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ORIGINAL ARTICLE / ÖZGÜN MAKALE

Second harvest of Congenital Heart Surgery Database in Türkiye: Current outcomes

Türkiye'deki Çocuk Kalp Cerrahisi Veritabanı'nın ikinci hasadı: Güncel sonuçlar

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ABSTRACT

Background: This second harvest of the Congenital Heart Surgery Database intended to compare current results with international databases.

Methods: This retrospective study examined a total of 4007 congenital heart surgery procedures from 15 centers in the Congenital Heart Surgery Database between January 2018 and January 2023. International diagnostic and procedural codes were used for data entry. STAT (Society of Thoracic Surgeons and European Association for Cardiothoracic Surgery) mortality scores and categories were used for comparison of the data. Surgical priority status was modified from American Society of Anesthesiologist guidelines. Centers that sent more than 5 cases to the database were included to the study.

Results: Cardiopulmonary bypass and cardioplegic arrest were performed in 2,983 (74.4%) procedures. General risk factors were present in 22.6% of the patients, such as genetic anomaly, syndrome, or prematurity. Overall, 18.9% of the patients had preoperative risk factors (e.g., mechanical ventilation, renal failure, and sepsis). Of the procedures, 610 (15.2%) were performed on neonates, 1,450 (36.2%) on infants, 1,803 (45%) on children, and 144 (3.6%) on adults. The operative timing was elective in 56.5% of the patients, 34.4% were urgent, 8% were emergent, and 1.1% were rescue procedures. Extracorporeal membrane oxygenation support was used in 163 (4%) patients, with a 34.3% survival rate. Overall mortality in this series was 6.7% (n=271). Risk for mortality was higher in patients with general risk factors, such as prematurity, low birth weight neonates, and heterotaxy syndrome. Mortality for patients with preoperative mechanical ventilation was 17.5%. Pulmonary hypertension and preoperative circulatory shock had 11.6% and 10% mortality rates, respectively. Mortality for patients who had no preoperative risk factor was 3.9%. Neonates had the highest mortality rate (20.5%). Intensive care unit and hospital stay time for neonates (median of 17.8 days and 24.8 days, respectively) were also higher than the other age groups. Infants had 6.2% mortality. Hospital mortality was 2.8% for children and 3.5% for adults. Mortality rate was 2.8% for elective cases. Observed mortality rates were higher than expected in the fourth and fifth categories of the STAT system (observed, 14.8% and 51.9%; expected, 9.9% and 23.1%; respectively).

Conclusion: For the first time, outcomes of congenital heart surgery in Türkiye could be compared to the current world experience with this multicenter database study. Increased mortality rate of neonatal and complex heart operations could be delineated as areas that need improvement. The Congenital Heart Surgery Database has great potential for quality improvement of congenital heart surgery in Türkiye. In the long term, participation of more centers in the database may allow more accurate risk adjustment.

Keywords: Cardiac surgery, congenital heart disease, database, quality improvement.

ÖZ

Amaç: Çocuk Kalp Cerrahisi Veritabanı'nın bu ikinci hasadında, mevcut sonuçların uluslararası veritabanlarıyla karşılaştırılması amaçlandı.

Çalışma planı: Ocak 2018 ile Ocak 2023 tarihleri arasında yapılan bu retrospektif çalışmada, Çocuk Kalp Cerrahisi Veritabanında bulunan 15 merkezden toplam 4007 konjenital kalp cerrahisi işlemi incelendi. Veri girişi için uluslararası tanı ve işlem kodları, verilerin karşılaştırılması için STAT (Göğüs Cerrahları Derneği ve Avrupa Kardiyotorasik Cerrahi Birliği) mortalite skor ve kategorileri kullanıldı. Cerrahi öncelik durumu, Amerikan Anesteziyoloji Birliği kılavuzundan modifiye edildi. Veritabanına 5 ve üzerinde olgu gönderen merkezler çalışmaya alındı.

Bulgular: İşlemlerin 2,983'ünde (%74.4) kardiyopulmoner baypas ve kardiyoplejik arrest uygulandı. Hastaların %22.6'sında genetik anomali, sendrom veya prematürite gibi genel risk faktörleri mevcuttu. Genele bakıldığında, ameliyat öncesi risk faktörleri (örn., mekanik ventilasyon, böbrek yetersizliği ve sepsis) %18.9 hastada vardı. İşlemlerin 610'u (%15.2) yenidoğanlara, 1,450'si (%36.2) bebeklere, 1,803'ü (%45) çocuklara ve 144'ü (%3.6) yetişkinlere uygulandı. Ameliyat zamanlaması hastaların %56.5'inde elektif, %34.4'ünde erken, %8'inde acil ve %1.1'inde ise kurtarıcı özellikte idi. Hastaların 163'ünde (%4) ekstrakorporeal membran oksijenasyonu desteği kullanıldı ve bu hastalarda sağkalım oranı %34.3 idi. Bu çalışmada genel mortalite %6.7 (n=271) idi. Prematürite, düşük doğum ağırlıklı yenidoğanlar ve heterotaksi sendromu gibi genel risk faktörlerine sahip hastalarda mortalite riski daha yüksekti. Ameliyat öncesi mekanik ventilasyon uygulanan hastalarda mortalite %17.5 idi. Pulmoner hipertansiyon ve ameliyat öncesi sirkülatuar şok sırasıyla %11.6 ve %10 mortalite oranlarına sahipti. Ameliyat öncesi risk faktörleri olmayan hastalarda mortalite %3.9 idi. Yenidoğan hastalar en yüksek mortalite oranına (%20.5) sahipti. Yenidoğanların yoğun bakım ve hastane kalış süreleri de (sırasıyla, ortanca 17.8 gün ve 24.8 gün) diğer yaş gruplarına kıyasla yüksek bulundu. Bebeklerin mortalitesi %6.2 idi. Hastane mortalitesi çocuklar için %2.8 ve yetişkinler için %3.5 idi. Elektif ameliyatlarda mortalite oranı %2.8 idi. STAT sisteminin dördüncü ve beşinci kategorilerinde gözlenen mortalite oranları beklenden daha yüksekti (sırasıyla; gözlenen %14.8 ve %51.9; beklenen %9.9 ve %23.1).

Sonuç: Bu çok merkezli veritabanı çalışması ile ilk kez Türkiye'deki konjenital kalp cerrahisi sonuçları güncel dünya deneyimleri ile karşılaştırılabildi. Yenidoğan ve kompleks kalp cerrahisindeki artmış mortalite, iyileştirilmesi gereken noktalar olarak açığa çıkarıldı. Türkiye'de konjenital kalp cerrahisinin kalitesinin iyileştirmesi için Çocuk Kalp Cerrahisi Veritabanı büyük potansiyele sahiptir. Uzun vadede veritabanına daha fazla merkezin katılımı ile daha doğru risk belirlenmesi mümkün olabilir.

Anahtar sözcükler: Kalp cerrahisi, konjenital kalp hastalıkları, veritabanı, kalite iyileştirme.

Quality management programs are essential for almost all sectors across the world, particularly for healthcare. Self-awareness, benchmarking, feedback, continuous improvement, and monitoring significantly affect all establishments, including private and governmental organizations.[1] Without a good quality management system, companies cannot survive in this age of knowledge. The reflection of quality management in healthcare systems is the quality of care, which is one of the most frequently quoted principles of health policy, and it is currently the top priority issue in the agenda of policy-makers.[2] Although defining accurate parameters for quality measurements in congenital heart surgery is a complex issue, significant progress has been made in the last decades.[3-5] Several methodologies have been developed and refined. Consensus-based systems, such as the RACHS-1 (Risk Adjustment for Congenital Heart Surgery) and Aristotle Basic Complexity (ABC) and Aristotle Comprehensive Complexity (ACC) scores have been used for quality assessment by clinical investigators and administrative datasets for population-based health service research.[6-8] In 2009, the Society of Thoracic Surgeons (STS) and the European Association for Cardiothoracic Surgery (EACTS) introduced the first largely empirical metric for risk adjustment of operative mortality in congenital heart surgery. The STS-EACTS (STAT) congenital heart surgery mortality categories for risk stratification were created based on objective data from STS and EACTS databases.[9] Using these systems, more accurate quality assessment could be possible all over the world. Uniformity of data with the same diagnostic and procedural codes made it possible to evaluate and compare the outcomes between congenital heart services.

