Predictors of anesthesia ready time: Analysis and benchmark data

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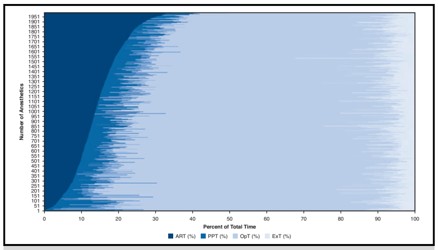
ABSTRACT

Objective: Patients undergoing congenital cardiac surgery require induction of anesthesia. Our objective was to identify the median anesthesia ready time and the predictors of this time.

Methods: By using the Society of Thoracic Surgeons Congenital Heart Surgery Database, we identified patients who underwent cardiopulmonary bypass procedures from 2017 to 2021. Univariate and multivariable regression modeling to predict the anesthesia ready time was performed using mixed-effects linear regression.

Results: After exclusion of outliers, 44,418 cases were analyzed. The median anesthesia ready time was 51 minutes (interquartile range, 38-66). On multivariable analysis, independent predictors of a longer anesthesia ready time included decreasing weight (0.3 min/10 kg, 95% CI, 0.1-0.6; $P = .011$), prematurity (1.5 minutes, 95% CI, 0.8-2.2; $P < .001$), and presence of chromosomal abnormality (3.4 minutes, 95% CI, 1.5-5.2; $P < .001$). An increase in the duration in anesthesia ready time was seen with increasing Society of Thoracic Surgeons-European Association for Cardiothoracic Surgery mortality category with an additional 7.8 minutes (95% CI, 5.2-10.4; $P < .001$) for a Society of Thoracic Surgeons-European Association for Cardiothoracic Surgery 5 procedure compared with Society of Thoracic Surgeons-European Association for Cardiothoracic Surgery 1. Emergency versus elective case designation was associated with an anesthesia ready time reduction of 3.6 minutes (95% CI, 1.1-6.1; $P = .005$), and an afternoon case start was associated with an anesthesia ready time reduction of 4.2 minutes (95% CI, 2.8-5.6; $P < .001$). The presence of an anesthesia trainee increased the anesthesia ready time by 3.8 minutes (95% CI, 2.6-5.0; $P < .001$). The presence of an airway in situ decreased the anesthesia ready time by 3.6 minutes (95% CI, 1.6-5.5; $P < .001$), whereas an in situ arterial line decreased the anesthesia ready time by 7.4 minutes (95% CI, 4.6-10.2; $P < .001$). Placement of a central venous line increased the anesthesia ready time by 8.5 minutes (95% CI, 5.9-11.1; $P < .001$).

Conclusions: The median anesthesia ready time was 51 minutes. For patients with characteristics associated with prolonged anesthesia ready time, consideration should be given to allocation of additional anesthesia staffing to improve efficiency. (JTCVS Open 2023;15:446-53)



We examine the national median ART and the predictors of this time.

CENTRAL MESSAGE

Benchmark data for patient preparation time by anesthesiologists immediately before congenital cardiac surgery and factors associated with prolonged preparation times are reported.

PERSPECTIVE

Data on the time required for anesthesiologists to prepare a patient with congenital heart disease for cardiac surgery are lacking. According to 44,418 cases requiring cardiopulmonary bypass in the STS congenital database, the median ART was 51 minutes (IQR, 38-66). Identification of risk factors for prolonged ART may guide the allocation of additional anesthesia staffing or changes in workflow to improve efficiency.

Patients who present for cardiac surgical procedures on cardiopulmonary bypass undergo induction of anesthesia, placement of an endotracheal tube, and placement of invasive lines that many include an arterial line, a central line, and peripheral intravenous lines. The patient also may have a transesophageal echocardiography probe

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Internal funds from the Department of Anesthesiology, Critical Care, and Pain Medicine were used to complete this project. There were no other outside sources of funding.

IRB# P00022312, 11/30/2017.

Read at the 103rd Annual Meeting of The American Association for Thoracic Surgery, Los Angeles, California, May 6-9, 2023.

