | 0.09 |
| Prolonged MV | 0.86 (0.25-2.89) | 0.80 | 1.37 (0.21-8.98) | 0.74 |

CI: Confidence interval, ECMO: Extracorporeal membrane oxygenation, LOS: Length of stay, CCM: Critical care medicine, OR: Odds ratio, MV: Mechanical ventilation

insufficient to fulfill the role of an intensivist.[13] In the same issue, Kulik *et al.* acknowledged the need for the additional training but also strongly reiterated that cardiologists who undergo 1 year of cardiac intensive care training are comparable to trainees who undergo critical care training in specialties such as anesthesia and surgery.[15]

Based on our data, the ICUs with cardiology-predominant attending were located in high-volume centers (as documented by higher annual CPB case volume and high annual ECMO deployment). High-volume centers are associated with lower mortality among children undergoing heart operations.[1-4] In our study, even though cardiology-predominant ICUs were associated with high-volume centers, the cardiology-predominant ICUs did not perform better than CCM- or indeterminate-predominant ICUs. It is conceivable that, despite extensive analyses, the patients in the different groups had different case mix that impacted the final results.

Based on our anecdotal experience and clinical practice, it is postulated that CCM-trained cardiac ICU physicians are more comfortable in managing multi-organ failure, renal failure, acute lung injury, neurological conditions (such as brain hemorrhage and stroke), brain death, cardiac arrest, postcardiac arrest management, management of ventilators, and performing procedures such as advanced airway placement and inserting chest and abdominal drains. In contrast, cardiology-trained cardiac ICU physicians are more comfortable in managing intractable arrhythmias, understanding cardiopulmonary interactions and single ventricle physiology, and interpreting echocardiogram, electrocardiogram, and cardiac catheterization.

It is further postulated that physicians with dual-training in CCM and cardiology are best equipped to be cardiac ICU physicians, with knowledge base and skill set in both domains. Another pathway to become a cardiac ICU physician is to do an advanced 1-year fellowship in cardiac intensive care that is primarily offered to physicians who are board eligible or board certified in Pediatric Critical Care or Pediatric Cardiology (with exceptions of some centers offering this training to physicians with primary training in Neonatology or Pediatric Anesthesia). This training offers an opportunity for consistency in cardiac critical care with satisfactory cross-training depending on the physician's categorical fellowship training. This training is currently being offered at 22 centers in North America (http://www.pcics.org/resources/programs/na-fellow/). The Accreditation Council of Graduate Medical Education has not approved this 1-year advanced fellowship training, so the curriculum for this training varies among different centers.

Our study has many limitations. Although we attempted to adjust for important patient- and center-level factors, our dataset lacked important severity of illness scores such as pediatric index of morality score and pediatric risk of mortality score. It is also possible that there could be other unmeasured confounders present that could have an impact on our analysis. The another limitation of this study is the use of an administrative database for case ascertainment that may lead to differences in the coding of procedures and clinical datasets and the resultant differences in reported outcomes with these procedures.[16] Misclassification bias may have been introduced because many ICD-9-related conditions lack explicit definitions. ICD-9-CM diagnosis codes are collected primarily for billing purposes and are not assigned to a specific hospital day. They are also subject to errors at multiple points including diagnostic errors, communication errors, and transcription errors. We could not account for team structure, or night time in-house resident, fellow or advanced nurse practitioner coverage that could have potentially affected the study outcomes. Nevertheless, PHIS database has been extensively used to conduct outcomes research that has been published in high-impact journals.[17-18]

## CONCLUSIONS

Data from this large, multicenter observational study did not demonstrate a significant impact of ICU attending physician training background on the outcomes (including mortality) in children undergoing heart operations. However, among patients undergoing high complexity heart operations, we noted higher mortality in the cardiology-predominant attending group compared to the CCM-predominant attending group. Given our inability to control for other ICU-level organizational factors, these findings should be interpreted with caution and considered exploratory. Further study is warranted.

### Financial support and sponsorship

Nil.

### Conflicts of interest

There are no conflicts of interest.