Although the beginning of congenital heart surgery in Türkiye goes back to 1960, there was no national database for congenital heart surgery until 2018. Database studies have been limited with the participation of some centers in international databases in our country. The main drawbacks of using international databases are the difficulty of analyzing own institutional data, limited participation of database studies due to costs, and risk of institutional data loss.

A new Congenital Heart Surgery Database (CHSD) was introduced in 2018 by the Children's Heart Foundation in Türkiye. International diagnostic and procedural codes and risk scoring systems were used. An internet-based system was chosen to facilitate data collection, which is available for desktop computers, laptop computers, tablets, and smart phones. As a novel application, a real-time online reporting system was developed. Users can see all their data by using 10 different automated reports, including the total number of procedures, mortality rates, morbidity parameters, complications, intensive care unit (ICU) and hospital stay, extracorporeal membrane oxygenation (ECMO) rates, and outcomes. Users can instantly compare their results with the peer centers using Aristotle and STAT categories. The first harvest of the CHSD was published in 2021 with the participation of 12 centers and 2,307 procedures.[10]

In this second harvest, we aimed to analyze our current multicenter outcomes and compare them with the current results of international databases to reveal the areas that need improvement. We seek to encourage more national centers to participate in the project and to improve the potential for quality improvement.

PATIENTS AND METHODS

In this retrospective study, 4,007 procedures from 15 centers included in the CHSD were analyzed between January 2018 and January 2023. The International Pediatric and Congenital Cardiac Codes and the ICD-10 (International Classification of Diseases) have been used for the unification and standardization of the nomenclature in the CHSD. The complexity, risk factors, and difficulty levels of individual procedures were analyzed using the ABC and STAT mortality scores and categories. The ACC scoring system was modified to simplify data entry. Modification was utilized only for the definition of some procedure-dependent factors. Any unusual anatomical variant detected during operations was considered "difficult anatomy" and added to the ACC score a standard extra point (for example, any coronary anomaly detected during an arterial switch operation (ASO) added an extra 1 point). By modification, instead of entering multiple different parameters with small impact on the ACC for every procedure (between 0.5 and 2 points), we simplified data entry considerably without causing significant distortion of the data. Procedures were counted instead of patients. No follow-up data was included. For instance, Glenn and Fontan operations for the same patient in different hospitalizations were considered two different procedures. For patients who underwent more than one procedure during the same hospitalization, the procedure having the highest risk score was considered the primary procedure. Surgical priority status was modified from the American Society of Anesthesiologists guidelines. Rescue procedures were defined for patients who may have had mortality in hours without intervention. Emergent procedures were described for patients who had a great risk of mortality in days without operation. Urgent procedures were defined for patients who can wait for an intervention no more than weeks. All other procedures were considered elective. Age categories were classified as follows: neonate (0-30 days), infant (1-12 months), children (1-18 years), and adult congenital (>18 years). Simple operative data, including surgical approach, cardiopulmonary bypass (CPB) use, cardioplegia, and perfusion techniques were collected. The definition of preoperative and general risk factors was modified from "procedure independent factors" according to the European Congenital Heart Surgeons Association database.[8] Complications were defined as major and minor, and all complications in the same hospital stay were counted. Indications of ECMO support, duration of support, and outcomes were collected. Mortality was defined as hospital death. Transfer was defined for patients who were sent to other healthcare facilities for further therapy and rehabilitation.[10] Data validation was not performed and is planned as a part of the next step of the research. Some centers sent all their cases to the database, while some centers contributed a part of their data in a specific timeframe. Centers that sent more than five cases to the database were included in the study.

Interfaces were designed by using Bootstrap technology. The SQL Server (Microsoft Corp., Redmond, WA, USA) was chosen as the database, and the ASP.NET and Visual Basic. NET were used as the software language. Ten real-time online analysis reports were created. No follow-up data was requested.

Statistical analysis

Statistical analysis was performed using SPSS version 11.0 software (SPSS Inc., Chicago, IL, USA). Pearson's chi-square test was performed for categorical data to determine whether the observed data were significantly different from the overall results. Mean and standard deviations (SD) were presented for normally distributed variables and median (min-max) values were used for skewed distributions. One sample proportion test in R Studio version 1.1.463 (R Foundation for Statistical. Computing, Vienna, Austria) was used for estimation of confidence interval of the given values. A p-value <0.05 was considered statistically significant.

RESULTS

Among the procedures, 54.6% (n=2,188) were performed on males. The median sternotomy approach was used in 3,402 (84.9%) procedures. Left thoracotomy was performed in 298 (7.4%) procedures. Right thoracotomy was performed in 186 (4.6%) operations. Lower or upper partial sternotomy was performed in 66 (1.6%) operations. A parasternal incision was used in 18 (0.5%) procedures. Other approaches (not defined) were used for the remaining 37 (0.9%) procedures.

Cardiopulmonary bypass and cardioplegic arrest were performed in 2,983 procedures (74.4%). On-pump beating heart technique was applied in 367 (9.1%) procedures. A total of 657 (16.3%) procedures were performed off-pump. Cardioplegia shifted towards single-dose del Nido or the Custodiol HTK solution over blood cardioplegia in recent years. Single-dose cardioplegia was used in 1,550 (36.8%) procedures. Intermittent tepid blood cardioplegia was preferred in 988 (24.6%) procedures. Intermittent cold blood cardioplegia was chosen in 346 (8.6%) procedures. Intermittent crystalloid cardioplegia was used in only 94 (2.3%) procedures. No statistical difference was observed between mortality rates of different cardioplegia techniques. Antegrade selective cerebral perfusion techniques were used in 228 (5.6%) procedures. Sixty-four (28%) patients died in this group (p<0.001). Fifty-four (1.3%) procedures were performed by using the hypothermic circulatory arrest technique, and mortality was observed in 21 (38.8%) procedures (p<0.001). Retrograde cerebral perfusion was used for 11 (0.2%) patients during circulatory arrest.

Overall mortality among 4,007 procedures was 6.7% (n=271). Additionally, 130 (3.2%) patients were transferred for further treatment or rehabilitation to another center. Most of them were patients operated on without CPB, such as premature neonates undergoing patent ductus arteriosus ligation. The mortality for procedures with CPB with cardioplegic arrest was 7.3% (n=219). Seventeen (4.6%) patients died in the on-pump beating heart surgery group, while the mortality rate was 5.3% (n=35) for those undergoing off-pump procedures.

Among all procedures, 623 (15.5%) were reoperations, and 214 (5.3%) had more than two sternotomies before; mortality rates were 8.1% and 4.2%, respectively (p=0.2). According to this study, resternotomy did not affect mortality. Minimally invasive surgeries grew in popularity, and 295 (7.3%) patients underwent these procedures without any mortality.

General risk factors

General risk factors were present in 891 (22.2%) patients in the study. The primary risk factors affecting mortality included prematurity (23.5%), heterotaxy/dextrocardia (14.8%), low body weight (<2,500 gr; 14.1%), and possessing more than two risk factors (21.8%). Severe prematurity (<32 weeks) did not affect mortality (5.9%). In this group, the most common procedure was patent ductus arteriosus ligation, none of which were open heart operations. Mortality in patients without general risk

Table 1. General risk factors

	Total		Exitus			Transfer	
	n	%	n	%	*p*	n	%
No risk factor	3103	77.4	157	5.1	<0.003	39	1.3
Genetic anomaly	396	9.9	30	7.6	0.54	15	3.8
Heterotaxy/dextrocardia	115	2.9	17	14.8	0.001	3	2.6
Low body weight (<2500 g)	78	1.9	11	14.1	0.01	2	2.6
Severe prematurity (<32 w)	17	0.4	1	5.9	0.89	8	47
Extracardiac anomaly	47	1.2	4	8.5	0.64	3	6.4
Prematurity (32-35 w)	34	0.8	8	23.5	<0.001	4	11.8
≥2 risk factors	197	4.9	43	21.8	<0.001	56	28.4
Total	4007		271	6.7		130	3.2

factors was 5.1%. Details of the data are presented in Table 1.