Received for publication April 7, 2023; revisions received June 20, 2023; accepted for publication June 23, 2023; available ahead of print Aug 3, 2023.

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2666-2736

https://doi.org/10.1016/j.xjon.2023.06.016

Abbreviations and Acronyms

ART = anesthesia ready time
ICU = intensive care unit
IQR = interquartile range
PPT = position and preparation time
STAT = Society of Thoracic Surgeons-European Association for Cardiothoracic Surgery
STS = Society of Thoracic Surgeons

placed. Anesthesia ready time (ART) is defined as the time interval from the patient entering the operating room to when the patient has a sufficient level of anesthesia established to begin surgical preparation, and remaining anesthetic activities do not preclude positioning and further preparation.[1] The time spent on ART is often targeted, with a goal to improve overall operating room efficiency.

The duration of ART for patients undergoing congenital cardiac surgery has not been delineated. Our aim was to provide benchmark ART data using a large national dataset from the Society of Thoracic Surgeons (STS) Congenital Heart Surgery Database. In addition, our objective was to identify predictors of increasing ART, specifically any modifiable factors.

MATERIALS AND METHODS

A participant user file was obtained from the STS using the STS participant user file Research Program from 2017 to 2021. Because of the deidentified nature of this data, our Institutional Review Board waived the need for research consent (IRB-P00022312, November 30, 2017). The STS Congenital Heart Surgery Database contains data on children and adults undergoing cardiac surgical procedures for congenital heart disease. Cases for which cardiopulmonary bypass was used were selected. There is an optional module in the database called the "STS Congenital Cardiac Anesthesia Society." This module contains a field entitled "end of induction time." We defined ART as the difference between the end of induction time and the time when the patient entered the operating room. Only procedures that contained data for ART were included. The top and bottom 1% of ART values were removed from further analysis to eliminate outliers and nonsensical data. A sensitivity analysis was not performed for the excluded cohort in the upper and lower 1% of the distribution of each time variable, because these outlier observations may have a high leverage if included in a sensitivity analysis, leading to potentially biased results with a high amount of variability. These exclusions were also implemented to avoid extreme values with potentially diminished clinical relevance or generalizability. We had anesthesia data from 62 different sites that represent approximately 50% of sites submitting congenital cardiac surgical cases.

Variables included age, weight, prematurity, race, syndrome, and presence of chromosomal abnormalities. The procedure variables included the urgency of the procedure, the operating room entry time, and the Society of Thoracic Surgeons-European Association for Cardiothoracic Surgery (STAT) mortality category. The operating room entry time was divided into morning (6 AM to noon), afternoon (noon to 6 PM), and evening/overnight (6 PM to 6 AM). The preoperative presence of an in situ airway, arterial line, or central line was recorded. The variables arterial line and central line placed by anesthesia were also included. Provider variables included the presence of a certified registered nurse anesthetist, resident or fellow, or a second attending anesthesiologist.

The time used to place a urinary catheter, position, skin preparation, and draping for surgery (position and preparation time [PPT]) was calculated using the time from operating room entry to incision and subtracting the ART (Figure 1). To remove outlier observations, the top and bottom 1% of the distribution of each time variable were excluded from further analysis in a similar fashion to ART. The operating time includes the time between skin incision and skin closure. The exit time includes the time from the surgical incision stop time to the operating room exit time. This includes time for dressings to be applied, drapes to be removed, and the patient to be transferred to the intensive care unit (ICU).

Descriptive analyses were performed using medians and interquartile ranges (IQRs) for continuous data and using frequencies and percentages for categorical data. The number of nonmissing observations were reported for each variable. A histogram was constructed to visualize the distribution of ART. Univariate and multivariable regression modeling to predict the ART was performed using mixed-effects linear regression to account for clustering of patients within centers. Variables significant on univariate analysis were included in the multivariable model. Variables were checked for collinearity, and covariates were excluded as appropriate. Results of regression analyses are presented as adjusted coefficients, 95% CIs, and *P* values. The relationship of ART to these other times in the operating room was examined using the Spearman correlation coefficient. All statistical analyses were performed using Stata (version 16.1, StataCorp LLC).