## REFERENCES

1. Pasquali SK, Li JS, Burstein DS, Sheng S, O'Brien SM, Jacobs ML, *et al.* Association of center volume with mortality and complications in pediatric heart surgery. Pediatrics 2012;129:e370-6.
2. Pasquali SK, Jacobs JP, He X, Hornik CP, Jaquiss RD, Jacobs ML, *et al.* The complex relationship between center volume and outcome in patients undergoing the Norwood operation. Ann Thorac Surg 2012;93:1556-62.
3. Gupta P, Tang X, Gossett JM, Gall CM, Lauer C, Rice TB, *et al.* Variation of ventilation practices with center volume after pediatric heart surgery. Clin Cardiol 2015;38:178-84.
4. Gupta P, Jacobs JP, Pasquali SK, Hill KD, Gaynor JW, O'Brien SM, *et al.* Epidemiology and outcomes after in-hospital cardiac arrest after pediatric cardiac surgery. Ann Thorac Surg 2014;98:2138-43.
5. Gupta P, Beam BW, Noel TR, Dvorchik I, Yin H, Simsic JM, *et al.* Impact of preoperative location on outcomes in congenital heart surgery. Ann Thorac Surg 2014;98:896-903.
6. Chang AC. Pediatric cardiac intensive care: Current state of the art and beyond the millennium. Curr Opin Pediatr 2000;12:238-46.
7. Anand V, Kwiatkowski DM, Ghanayem NS, Axelrod DM, DiNardo J, Klugman D, *et al.* Training pathways in pediatric cardiac intensive care: Proceedings from the 10th International Conference of the Pediatric Cardiac Intensive Care Society. World J Pediatr Congenit Heart Surg 2016;7:81-8.
8. Owner Hospitals. Child Health Corporation of America. Available from: http://www.chca.com/index_flash.html. [Last accessed on 2016 Sep 18].
9. Centers for Disease Control and Prevention, National Center for Health Statistics. International Classification of Diseases. 9th Revision, Clinical Modification. Available from: http://www.cdc.gov/nchs/icd/icd9cm.htm. [Last accessed on 2016 Sep 18].
10. Feudtner C, Christakis DA, Connell FA. Pediatric deaths attributable to complex chronic conditions: A population-based study of Washington State, 1980-1997. Pediatrics 2000;106:205-9.
11. Stromberg D. Pediatric cardiac intensivists: Are enough being trained? Pediatr Crit Care Med 2004;5:391-2.
12. Feltes TF, Roth SJ, Almodovar MC, Andropoulos DB, Bohn DJ, Costello JM, *et al.* Task force 5: Pediatric cardiology fellowship training in critical care cardiology. SPCTPD/ACC/AAP/AHA. Circulation 2015;132:e81-90.
13. Baden HP, Berger J, Brilli RI, Burns JP, Checchia PA, Dalton HJ, *et al.* Pediatric cardiac critical care patients should be cared for by intensivists. J Am Coll Cardiol 2006;48:221-2.
14. Rosenberg DI, Moss MM. American College of Critical Care Medicine of the Society of Critical Care Medicine. Guidelines and levels of care for pediatric Intensive Care Units. Crit Care Med 2004;32:2117-27.
15. Kulik T, Giglia T, Mahoney L, *et al.* Pediatric cardiac critical care patients should be cared for by intensivists-Reply. J Am Coll Cardiol 2006;48:222-3.
16. Peabody JW, Luck J, Jain S, Bertenthal D, Glassman P. Assessing the accuracy of administrative data in health information systems. Med Care 2004;42:1066-72.
17. Freeman CL, Bennett TD, Casper TC, Larsen GY, Hubbard A, Wilkes J, *et al.* Pediatric and neonatal extracorporeal membrane oxygenation: Does center volume impact mortality?. Crit Care Med 2014;42:512-9.
18. Gupta P, Rettiganti M. Association between extracorporeal membrane oxygenation center volume and mortality among children with heart disease: Propensity and risk modeling. Pediatr Crit Care Med 2015;16:868-74.