Preoperative risk factors

In the study, 761 (18.9%) patients had at least one preoperative risk factor. The most common preoperative risk factors affecting mortality were mechanical ventilation (17.5%), pulmonary hypertension (11.6%), circulatory shock (10%), and hepatic dysfunction (33.3%). Presence of two or more preoperative risk factors caused 30.0 and 41.9% mortality, respectively. The mortality rate was 3.9% among patients who had no preoperative risk factors. Details of the preoperative risk factors are outlined in Table 2.

Age groups

Outcomes of the age groups were statistically different in terms of mortality rates, ICU stay, and hospital stay. In the study group, 610 (15.2%) patients were neonates, 1,450 (36.2%) were infants, 1,803 (45%)

Table 2. Preoperative risk factors

	Total		Exitus			Transfer	
	n	%	n	%	*p*	n	%
No risk factor	3250	81.1	126	3.9	<0.001	47	1.2
Mechanical ventilation	246	6.1	43	17.5	<0.001	44	17.9
Pulmonary hypertension (>4 wu)	86	2.1	10	11.6	0.08	2	2.3
Circulatory shock	50	1.2	5	10	0.37	2	4
Myocardial dysfunction	36	0.9	2	5.6	0.77	2	5.6
Cerebrovascular event	29	0.7	1	3.4	0.48	0	0
Hypothyroidism	27	0.7	2	7.4	0.89	1	3.7
Sepsis/endocarditis/NEC	21	0.5	1	4.8	0.72	3	14.3
Coagulation disorder	8	0.2	0	0	0.45	0	0
Hepatic dysfunction	3	0.07	1	33.3	0.07	0	0
Renal failure	5	0.1	0	0	0.55	0	0
CPR (within 48 h)	4	0.1	0	0	0.59	1	
Mechanical circulatory support (ECMO)	1	0.02	0	0	0.79	0	0
2 risk factors	283	7.3	85	30	<0.001	31	11
>3 risk factors	93	2.32	39	41.9	<0.001	10	10.7
Total	4007		271	6.7		130	3.2

wu: Wood unit; NEC: Necrotizing enterocolitis; CPR: Cardiopulmonary resuscitation; ECMO: Extracorporeal membrane oxygenation.

Table 3. Age group statistics

	Neonate			Infant			Child			Adult			Total		
	n	%	Mean±SD	n	%	Mean±SD	n	%	Mean±SD	n	%	Mean±SD	n	%	Mean±SD
No. of patients	610	15.2		1450	36.2		1803	45		144	3.6		4007		
Mortality	125	20.5		90	6.2		51	2.8		5	3.5		271	6.8	
ICU duration			17.8±21.1			10.1±18.2			3.4±7.5			2.3±4.8			8±15.5
Hospital duration			24.8±23			18±23.5			11.1±14.3			11.1±11			15.7±20
Major complication	220	36.1		258	17.8		171	9.5		13	9		662	16.5	
Minor complication	231	37.9		306	21.1		203	11.3		18	12.5		758	18.9	
No complication	296	48.5		1034	71.3		1517	84.1		121	84		2968	74.1	
MACC score			11.5±4			8.8±2.9			7.5±2.7			7.7±2.6			8.6±3.3

SD: Standard deviation; ICU: Intensive care unit; MACC: Modified Aristotle Comprehensive Complexity Score.

were children, and 144 (3.6%) were adults. Neonates had the highest mortality rate with 20.5% (p<0.001). Intensive care unit and hospital stay times of neonates were longer than other age groups (mean duration of 17.8±21.1 days and 24.8±23 days, respectively; p<0.001). Additionally, 36.1% of them had at least one major complication. The modified ACC (MACC) complexity score of the neonates was also higher than the other age groups, with a mean score of 11.5±4. The mortality rate was 6.2% in infants. Their mean ICU and hospital stay times were 10.1±18.2 and 18±23.5 days, respectively, and 17.8% of the infants experienced at least one major complication. Children had the best survival rate with 2.8% mortality. Their ICU and hospital stay times were shorter than neonates and infants (mean duration of 3.4±7.5 days and 11.1±14.3 days, respectively). The major complication rate of the children (9.5%) was also less than neonates and infants. The mortality rate of the adult congenital age group was 3.5%. Their ICU and hospital stay times and major complication rates were similar to the children's. All age groups' data are depicted in Table 3, and mortality rates of age groups are shown in Figure 1.

Priority of procedures

It is generally accepted that surgical priority categories of the procedures affect mortality and morbidity significantly, but they are not usually considered in standard database systems. Our simple definition of priority categories may improve the analysis of the outcomes. Rescue procedures had the highest mortality rate, as expected (45.5%, p<0.001). The mortality rate of emergent and urgent procedures was 17.7% (p<0.001) and 9.4% (p=0.01), respectively. In this study, 56.5% of the procedures were considered elective cases, and their mortality rate was 2.8%. Elective cases had statistically significantly lower

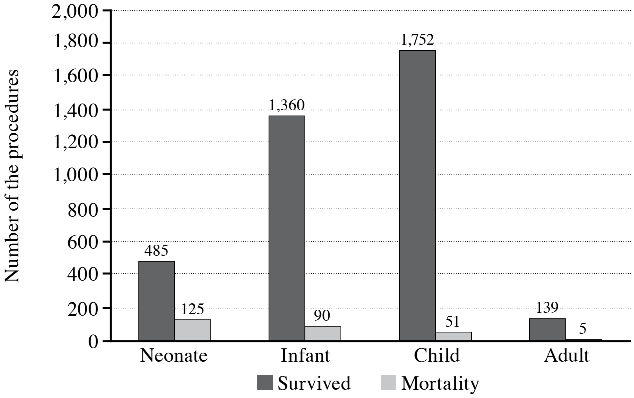

Figure 1. Mortality rates according to age groups.

Table 4. Outcomes according to the priority of the procedures

	Elective		Urgent		Emergent		Rescue		Total	
	n	%	n	%	n	%	n	%	n	%
No. of patients	2,262	56.5	1,379	34.4	322	8	44	1.1	4,007	
Mortality	64	2.8	130	9.4	57	17.7	20	45.5	271	6.8
Major complications	208	9.2	309	22.4	118	36.6	27	61.4	662	16.5
Minor complications	262	11.6	343	24.9	135	41.9	18	40.9	758	18.9
No complication	1,897	83.9	905	65.6	154	47.8	12	27.3	2,968	74.1

mortality rates than the other priority classes and overall mortality rates (2.8% *vs*. 6.8%, p<0.001). Major complication rates were correlated with the priority status as well. All detailed data are shown in Table 4.

Observed and expected STAT score mortality rates of the procedures

Expected mortality rates of the procedures according to the STAT scoring system were very well defined. Observed mortality rates of the procedures in this study and their comparison with the STAT scoring system are shown in Table 5. Overall mortality in this study was higher than expected (6.7% *vs*. 4.3%). Although the observed mortality rates of the procedures in the first three STAT categories were comparable with the expected values, improvement may be necessary for some procedure subgroups. Norwood procedure had the highest mortality rate (56.7%). Considering that the expected mortality rate is 23.6%, there is a need for significant improvement in hypoplastic left heart surgery. Mortality for ASO was 8%. While the mortality rate of ASO with ventricular septal defect (VSD) repair was 14.1%, ASO with VSD and aortic arch repair was 40%. Those were almost two times higher than expected. Furthermore, mortality of aortic arch repair was almost four times higher than expected (28.3% *vs*. 7.8%). Fontan modifications, tetralogy of Fallot (TOF) repair, Rastelli procedure, truncus arteriosus, and total anomalous pulmonary venous connection repair had higher than expected mortality rates. Aortopulmonary shunt and pulmonary banding operations had also higher mortality rates than expected mortality rates.