RESULTS

There were 45,400 cardiopulmonary bypass cases with complete ART data. After exclusion of outliers, 44,418 cases were analyzed. The median ART was 51 minutes (IQR, 38-66) (Figure 2). The median PPT time was 36 minutes (IQR, 25-48), the median operating time was 239 minutes (IQR, 179-326), and the median exit time was 18 minutes (IQR, 13-27). The distribution of time spent in the operating room is shown in Figure 3 for 2000 patients who were representative of the larger sample. The median age was 0.9 years (0.3-6.3 years), and median weight was 8.1 kg (IQR, 4.7-20.4 kg) (Table 1). Figure 4 shows the median ART for various age groups.

On multivariable analysis (Table 2), independent predictors of a longer ART included decreasing weight (0.3 minutes/10 kg, 95% CI, 0.1-0.6; $P = .011$), prematurity (1.5 minutes, 95% CI, 0.8-2.2; $P < .001$), and the presence of chromosomal abnormality (3.4 minutes, 95% CI, 1.5-5.2; $P < .001$). A progressive increase in ART duration was seen with increasing STAT mortality category, up to an additional 7.8 minutes (95% CI, 5.2-10.4; $P < .001$) for a STAT 5 procedure compared with a STAT 1. Emergency versus elective case designation was associated with an ART reduction of 3.6 minutes (95% CI, 1.1-6.1; $P = .005$), and an afternoon case start was associated with an ART reduction of 4.2 minutes (95% CI, 2.8-5.6; $P < .001$). The presence of an anesthesia trainee increased the ART by 3.8 minutes (95% CI, 2.6-5.0; $P < .001$). The presence of an airway in situ decreased the ART by 3.6 minutes (95% CI, 1.6-5.5; $P < .001$), whereas an in situ arterial line decreased the ART by 7.4 minutes (95% CI, 4.6-10.2; $P < .001$). Placement of a central venous line increased the ART by 8.5 minutes (95% CI, 5.9-11.1; $P < .001$).

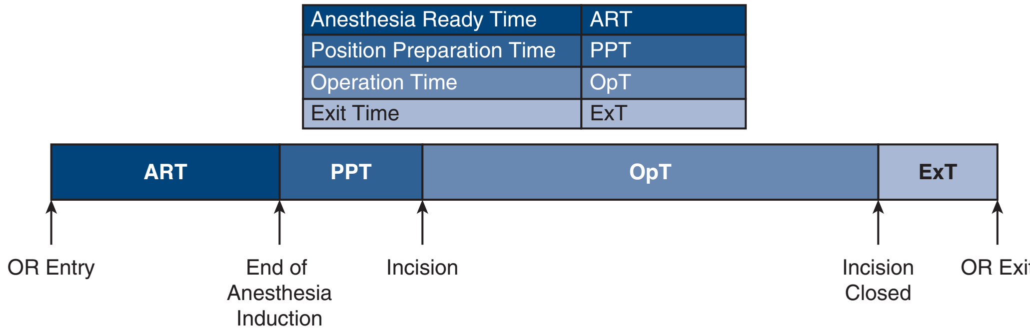

FIGURE 1. Operating room times. The time from entry to the operating room until exit is labeled. *ART*, Anesthesia ready time; *PPT*, position and preparation time; *OpT*, operation time; *ExT*, exit time; *OR*, operating room.

For the multivariable mixed-effects linear regression model of ART, the mean absolute error is 2.1 minutes. The mean relative error is 4.5%, demonstrating good model accuracy. A longer ART time was weakly associated with a shorter PPT (−0.2, $P < .001$), a longer operating time (0.1, $P < .001$), and a longer exit time (0.1, $P < .001$).

DISCUSSION

This study provides benchmark data for institutions with pediatric cardiac surgical programs and for individual congenital cardiac anesthesiologists. The median ART was 51 minutes with an IQR of 38 to 66 minutes. The preoperative independent predictors of a longer ART included decreasing weight, prematurity, presence of a chromosomal abnormality, an elective procedure, a morning start time, and a higher STAT mortality category. None of these characteristics are modifiable.