Table 5 shows information about the current trend in surgical techniques. For example, 90% of Fontan procedures were performed with extracardiac conduit; the remaining procedures were lateral tunnel modifications. The fenestration rate was 57%. Among 361 procedures for TOF repair, 59.8% had transannular repair. Nontransannular patch with infundibulotomy was performed in 28.3%, and 4.4% of the patients needed right ventricle to pulmonary artery conduit. Transatrial approach in TOF repair was performed in only 7.2% of the patients.

Extracorporeal membrane oxygenation results

In this series, 163 (4.0%) patients required ECMO support during hospital stay. Almost all patients underwent venoarterial ECMO with central cannulation. Two patients needed peripheral cannulation, and three needed venovenous ECMO support. Out of the total number of patients who were on ECMO support, 79 (48.4%) patients were weaned successfully from ECMO support, and 56 (34.3%) patients were discharged. While the median duration for ECMO support in surviving patients was 5 (2-55) days, the median ECMO support duration in nonsurviving patients was 8 (1-37) days. Most common indication was low cardiac output syndrome with 40.5% survival rate. Unable to wean from CPB was the second most common indication for ECMO, and they had the lowest survival rate (25%). Seventeen patients underwent ECPR with six survivors (35.2%). Details of the ECMO use are shown in Table 6.

Scoring categories

Expected mortality rates for the categories of expert consensus scoring systems, such as ABC and ACC scores, were not well defined. The MACC score was utilized to compare outcomes across centers and specific time periods, and the MACC categories and mortality rates are shown in Table 7. As expected, mortality and morbidity rates (reflected by ICU and hospital stay) increased in correlation with the categories.

The STAT scoring system categories were well defined and reflected the mortality rates of the large cumulative congenital heart surgery data of STS and

Table 5. Observed and expected STAT score mortality rates of the procedures

Procedures	n	Observed mortality (n)	Observed mortality %	Observed mortality 95% CI	STAT score	STAT category	Expected mortality %	Expected mortality 95% CI
ASD repair, patch	202	0	0	0.0-1.8	0.1	1	0.3	0.1-0.5
ASD repair, primary closure	105	0	0	0.0-3.5	0.1	1	0.9	0.5-1.3
AVSD repair partial	54	1	1.8	0.3-9.7	0.1	1	0.5	0.2-0.9
PFO, primary closure	2	0	0		0.2	1	1.1	0.3-2.5
ASD + PAPVC repair	97	0	0.0	0.0-3.8	0.2	1	0.6	0.2-1.4
Aortic stenosis, subvalvar repair	97	1	1	0.1-5.6	0.2	1	0.6	0.3-1.0
DORV repair	1	0	0		0.2	1	0.8	0.2-1.6
VSD repair, patch	431	5	1.2	0.4-2.7	0.2	1	0.9	0.7-1.1
Vascular ring repair	14	0	0.0	0.0-21.5	0.2	1	0.9	0.4-1.6
Coarctation repair, end-to-end	43	0	0.0	0.0-8.2	0.2	1	1.0	0.6-1.5
Pacemaker/ICD procedure	42	0	0.0	0.0-8.2	0.2	1	1.0	0.2-2.9
VSD closure, primary	22	0	0.0	0.0-14.8	0.2	1	0.9	0.7-1.1
AVR, bioprosthetic	7	0	0		0.3	1	1.2	0.2-3.4
PVR	87	0	0.0	0.0-4.2	0.3	1	1.3	0.6-2.3
Conduit reoperation	33	1	3	0.5-15.3	0.3	1	1.4	0.8-2.1
TOF repair, ventriculotomy, non-transannular patch	100	4	4	1.5-9.8	0.3	1	1.5	0.8-2.4
TOF repair, no ventriculotomy	26	0	0.0	0.0-14.8	0.3	1	1.5	0.8-2.3
AVSD repair, intermediate	35	1	2.9	0.5-14.5	0.3	1	1.6	0.7-3.0
Coarctation repair, interposition graft	8	0	0		0.3	1	1.7	0.4-4.1
Fontan, lateral tunnel, fenestrated	12	2	16.7	4.6-44.8	0.3	1	1.7	0.9-2.7
Sinus of Valsalva aneurysm repair	3	1	33.3		0.3	1	1.7	0.3-5.7
AVR, mechanical	33	1	3.0	0.5-15.3	0.3	1	1.7	0.7-3.2
Unidirectional Glenn procedure	4	0	0		0.3	1	1.5	0.2-4.3
PDA closure, surgical	121	2	1.6	0.5-5.8	0.4	2	1.9	1.3-2.5
PA reconstruction, main	7	1	14.3		0.4	2	1.9	0.6-4.0
Valvuloplasty, mitral	67	2	2.9	0.8-10.2	0.4	2	1.9	1.3-2.6
Valvuloplasty, aortic	73	1	1.4	0.2-7.3	0.4	2	1.9	1.1-2.9
1 ½ ventricle repair	4	0	0		0.4	2	2.0	0.3-6.2
Ross procedure	5	0	0		0.4	2	2.2	1.3-3.4
Glenn + PA reconstruction	38	0	0.0	0.0-9.1	0.4	2	2.2	1.1-3.8
Bilateral bidirectional Glenn procedure	40	3	7.5	2.5-19.8	0.4	2	2.4	1.2-3.8
Pericardiectomy	2	0	0		0.5	2	2.9	0.5-7.5
Aneurysm, ventricular, left, repair	3	0	0		0.5	2	3.0	0.5-7.8
Aortic root replacement, mechanical	5	1	20		0.5	2	2.4	0.7-5.1
Coarctation repair, end to end, extended	61	0	0	0.0-5.9	0.5	2	2.5	1.9-3.3
Anomalous origin of coronary artery repair	21	1	4.8	0.8-22.6	0.5	2	2.6	1.2-4.4
RVOT procedure	106	8	7.5	3.8-14.2	0.5	2	2.6	1.9-3.5
Aortic aneurysm repair	15	1	6.7	1.1-29.8	0.5	2	2.6	1.3-4.5