However, the preoperative presence of an endotracheal tube in situ decreased the ART by 3.6 minutes (95% CI, 1.6-5.5), an arterial line in situ decreased the ART by 7.4 minutes (95% CI, 4.6-10.2), and placement of a central venous line increased the time by 8.5 minutes (95% CI, 5.9-11.1). Unlike adults, most children cannot tolerate line placement preoperatively without anesthesia/sedation. Consequently, preoperative invasive line placement likely necessitates preoperative ICU admission, a practice used in some centers (M. L. Brown, MD, PhD, personal communication, September 2022). The other described alternative is a system of parallel processing using an induction room for second cases.[2] We did not attempt to assess whether the anatomic location of the arterial line or central venous catheter had an impact on ART. The use of surgical lines (instead of placing a central line) also increased the ART, but this may be due to a desire to place additional peripheral intravenous access, which also can take time especially in small patients. The number of peripheral intravenous lines is not recorded in this database. The ART was shorter in patients who had an urgent or emergency procedure, as well as for afternoon (noon to 6 PM) starts. In these scenarios, there

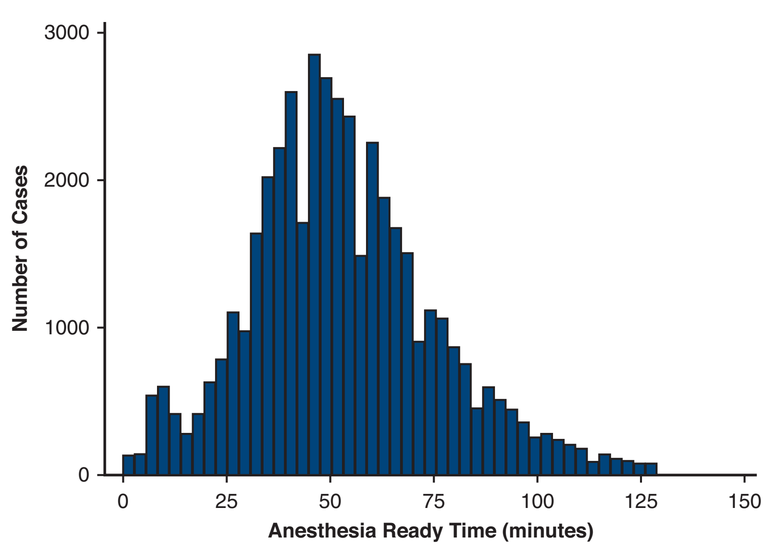

FIGURE 2. Anesthesia ready times. The distribution of ARTs is shown.