Table 5. Continued

Procedures	n	Observed mortality (n)	Observed mortality		STAT score	STAT category	Expected mortality	
			%	95% CI			%	95% CI
AP window repair	13	1	7.7	1.4-33.3	0.5	2	2.7	0.9-5.6
Valvuloplasty, pulmonic	14	0	0.0		0.5	2	2.7	1.3-4.7
TOF repair, transannular patch	216	9	4.2	2.2-7.7	0.5	2	2.7	2.1-3.4
Bidirectional Glenn procedure	99	5	5.0	2.2-11.3	0.5	2	2.7	2.1-3.4
Aortic stenosis, supravalvar repair	30	2	6.7	1.8-21.3	0.5	2	2.8	1.4-4.6
Fontan, external conduit, fenestrated	66	7	10.6	5.2-20.3	0.6	2	3.0	2.1-4.0
Hemitruncus repair	5	2	40.0		0.6	2	3.1	0.6-8.2
ASD, common atrium, septation	4	0	0		0.6	2	3.1	0.5-8.3
PAPVC, Scimitar repair	8	0	0		0.6	2	3.2	0.8-7.7
Fontan, external conduit, non-fenestrated	52	2	3.8	1.0-12.9	0.6	2	3.2	2.1-4.6
Coronary artery fistula ligation	1	0	0		0.6	2	3.4	0.6-9.2
Aortic root replacement, valve sparing	4	0	0		0.6	2	3.4	0.6-9.2
Mitral stenosis, supravalvar ring repair	6	0	0		0.6	2	3.6	1.0-7.7
Arrhythmia surgery-atrial, surgical ablation	1	0	0		0.7	2	3.6	1.9-5.9
Atrial baffle procedure (non-Mustard, non-Senning)	1	0	0		0.7	2	4.0	0.7-11
Systemic venous stenosis repair	2	0	0		0.7	2	3.7	0.9-8.6
PA reconstruction, peripheral	8	1	12.5		0.7	2	3.7	1.6-6.5
Valvuloplasty, tricuspid	36	1	2.8	0.5-14.2	0.7	2	3.7	2.8-4.9
TVR	6	1	16.7		0.7	2	3.7	2.8-4.9
Valve replacement, truncal valve	1	0	0		0.7	2	3.8	0.4-13.8
Fontan, lateral tunnel, non-fenestrated	1	0	0		0.7	2	3.9	1.3-7.9
Cor triatriatum repair	7	1	14.3		0.7	2	4.0	1.8-7.2
VSD, multiple repair	20	2	10	2.7-30.1	0.7	2	4.0	2.2-6.3
Coarctation repair, subclavian flap	14	0	0	0.0-20.3	0.7	2	4.1	2.0-6.9
TOF repair, RV-PA conduit	16	0	0	0.0-19.3	0.7	2	4.2	2.4-6.4
Konno procedure	8	1	12.5		0.8	3	4.3	1.9-7.6
Coarctation repair, patch aortoplasty	15	0	0		0.8	3	4.3	2.6-6.5
PA reconstruction, central	57	3	5.2	1.8-14.4	0.8	3	4.3	2.9-5.9
Ventricular septal fenestration	2	0	0		0.8	3	4.4	0.8-12.4
Valvuloplasty, truncal valve	1	1	100		0.8	3	4.8	0.8-13.5
Shunt, ligation and takedown	1	0	0		0.8	3	4.5	1.3-9.9
Occlusion MAPCA(s)	3	0	0		0.8	3	4.2	0.7-12.1
Hemi-Fontan procedure	1	0	0		0.8	3	4.5	2.4-71
Aneurysm, pulmonary artery, repair	4	1	25		0.8	3	4.3	0.8-12.2
Aneurysm, ventricular, right, repair	1	0	0		0.8	3	4.3	1.4-8.8
AVSD repair, complete	160	10	6.2	3.4-11.1	0.8	3	4.6	3.9-5.4
Anomalous systemic venous connection repair	4	0	0		0.8	3	4.8	2.2-8.6

Table 5. Continued

Procedures	n	Observed mortality (n)	Observed mortality %	Observed mortality 95% CI	STAT score	STAT category	Expected mortality %	Expected mortality 95% CI
ASO	100	8	8	4.1-14.9	0.8	3	4.8	3.9-5.7
Rastelli operation	47	4	8.5	3.3-19.9	0.9	3	5.3	3.2-7.8
ASD partial closure	2	0	0		0.9	3	5.1	1.1-12.7
AVR, homograft	1	0	0		1	3	5.8	1.3-13.8
Pulmonary artery sling repair	4	0	0		1.1	3	6.4	2.5-11.9
Pulmonary atresia-VSD repair	12	1	8.3	1.5-35.4	1.1	3	6.4	4.0-9.3
Pulmonary embolectomy, acute pulmonary embolus	1	1	100		1.2	3	7.1	1.0-21.1
Conduit placement RV-PA	16	0	0	0.0-19.3	1.2	3	6.7	5.2-8.4
Pericardial drainage procedure	21	0	0	0.0-14.8	1.3	4	7.5	4.7-11.0
MVR	24	2	8.3	2.3-25.8	1.3	4	7.3	5.4-9.4
Aortic arch repair	60	17	28.3	18.5-40.7	1.4	4	7.8	6.1-9.8
Fontan revision	6	2	33.0		1.4	4	7.9	3.1-14.6
DORV, intraventricular tunnel repair	53	5	9.4	4.1-20.2	1.4	4	8.0	6.0-10.3
ASO + aortic arch repair	5	2	40.0		1.4	4	8.0	1.7-20.6
PA debanding	7	0	0		1.4	4	8.0	3.7-13.7
ASO + VSD repair	71	10	14.1	7.8-24.0	1.4	4	8.2	6.6-10
Cardiac tumor resection	13	0	0.0	0.0-22.8	1.4	4	8.3	5.1-12.2
Valve excision, tricuspid (without replacement)	1	0	0		1.5	4	8.8	1.2-28.1
Coronary artery bypass	2	1	50.0		1.5	4	8.5	3.5-16.0
TOF, absent pulmonary valve repair	8	1	12.5		1.5	4	8.6	5.0-13.1
Shunt, MBTS	90	12	13.3	7.7-21.8	1.5	4	8.9	7.9-10
TOF-AVSD repair	13	3	23.1	8.1-50.2	1.6	4	9.1	5.0-14.1
Ross-Konno procedure	4	2	50.0		1.6	4	9.4	5.8-13.9
Senning procedure	3	0	0		1.6	4	9.4	3.5-18.6
Ebstein’s repair	8	0	0		1.6	4	9.5	4.0-17.6
Aortic dissection repair	2	0	0		1.7	4	10.0	3.0-21.1
Aortic arch + VSD repair	39	5	12.8	5.6-26.7	1.7	4	9.8	6.9-13.1
PA banding	149	20	13.4	8.8-19.8	1.7	4	9.8	8.3-11.5
Unifocalization, MAPCAs	13	0	0	0.0-22.8	1.7	4	10.0	7.4-13.4
VSD creation, enlargement	6	0	0		1.8	4	10.4	5.6-16.6
HLHS biventricular repair	2	1	50.0		1.9	4	10.9	4.8-18.8
TAPVC repair	65	12	18.4	10.8-29.5	1.9	4	11.2	9.5-12.8
Pulmonary venous stenosis repair	8	1	12.5		2	4	11.4	8.0-15.3
Shunt, central	49	8	16.3	8.5-29.0	2.1	4	12.1	9.7-14.6
Interrupted aortic arch repair	29	5	17.2	7.5-34.5	2.1	4	12.2	9.6-15.1
ASO, VSD, aortic arch repair	12	2	16.6	4.6-44.8	2.4	4	14.0	8.5-20.5
Truncus arteriosus repair	14	4	28.6	0.05-0.5	2.4	4	14.1	11.4-16.8

Table 5. Continued

Procedures	n	Observed mortality (n)	Observed mortality %	Observed mortality 95% CI	STAT score	STAT category	Expected mortality %	Expected mortality 95% CI
ASD creation/enlargement	2	2	100		2.5	4	14.5	9.4-20.9
Atrial septal fenestration	4	2	50.0		2.6	4	15.1	4.5-30.8
Valve closure, tricuspid	1	1	100		2.6	4	15.6	2.7-41.6
Damus-Kay-Stansel procedure	2	0	0		2.9	5	17.1	13.2-21.5
CCTGA, atrial switch and Rastelli operation	1	0	0		3.2	5	18.9	6.3-37.2
CCTGA, atrial switch and ASO	6	2	33.3		3.4	5	20.0	9.1-34.7
Norwood procedure	67	38	56.7	44.8-67.8	4	5	23.6	21.9-25.3
Hybrid approach, Stage I, bilateral bands	46	9	19.6	10.6-33.1	4.8	5	36.8	31.7-42.2*
Truncus + IAA repair	4	1	25.0		5	5	29.8	17.7-44.3
Total	4007	271	6.7	6.0-7.5			4.3	4.1-4.4

STAT: Society of Thoracic Surgeons and European Association of Cardiothoracic Surgery; CI: Confidence interval; ASD: Atrial septal defect; AVSD: Atrioventricular septal defect; PFO: Patent foramen ovale; PAPVC: Partial abnormal pulmonary venous connection; DORV: Double outlet right ventricle; VSD: Ventricular septal defect; ICD: Intermittent cardioverter defibrillator; PVR: Pulmonary valve replacement; TOF: Tetraloji of Fallot; AVR: Aortic valve replacement; PDA: Patent ductus arteriosus; PA: Pulmonary atresia; RVT: Rgiht ventricle outflow tract; AP: Aorto-pulmonary; TVR: Tricuspid valve replacement; RV: Right ventricle; MAPCA: Major aorto-pulmonary collaterals; ASO: Arterial switch operation; MVR: Mitral valve replacement; MBTS: Modified Blalock-Taussig shunt; HLHS: Hypoplastic left heart syndrome; TAPVC: Total abnormal pulmonary venous connection; CCTGA: Congenitally corrected transposition of the great arteries; IAA: Interrupted aortic arch

Table 6. Extra corporeal membrane oxygenation results

ECMO indications	n	Weaned from ECMO n	Weaned from ECMO %	Survived n	Survived %
Low cardiac output	74	42	56.7	30	40.5
Unable to wean from CPB	60	22	36.6	15	25.0
ECPR	17	8	47.0	6	35.2
Respiratory support	12	7	58.3	5	41.6
Total	163	79	48.4	56	34.3

ECMO: Extra corporeal membrane oxygenation; CPB: Cardiopulmonary bypass; ECPR: Extracorporeal cardiopulmonary resuscitation.