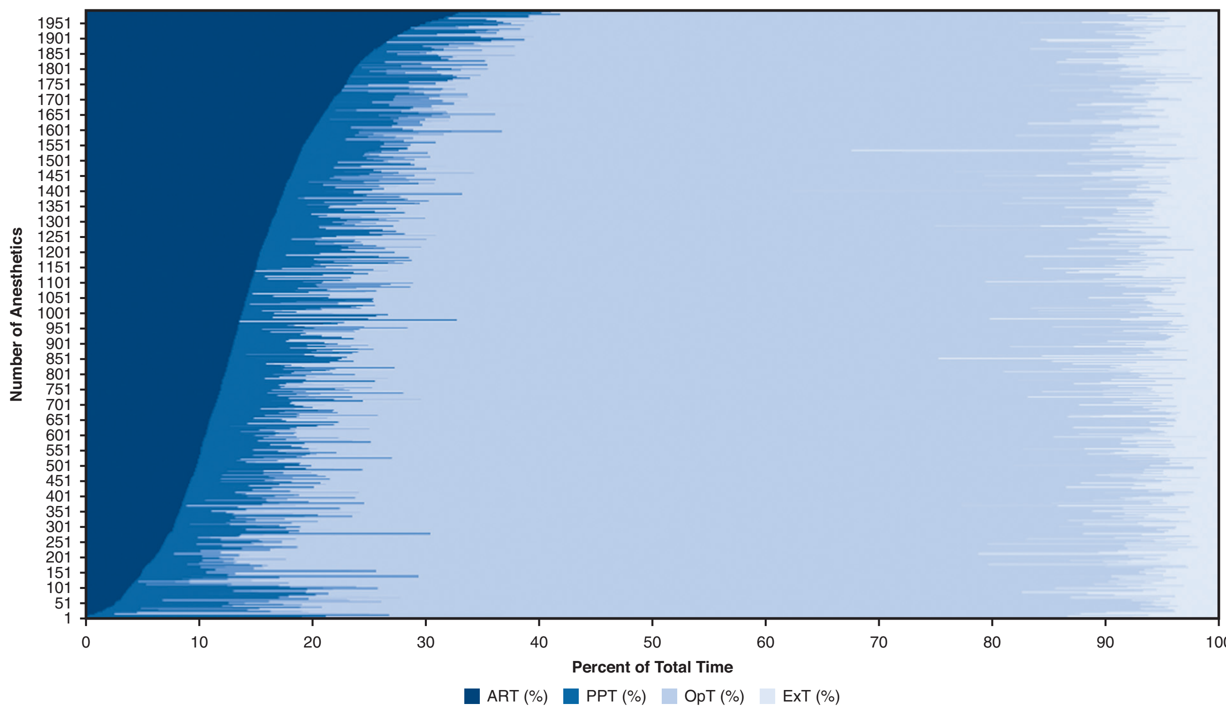

FIGURE 3. All times in the operating room. Operating room times for 2000 patients representative of the overall operating room population are illustrated. Times are sorted from shortest to longest by the ART. *ART*, Anesthesia ready time; *PPT*, position and preparation time; *OpT*, operation time; *ExT*, exit time.

is some urgency experienced by the entire surgical team due to the perceived length of the remaining workday.

The presence of a resident or fellow was an independent predictor of longer ART 3.8 minutes (95% CI, 2.6-5.0; $P < .001$). This is certainly due to time devoted to teaching and a relative lack of operator experience. For those centers where training is part of their mission, particularly Accredited Council Graduate Medical Education–accredited institutions, this variable is likely only partially modifiable.[3] Strategies to remain true to the teaching mission while limiting ART include strictly defining the time interval or number of attempts allocated to the trainee to perform procedures, limiting the number of procedures performed by the trainee during any one case (ie, the central line or arterial line, but not both), and using an additional attending anesthesiologist to assist with patient management or trainee supervision. This latter strategy may be particularly useful in patients identified as high risk for a prolonged ART. That said, we did not find that the presence of a second attending anesthesiologist was an independent predictor of ART. This analysis is hampered by the fact that the STS Congenital Cardiac Anesthesia Society congenital module does not define when the second anesthesiologist was present during a case and may reflect handovers of care rather than 2 attending anesthesiologists present for the induction period. A prior study found that centers have a ratio of 1 attending anesthesiologist to 1 congenital cardiac operating room.[4]

For a 3-kg premature infant with a chromosomal abnormality undergoing a Norwood procedure (STAT 5) who requires intubation, central line, and arterial line placement with an anesthesia trainee as a first case, the estimated ART is 52.8 minutes. By comparison, for a 60-kg teenager who has an emergency, afternoon operation for removal of an atrial septal device, with an endotracheal tube and an arterial line in situ from the cardiac catheterization laboratory and for whom placement of a central line is deemed unnecessary, the estimated ART is 5.5 minutes. It is important to note that each individual modifiable factor only contributes a few minutes, so targeting only one factor will not be significantly impactful.