EACTS databases. For this reason, STAT categories were chosen for comparing our data with the world experience. Observed and expected mortality rates of STAT scoring categories are shown in Table 8 and Figure 2. Although our results were similar in the first three categories, a marked difference was detected for the fourth and fifth STAT categories. Our mortality rates were higher than expected for procedures with high complexity scores. It shows that efforts for improvement should be focused on more complex procedures.

Comparison of the centers

Bubble graphs in Figure 3 show the comparison of the centers according to the STAT scores. The X-axis shows the mean complexity scores of the procedures performed by a specific center. The Y-axis shows the overall outcome of all procedures of a specific center. Sizes of the bubbles show the number of the procedures performed at related centers.

DISCUSSION

The main finding of this study was that the CHSD had comparable outcomes with the world databases for the first three STAT categories. Significant improvement is still needed for complex operations, particularly in STAT categories four and five, neonatal congenital heart surgery, and for patients who need antegrade cerebral perfusion and total circulatory

Table 7. Number and outcomes according to MACC categories

	Category 1			Category 2			Category 3			Category 4			Category 5			Category 6		
MACC category	n	%	Mean±SD	n	%	Mean±SD	n	%	Mean±SD	n	%	Mean±SD	n	%	Mean±SD	n	%	Mean±SD
No of procedures	521	13		1,156	28.8		1,038	25.9		1,107	27.6		158	3.9		27	0.7	
Mortality	1	0.2		20	1.7		39	3.8		135	12.2		59	37.3		17	63	
ICU duration (days)			1.3±1.5			4.5±10.7			6.7±12.8			12.9±17.2			27.8±35.5			16.1±18.8
Hospital duration (days)			4.2±6.2			11.8±16.2			15.1±17.1			21.9±22.5			35.2±40.2			20±21.7
MACC score			3.9±0.8			6.7±0.6			8.5±0.6			11.4±1.3			16.6±1.4			23.3±3.3

SD: Standard deviation; MACC: Modified Aristotle Comprehensive Complexity Score; ICU: Intensive care unit.

Table 8. Number and outcomes according to STAT categories

	Category 1			Category 2			Category 3			Category 4			Category 5		
STAT category	n	%	95% CI	n	%	95% CI	n	%	95% CI	n	%	95% CI	n	%	95% CI
No of procedures	1,275	31.8		1,146	28.6		504	12.6		1005	25.1		77	1.9	
Observed mortality	10	0.8	0.3-1.5	43	3.75	2.7-5.1	29	5.7	3.9-8.2	149	14.8	12.7-17.2	40	51.9	40.3-63.3
Expected mortality		0.8			2.6			5.0			9.9			23.1	

STAT: Society of Thoracic Surgeons and European Association of Cardiothoracic Surgery; CI: Confidence interval.

arrest. Efforts should be focused on general and preoperative risk factors, which affected the outcomes significantly. Use of ECMO and the results were comparable with the outcomes of the world experience.

This second harvest of the CHSD delineated a limited part of the current practice of congenital heart surgery in Türkiye. Although data is varied, it is estimated that approximately 7,000 to 9,000 congenital heart operations are performed annually in Türkiye.[4,5] Establishment of new congenital heart surgery centers, increased patient transportation capacity, and enhanced prenatal diagnosis capabilities made it possible for almost all children born with congenital heart disease (CHD) to access proper healthcare services. The best way to ensure high-quality care that meets world standards for patients is by implementing effective quality management and improvement policies. Data collection is the first step of quality improvement. Benchmarking and comparison of outcomes with the world experience have great potential for improving results.[1,2]

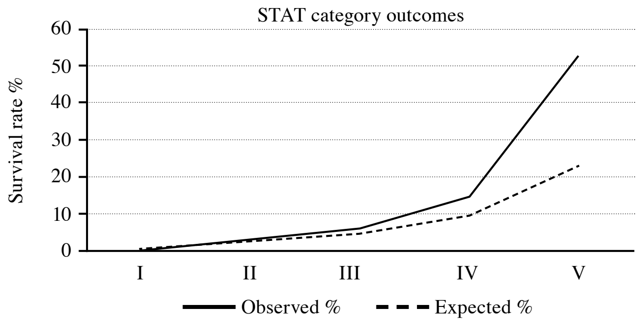

Figure 2. Observed and expected mortality rates according to the STAT scoring categories.

STAT: Society of Thoracic Surgeons and European Association of Cardiothoracic Surgery.

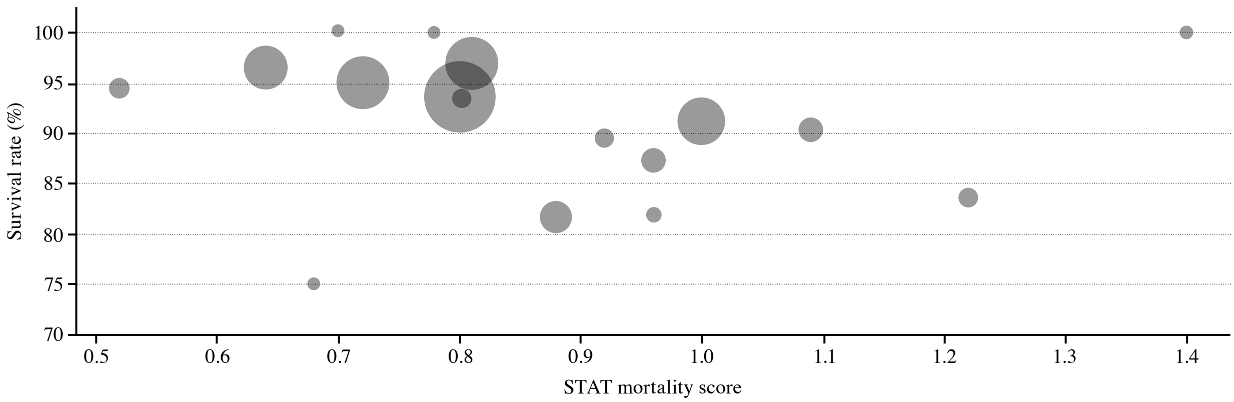

Figure 3. Comparison of the centers according to the STAT scoring system.

STAT: Society of Thoracic Surgeons and European Association of Cardiothoracic Surgery.

Overall mortality was 6.7% in this study. Considering the overall 4.3% mortality rate of STS and EACTS databases, outcomes in this study need improvement.[9] The impact of general and preoperative risk factors, the emergency status of patients, and age categories significantly influenced mortality rates. Although it is not always possible, timely intervention in stabilized patients may improve the results. Nevertheless, considering the small size of the CHSD, comparison of overall results may be unfair. Expected and observed mortality rates of the procedures, demonstrated in Table 5, may provide better analysis for the delineation of specific procedures that need improvement.