To achieve clinically significant differences in ART, efforts to shorten ART should be multifaceted. These benchmark data should not be used as an absolute standard. There will always be complex patients and scenarios wherein patient characteristics and unpredictable occurrences prolong ART above the median value. Although we did not analyze the relationship between clinical outcomes and ART, prolonged ARTs, with the potential for progressive systemic hypothermia and changes in systemic vascular resistance, may be detrimental to patients with vulnerable, unstable single ventricle or outflow tract obstruction physiology necessitating the institution of inotropic or vasopressor support before incision. Although efforts "to save time" may not be in a patient's best interest, our data may be useful in identifying providers who could

TABLE 1. Demographics

Variable	N (%) or median (IQR) N = 44,418	Nonmissing (N)
Patient characteristics		
Age (y)	0.9 (0.3-6.3)	44,418
Weight (kg)	8.1 (4.7-20.4)	44,414
BSA (m^2)	0.38 (0.26-0.8)	44,208
Premature		44,275
Yes	7556 (17.1%)	
No	33,625 (76%)	
Unknown	3094 (7%)	
Race		
Asian	2105 (5.2%)	40,144
Black/African American	7056 (17.6%)	40,151
White	27,787 (69%)	40,283
American Indian/Alaskan Native	485 (1.2%)	40,129
Native Hawaiian/Pacific Islander	290 (0.7%)	40,120
Other	4125 (10.3%)	40,170
Hispanic or Latino ethnicity		44,099
Yes	7825 (17.7%)	
No	32,791 (74.4%)	
Not documented	3483 (7.9%)	
Syndrome	11,951 (27.4%)	43,564
Chromosomal abnormalities	10,726 (24.3%)	44,127
Procedures		
Status		43,885
Elective	32,640 (74.4%)	
Urgent	10,223 (23.3%)	
Emergency	936 (2.1%)	
Salvage	86 (0.2%)	
OR entry time category		44,418
6 AM to noon	38,605 (86.9%)	
Noon to 6 PM	5192 (11.7%)	
6 PM to 6 AM	621 (1.4%)	
STAT mortality category		39,191
1	10,609 (27.1%)	
2	11,532 (29.4%)	
3	5695 (14.5%)	
4	9351 (23.9%)	
5	2004 (5.1%)	
Airway		
Airway in situ	4453 (10.4%)	42,635
Lines		
Arterial line preoperatively	3955 (9.4%)	42,274
Central venous line or PICC line preoperatively	6728 (17.6%)	38,281
Arterial line placed	44,094 (99.5%)	44,301
Central venous line placed	33,522 (76.4%)	43,862
Surgical Lines	2478 (5.8%)	42,592
Provider		
CRNA present	9834 (27%)	36,370
Resident/Fellow present	19,631 (54%)	36,370
Second anesthesiologist present	1351 (3.7%)	36,370

IQR, Interquartile range; *BSA*, body surface area; *OR*, operating room; *STAT*, Society of Thoracic Surgeons-European Association for Cardiothoracic Surgery; *PICC*, peripherally inserted central catheter; *CRNA*, certified registered nurse anesthetist.