Some of the common procedures, such as TOF repair, Fontan modifications, Rastelli operation, and aortic arch repair, had more than expected mortality rates. Arterial switch operation with/without VSD, aortic arch repair, and Norwood procedures also had higher mortality rates than expected. Better overall national outcomes can only be possible by improving the performance of each center. Identification of key areas in need of improvement may facilitate this process.[2-4] All areas for quality improvement should be evaluated to find weak points. Strategies may be focused on early referral for surgery, intensive preoperative corrective therapies, the use of checklists, minimizing human errors, performance monitoring, training, continuing education, and, more importantly, finding an explanation for the outcome through a forensic approach.[11] Significant variation in outcomes also exists among centers in the USA.[12]

High-volume centers demonstrate superior outcomes compared to other centers for complex neonatal and high-risk procedures.[13,14] According to the new "Recommendations for centers performing pediatric heart surgery in the United States" guideline, centers are divided into comprehensive care and essential care centers based on their case volume, and it was suggested that high-risk operations should be performed in comprehensive care centers.[12] Same recommendation is also evident for the European centers.[15] The same concept of concentrating the complex cases in specialized centers may be beneficial for our centers to improve patient care in Türkiye. In this database study, almost all patients' specific risk factors were analyzed. We believe that a better outcome analysis may be possible to demonstrate not only the procedures performed but also patient-specific risk factors. The STAT scoring system, which is based on the statistics of EACTS and STS big data, does not take into account any patient-specific risk factors. However, they argue that the status of individual patients in such a vast database does not significantly impact the overall outcome. Nevertheless, many studies demonstrated the accuracy and feasibility of outcome analysis by using STAT mortality categories across the wide spectrum of distinct congenital heart surgery operations, including infrequently performed procedures.[16] Another drawback of the STAT scoring system is that some of the challenging surgeries, such as the Ross procedure, are in the second category. In practice, the Ross procedure has been performed only by some experienced surgeons and centers. This does not mean that Ross procedure is a simple, low-risk operation, despite statistics showing low mortality and morbidity. Recent updates to STAT mortality scores and categories now encompass a broader range of procedure codes, also considering the risk associated with operations involving multiple components.[17] Conversely, the Aristotle score is based on expert opinions and considers patient-specific risk factors. The highest ABC, which represents the complexity of the procedures, is 15 points, and the ACC score considers the patient's clinical status at the time of the operation. General risk factors, preoperative risk factors, surgical priority, and organ functions are all included and increase the complexity point from 15 to 25 points.[18] From our perspective, the ACC score appears to be more accurate in evaluating small groups of patients. In this study, we also used an MACC score, which may be beneficial for comparison of outcomes between participating centers.

Morbidity is as important as mortality for quality measurement. The most important parameters defining morbidity are ICU and hospital stay times, which are highly correlated with the complications occurring after the operations.[9,17,18] The neonatal age group had the highest mortality rate and had the longest ICU and hospital stays in this study. Knowledge of potential complications, whether major or minor, is also of great value when informing patients and their families prior to surgeries. Knowing the median durations of ICU and hospital stays, as well as the expected percentages of specific complications associated with a particular procedure, may assist surgeons in providing information to the families.

Several national and international databases are present for congenital heart surgery.[19-21] Healthcare systems aim to ensure and organize care for individuals with CHD, focusing on clinical outcomes and costs at a population level to ensure coordinated healthcare delivery and optimal results. Therefore, extensive multicenter databases are virtually indispensable for supplying the information required by healthcare systems. It is obvious that comprehensive databases affect national policies as well and make it possible to act in the right direction at the right time for the improvement of the healthcare of patients with CHD. We hope that the CHSD initiative will cover all of the country in the near future. The CHSD may provide not only the improvement of healthcare of patients with CHD but also facilitate and transform healthcare policies.

Society of Thoracic Surgeons congenital heart surgery database is the oldest database and has the highest number of patients, with the participation of approximately 90% of all centers from the USA. According to the 2020 report, they have 535,184 operations since the inception of the database.[22] Numerous reports and research, which have been performed throughout the years, have been the mainstay of the knowledge about CHD. The STS congenital database not only publishes their studies in the scientific area but also publicly reports outcomes according to their mortality risk model. There are pros and cons of public reporting, which may force centers for better outcomes. On the other hand, some centers may become less reluctant to accept patients with high risk of mortality.[23-25] Although controversy still exists in the USA about whether public reporting should be done or how it should be done, we believe that the CHSD might have a module for public information in the future.

Artificial intelligence-based algorithms have recently been introduced in clinical assessment, diagnosis, procedure planning, and intervention management in pediatric cardiology and congenital heart surgery.[26,27] Effective artificial intelligence model training relies on comprehensive and diverse datasets. This emphasizes the importance of large and accurate databases.[28] The integration of artificial intelligence into clinical practice may have profound implications, such as tailored treatment planning, cost-effectiveness, and further enhancing patient care.[29]

Analysis of outcomes, according to the currently available scoring systems for congenital heart surgery, is not new in Türkiye. Some centers use their own database for the comparison of their results with the current world statistics as an effort for quality improvement in congenital heart surgery.[30-32] However, a national database was not available for all centers with a standardized nomenclature and scoring system until the CHSD. It has been shown that the improvement process immediately begins when centers participate in a database study and when they start analyzing and comparing their outcomes with other centers.[33]

This study has several limitations. First, it represents only a small part of the national congenital heart surgery results. All centers that shared their data with more than five patients were included in the study. Some centers joined with all their data, but some centers sent only a part of their cases from a specific timeframe, and no verification of the data has been performed yet. The results of the patients who were transferred to another center are unknown. The database shows the results of procedures, and no follow-up data is available. Patients who underwent different operations in different hospitalization periods were considered different procedures. Since the database does not use patients' identity information, operations that a patient undergoes in different hospitals are processed as different patients.

In conclusion, outcomes of congenital heart surgery in Türkiye could be compared to the current world experience with this multicenter database study. Several critical areas requiring improvement were identified. By creating the Congenital Heart Surgery Database, the Children’s Heart Foundation is taking a crucial step in enhancing care for children with congenital heart disease in Türkiye. A real-time online reporting system provides instant detailed analysis of the outcomes and comparison of the results. Use of international parameters and scoring systems makes it possible to compare the results with the world experience. In the long term, we anticipate that the participation of more centers in the database will allow more accurate risk adjustment. We invite all centers to participate fully and honestly in this important initiative for the quality improvement of congenital heart disease in our country.

Ethics Committee Approval: The study protocol was approved by the Acıbadem University Ethics Committee (date: 30.09.2021, no: ATADEK 2021 19/12). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Patient Consent for Publication: A written informed consent was obtained from the patients and/or parents of the patients.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

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REFERENCES

1. What is quality management system? American Society of Quality: Available at: https://asq.org/quality-resources/quality-management-system [Accessed: 10.08.2023]
2. Gupta SD, Sharma SK, Kumar S. Quality management in health care. In: Gupta, SD, editor. Healthcare System Management. Singapore: Springer; 2022. p. 339-367.
3. Lacour-Gayet F, Maruszewski B, Mavroudis C, Jacobs JP, Elliott MJ. Presentation of the International Nomenclature for Congenital Heart Surgery. The long way from nomenclature to collection of validated data at the EACTS. Eur J Cardiothorac Surg 2000;18:128-35. doi: 10.1016/s1010-7940(00)00463-2.
4. Sarıoğlu T, Erek E, Yalçınbaş YK. Why national databases are necessary for pediatric and congenital heart surgery practice? Turk Gogus Kalp Dama 2019;27:418-22. doi: 10.5606/tgkdc.dergisi.2019.17945.
5. Sarıoğlu CT, Sarıoğlu A. Hasta güvenliği ve kalite geliştirme programı. Çocuk kalp merkezlerinin standartları. İstanbul: Çocuk Kalp Vakfı Yayınları; 2021. p. 40-3.
6. Jenkins KJ. Risk adjustment for congenital heart surgery: The RACHS-1 method. Semin Thorac Cardiovasc Surg Pediatr Card Surg Annu 2004;7:180-4. doi: 10.1053/j.pcsu.2004.02.009.
7. Jenkins KJ, Gauvreau K, Newburger JW, Spray TL, Moller JH, Iezzoni LI. Consensus-based method for risk adjustment

for surgery for congenital heart disease. J Thorac Cardiovasc Surg 2002;123:110-8. doi: 10.1067/mtc.2002.119064.