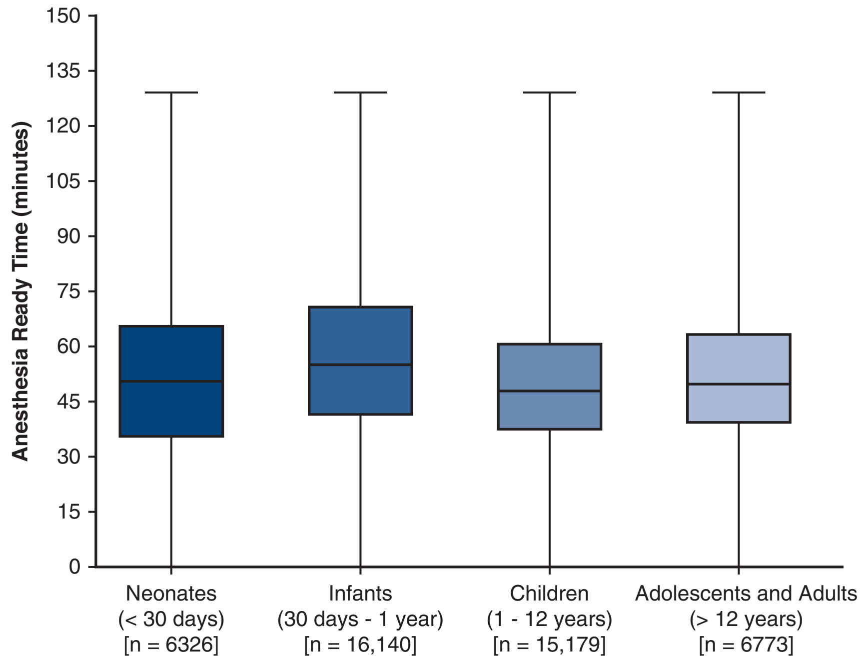

FIGURE 4. Median ART for subgroups of age. Box-and-whisker plot demonstrating the ART based on the age of the patient. The median is the *horizontal line in the box*, the *box* represents the IQR, and the *whiskers* represent the maximum ART.

benefit from additional education or training to reduce excessive ARTs.

We did not identify any meaningful association of ART with other operating room times. It may be possible that when ART is longer, the remainder of the team works to decrease other time intervals. It is important to note that ART comprises, on average, 15% of the total time in the operating room, whereas PPT comprises 10.5%, operating time comprises 68.5%, and exit time comprises 6%. This suggests that targets other than ART should be considered in efforts to improve efficiency.[5]

Although the focus of this study is benchmarking ART and to analyze its contributing factors, our data do provide benchmark data for preparation and exit times. The median PPT was 36 minutes (IQR, 25-48), and the median exit time was 18 minutes (IQR, 13-27). Both contributions to the overall operating room efficiency should be considered for quality improvement measures at individual institutions.

Achieving operating room efficiencies is complex.[6] They not only involve potential cost savings but also may affect patient outcomes. The case duration and the associated case end time have downstream effects that may impact patient care. These include late arrival time to the ICU, an increased number of intraoperative handovers, and team fatigue leading to reduced team morale and burnout. Additional important factors beyond the scope of this study are case start times and in-between case turnover times.[7,8]

Study Limitations

Not all centers contribute anesthesia data to the database, and we are unable to determine differences in centers that contribute anesthesia data from those that do not. We also did not have data on volume at each individual center. From our dataset, we cannot precisely delineate how the presence of an additional anesthesiologist influences ART. Furthermore, there are various types of support available for cardiac anesthesiology teams. Some institutions have anesthesia technicians or other ancillary staff who can perform room setup and facilitate performance of procedures. At some centers, the only source of additional help may be a circulating nurse. The database did not contain information on the experience level of trainees or indicate whether locums or traveler staff were involved in delivery of care; therefore, we could not adjust for these factors. Experienced fellows may function at the level of an attending and could potentially shorten ART.

Because of dataset limitations, we were unable to adjust for other individual center variations such as having more personnel available in the afternoon to help start cases, a policy of complex cases starts as a "first start case," and the relationship of center volume to the number of afternoon case starts. We also do not have data on how many attempts were made at vascular access, and issues such as prior occlusions could contribute to a lengthier ART.

The reporting of the end time of ART can be variable and subjective. Ideally, it is reported as the end of anesthesia

TABLE 2. Univariate and multivariable analyses of variables associated with a greater anesthesia ready time

Variable	Univariate analysis		Multivariable analysis	
	Coefficient (95% CI)	*P* value	Adjusted coefficient (95% CI)	*P* value
Patient Characteristics				
Age (y)	−0.14 (−0.2 to −0.08)	**<.001**	−0.06 (−0.13 to 0.02)	.137
Weight (kg)	−0.05 (−0.08 to −0.03)	**<.001**	−0.03 (−0.06 to −0.01)	**.011**
Premature	1.99 (1.44-2.55)	**<.001**	1.47 (0.79-2.15)	**<.001**
Race				
Black/African American	0.73 (0.21-1.24)	**.006**	0.49 (−0.09 to 1.08)	.095
White	0.22 (−0.19 to 0.64)	.293		
All other races	−0.62 (−1.33 to 0.08)	.084		
Syndrome	3.83 (3.11-4.57)	**<.001**	Omitted due to collinearity with chromosomal abnormalities	
Chromosomal Abnormalities	4.17 (3.44-4.91)	**<.001**	3.46 (2.54-4.37)	**<.001**
Procedure characteristics				
Status				
Elective	Reference		Reference	
Urgent	1.33 (−0.24 to 2.89)	.096	3.39 (1.54-5.23)	**<.001**
Emergency	−8.86 (−11.9 to −5.8)	**<.001**	−3.61 (−6.12 to −1.09)	**.005**
Salvage	−16.5 (−20.8 to −12.1)	**<.001**	−3.79 (−11.1 to 3.56)	.312
OR entry time				
6 AM to noon	Reference		Reference	
Noon to 6 PM	−5.8 (−7.5 to −4.16)	**<.001**	−4.23 (−5.64 to −2.82)	**<.001**
6 PM to 6 AM	−2.91 (−5.08 to −0.74)	**.008**	−1.28 (−3.63 to 1.07)	.285
STAT mortality category				
1	Reference		Reference	
2	1.55 (0.72-2.37)	**<.001**	1.73 (0.87-2.58)	**<.001**
3	4.35 (3.48-5.23)	**<.001**	4.09 (3.42-4.75)	**<.001**
4	3.59 (2.37-4.81)	**<.001**	4.69 (3.62-5.76)	**<.001**
5	4.39 (1.92-6.86)	**.001**	7.79 (5.21-10.37)	**<.001**
Airway				
Airway in situ	−6.72 (−10 to −3.5)	**<.001**	−3.56 (−5.54 to −1.58)	**<.001**
Lines				
Aline	10.9 (4.3-17.5)	**.001**	Cannot calculate	
Aline preoperatively	−8.7 (−12.7 to −4.7)	**<.001**	−7.4 (−10.2 to −4.6)	**<.001**
PICC preoperatively	−4.75 (−7.56 to −1.93)	**.001**	−0.08 (−2.2 to 2.04)	.944
Central line placed	8.2 (5.65-10.8)	**<.001**	8.49 (5.94-11.05)	**<.001**
Surgical lines	−2.16 (−4.09 to −0.23)	**.028**	3.56 (0.73-6.4)	**.014**
Anesthesia staffing				
Anesthesia provider present	Reference		Reference	
CRNA	−3.56 (−4.7 to −2.41)	**<.001**	−0.91 (−2.22 to 0.4)	.174
Resident/Fellow	4.2 (3.28-5.11)	**<.001**	3.79 (2.62-4.96)	**<.001**
Second Anesthesiologist	−0.85 (−2.61 to 0.91)	.342	0.9 (−1.25 to 3.06)	.412

P values with statistical significance are in bold. *CI*, Confidence interval; *OR*, operating room; *STAT*, Society of Thoracic Surgeons-European Association for Cardiothoracic Surgery; *PICC*, peripherally inserted central catheter; *CRNA*, certified registered nurse anesthetist.

induction and preparation time and generally indicates when the patient is ready for the nursing team to begin positioning and prepping. However, in some instances, both processes (ART and PPT) may be occurring simultaneously. In some institutions, induction of anesthesia and line placement may take place in induction rooms or in the ICU.

CONCLUSIONS

There are many nonmodifiable patient and procedural factors related to ART. Preoperative placement of invasive monitors may improve ART but is not always feasible. The presence of an anesthesia trainee increases ART. For patients with characteristics associated with prolonged ART, consideration should be given to allocation of additional anesthesia staffing to improve efficiency.

Conflict of Interest Statement

The authors reported no conflicts of interest.

The *Journal* policy requires editors and reviewers to disclose conflicts of interest and to decline handling or reviewing manuscripts for which they may have a conflict of interest. The editors and reviewers of this article have no conflicts of interest.

The data for this research were provided by The Society of Thoracic Surgeons' National Database Participant User File Research Program. Data analysis was performed at the investigators' institution.

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Key Words: anesthesia, congenital cardiac surgery, operating room efficiency, perioperative care