8. Lacour-Gayet F, Clarke D, Jacobs J, Comas J, Daebritz S, Daenen W, et al. The Aristotle score: A complexity-adjusted method to evaluate surgical results. Eur J Cardiothorac Surg 2004;25:911-24. doi: 10.1016/j.ejcts.2004.03.027.
9. O'Brien SM, Clarke DR, Jacobs JP, Jacobs ML, Lacour-Gayet FG, Pizarro C, et al. An empirically based tool for analyzing mortality associated with congenital heart surgery. J Thorac Cardiovasc Surg 2009;138:1139-53. doi: 10.1016/j.jtcvs.2009.03.071.
10. Erek E, Yalçınbaş YK, Sarıosmanoğlu N, Özkan M, Yıldız O, Şenkaya I, et al. First harvest of pediatric and congenital heart surgery multicenter database in Turkey: Novel application of real-time online reporting. World J Pediatr Congenit Heart Surg 2021;12:377-86. doi: 10.1177/2150135121995474.
11. Yacoub M, Hosny H, Afifi A. Improving postoperative outcome of congenital heart surgery in low/middle-income countries: Climbing Mount Excellence. Heart 2017;103:1658-9. doi: 10.1136/heartjnl-2017-311395.
12. Backer CL, Overman DM, Dearani JA, Romano JC, Tweddell JS, Ram Kumar S, et al. Recommendations for centers performing pediatric heart surgery in the United States. World J Pediatr Congenit Heart Surg 2023;14:642-79. doi: 10.1177/21501351231190353.
13. Welke KF, O'Brien SM, Peterson ED, Ungerleider RM, Jacobs ML, Jacobs JP. The complex relationship between pediatric cardiac surgical case volumes and mortality rates in a national clinical database. J Thorac Cardiovasc Surg 2009;137:1133-40. doi: 10.1016/j.jtcvs.2008.12.012.
14. Kansy A, Zu Eulenburg C, Sarris G, Jacobs JP, Fragata J, Tobota Z, et al. Higher programmatic volume in neonatal heart surgery is associated with lower early mortality. Ann Thorac Surg 2018;105:1436-40. doi: 10.1016/j.athoracsur.2017.11.028.
15. Daenen W, Lacour-Gayet F, Aberg T, Comas JV, Daebritz SH, Di Donato R, et al. Optimal structure of a congenital heart surgery department in Europe. Eur J Cardiothorac Surg 2003;24:343-51. doi: 10.1016/s1010-7940(03)00444-5.
16. Jacobs JP, Jacobs ML, Maruszewski B, Lacour-Gayet FG, Tchervenkov CI, Tobota Z, et al. Initial application in the EACTS and STS Congenital Heart Surgery Databases of an empirically derived methodology of complexity adjustment to evaluate surgical case mix and results. Eur J Cardiothorac Surg 2012;42:775-80. doi: 10.1093/ejcts/ezs026.
17. Jacobs ML, Jacobs JP, Thibault D, Hill KD, Anderson BR, Eghtesady P, et al. Updating an empirically based tool for analyzing congenital heart surgery mortality. World J Pediatr Congenit Heart Surg 2021;12:246-81. doi: 10.1177/2150135121991528.
18. Bojan M, Gerelli S, Gioanni S, Pouard P, Vouhé P. The Aristotle Comprehensive Complexity score predicts mortality and morbidity after congenital heart surgery. Ann Thorac Surg 2011;91:1214-21. doi: 10.1016/j.athoracsur.2010.10.071.
19. St Louis JD, Kurosawa H, Jonas RA, Sandoval N, Cervantes J, Tchervenkov CI, et al. The world database for pediatric and congenital heart surgery: The dawn of a new era of global communication and quality ımprovement in congenital heart disease. World J Pediatr Congenit Heart Surg 2017;8:597-9. doi: 10.1177/2150135117725458.
20. Ombelet F, Goossens E, Willems R, Annemans L, Budts W, De Backer J, et al. Creating the BELgian COngenital heart disease database combining administrative and clinical data (BELCODAC): Rationale, design and methodology. Int J Cardiol 2020;316:72-8. doi: 10.1016/j.ijcard.2020.05.059.
21. Hirata Y, Hirahara N, Murakami A, Motomura N, Miyata H, Takamoto S. Current status of cardiovascular surgery in Japan, 2015 and 2016: A report based on the Japan Cardiovascular Surgery Database. 1-Congenital heart surgery. Gen Thorac Cardiovasc Surg 2019;67:731-5. doi: 10.1007/s11748-019-01160-0.
22. Mayer JE Jr, Hill K, Jacobs JP, Overman DM, Kumar SR. The Society of Thoracic Surgeons Congenital Heart Surgery Database: 2020 update on outcomes and research. Ann Thorac Surg 2020;110:1809-18. doi: 10.1016/j.athoracsur.2020.10.004.
23. Dearani JA. Transparency and public reporting: Beyond the gathering storm. World J Pediatr Congenit Heart Surg 2020;11:9-13. doi: 10.1177/2150135119890514.
24. Pasquali SK, Banerjee M, Romano JC, Normand ST. Hospital performance assessment in congenital heart surgery: Where do we go from here? Ann Thorac Surg 2020;109:621-6. doi: 10.1016/j.athoracsur.2020.01.002.
25. Pasquali SK, Gaynor JW. The path forward in congenital heart surgery public reporting. Ann Thorac Surg 2022;114:534-5. doi: 10.1016/j.athoracsur.2021.07.008.
26. Sethi Y, Patel N, Kaka N, Desai A, Kaiwan O, Sheth M, et al. Artificial intelligence in pediatric cardiology: A scoping review. J Clin Med 2022;11:7072. doi: 10.3390/jcm11237072.
27. Chang Junior J, Binuesa F, Caneo LF, Turquetto ALR, Arita ECTC, Barbosa AC, et al. Improving preoperative risk-of-death prediction in surgery for congenital heart defects using an artificial intelligence model: A pilot study. PLoS One 2020;15:e0238199. doi: 10.1371/journal.pone.0238199.
28. Van den Eynde J, Manlhiot C, Van De Bruaene A, Diller GP, Frangi AF, Budts W, et al. Medicine-based evidence in congenital heart disease: How artificial intelligence can guide treatment decisions for individual patients. Front Cardiovasc Med 2021;8:798215. doi: 10.3389/fcvm.2021.798215.
29. Mohsin SN, Gapizov A, Ekhator C, Ain NU, Ahmad S, Khan M, et al. The role of artificial intelligence in prediction, risk stratification, and personalized treatment planning for congenital heart diseases. Cureus 2023;15:e44374. doi: 10.7759/cureus.44374.
30. Yıldız O, Kasar T, Öztürk E, Tüzün B, Altın HF, Onan İS, et al. Analysis of congenital heart surgery results: A comparison of four risk scoring systems. Turk Gogus Kalp Damar Cerrahisi Derg 2018;26:200-6. doi: 10.5606/tgkdc.dergisi.2018.15083.
31. Erek E, Yılmaz B, Kaya M, Onan Selen İ, Şen O, Öz K, et al. Analysis of results according to the Aristotle scoring system in congenital heart surgery. Turk Gogus Kalp Dama 2014;22:509-16.

32. Sabuncu T, Demircin M, Doğan R, Yılmaz M, Aypar Ü, Paşaoğlu İ. Comparison of risk scoring systems in congenital heart surgery. Turk J Pediatr 2016;58:512-7. doi: 10.24953/turkjped.2016.05.008.
33. Croti UA, Murakami AN, De Marchi CH, Borim BC, Dearani JA, Overman D, et al. Impact of partnership between Children's HeartLink and IQIC database with a pediatric cardiology and cardiovascular surgery center in Brazil. World J Pediatr Congenit Heart Surg 2019;10:270-5. doi: 10.1177/2150135118825151.