Risk-stratified outcome of congenital heart surgery in Assiut University Hospital

Khaled A. Kassem, Mostafa A. Abdelaziz, Ahmed I. Ismael, Ahmed M. Ghoneim

Department of General Surgery, Assiut University Hospital Cardiothoracic, Assiut, Egypt

Correspondence to Khaled A. Kassem, Assiut, Egypt
Tel: +20 106 447 9771;
Fax: +20 106 447 9771;
e-mail: dr_khaledkassem@yahoo.com

Received 11 August 2018
Accepted 14 October 2018

Journal of Current Medical Research and Practice
January-April 2019, 4:25–33

Context
Assessment of surgical performance in the field of congenital heart surgery is very difficult, so many risk scoring systems have been developed. The most popular used systems nowadays are the risk adjustment for congenital heart surgery (RACHS-1) system, Aristotle basic complexity score (ABC score), and the Society of Thoracic Surgeons-European Association for Cardiothoracic Surgery (STS-EACTS) mortality score and categories.

Aims
The aims of the study were the application of the three popular risk scoring systems to Assiut University Hospital for evaluation of the outcome results, determination of the correlations between the mortality and morbidity to the risk categories of these systems, comparison with other cardiac centers worldwide, and managing the factors that lead to different outcome in an attempt to improve our performance.

Materials and methods
A retrospective descriptive study including all pediatric patients (ages ranging from 0 to 16 years old, excluding preterm babies) who underwent cardiac surgery in Assiut University Hospital between January 2008 and December 2017 was conducted.

Statistical analysis
The receiver operating characteristic curve and univariate and multivariate analyses were performed with SPSS 16.0 for Windows.

Results
Postoperative in-hospital mortality was 5.8%, with increasing mortality rates at the higher levels of the RACHS-1 and the ABC. The mean ABC score was 5.57 ± 2.07, which represents a complexity between ABC levels 1 and 2. The mean STS-EACTS mortality score was 0.375 ± 0.376, which placed our complexity of procedures into categories 1–2.

Conclusion
The RACHS-1, ABC, and STS-EACTS mortality scoring systems are useful tools for assessing mortality discharge in a medium volume cardiac center in Egypt. These scores imply a procedural-based level of complexity in the institute, which would be useful information for a longitudinal study.

Keywords:
congenital, heart, morbidity, mortality, risk, stratification, surgery

J Curr Med Res Pract 4:25–33

2357-0121

Introduction

Surgical performance assessment in congenital heart surgery should not depend on the hospital mortality only but the complexity of the operation must be regarded; risk stratification systems have been developed to measure the performance in congenital heart surgery field [1].

Risk adjustment for congenital heart surgery (RACHS-1) method was introduced in 2002, and it stratified the patients into 6 categories depending on the age at the time of operation and the type of operation [2].

Aristotle basic complexity score (ABC score) developed in 2004 categorized the operations according to scores (range: 1.5–15) and levels 1–4 [3].

The European Association for Cardiothoracic Surgery (EACTS) and the Society of Thoracic Surgeons (STS) introduced a new model for risk stratification (STS-EACTS mortality scores and categories) in 2009 and applied it on their databases in 2009 [4].

We applied the three classification tools to the Assiut University Hospital patients to test our results in comparison with other centers. Besides the direct outcome comparison, we looked for correlations between the risk category and both the mortality and morbidity and also the risk factors for different outcomes in our center.

Materials and methods

Data source

The present study was designed as a retrospective descriptive study and approved by the Assiut Faculty of medicine Review Board and Ethics Committee (No. 17100404). All pediatric patients (ages ranging from 0 to 16 years old, excluding preterm babies) who underwent cardiac surgery in Assiut University Hospital between January 2008 and December 2017 were identified using the Assiut University Hospital database. Demographic data was reviewed for age at the first presentation at the hospital, sex, age at the onset of symptom presentation, presence of genetic syndrome, and diagnosis of congenital heart disease. The preoperative and intraoperative data included type of operation, cardiopulmonary bypass time (CPB time), and aortic cross clamp time (AoX time). The postoperative data included outcomes like in-hospital morbidities and mortalities, which were categorized by the RACHS-1 method, ABC level, and STS-EACTS mortality categories [2–4]. Retrospective variables were identified, and a statistical analysis was performed on the effects of preoperative and intraoperative factors on surgical outcomes.

Study variables

Postoperative death before hospital discharge was used as the main outcome variable. For secondary outcome variables, postoperative morbidities were considered. These included cardiac arrest, reoperation, postoperative reintubation, low cardiac output, acute renal failure requiring peritoneal dialysis, pyrexia (>38°C), pleural effusion, and serious cardiac arrhythmia such as complete Atrio-Ventricular (AV) block, junctional ectopic tachycardia, supraventricular tachycardia, atrial ectopic tachycardia, ventricular tachycardia, and ventricular fibrillation requiring medical or electrical cardioversion.

Data analysis

Patients' baseline characteristics and potential confounders were summarized using descriptive statistics (showing the percentage, median, and range). The receiver operating characteristic (ROC) curve was examined for validation of the RACHS-1 level, ABC level, and STS-EACTS mortality categories. Associations between potential risk factors and poor outcomes were assessed with univariate analysis. Continuous variables were assessed with a Mann–Whitney *U*-test, and the categorical variables were evaluated by a Fisher's exact test or a χ^2-test. Multivariate analysis was performed with forward stepwise logistic regression, combined for each outcome. A *P* value less than 0.05 was considered to be statistically significant. Statistical analysis was performed with SPSS 16.0 for Windows (SPSS Inc., Chicago, Illinois, USA).

Results

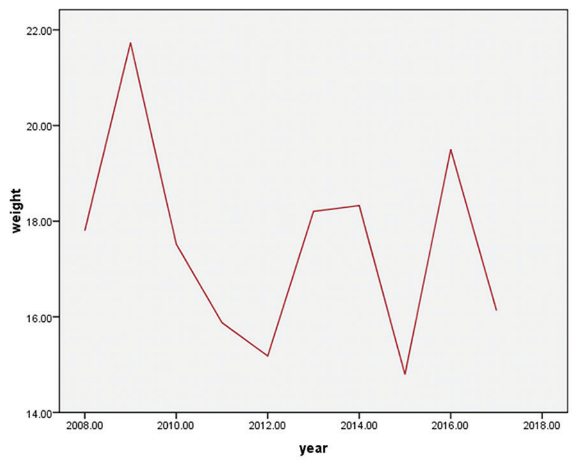
Demographic data

During the 10-year study period, a total of 1095 congenital cardiac surgical procedures were performed on patients at Assiut University Hospital. Their ages were less than 16 years old, and the study excluded preterm babies. Demographic data of these patients are shown in Table 1. The mean weight of our patients is shown in Fig. 1.

Table 1 Patients' baseline characteristics in the present study (*n*=1095)

Characteristics	*n* (%) or mean±SD (range)
Sex	
Male	532 (48.58)
Female	563 (51.42)
Age at surgery (years)	5.05±4.22 (0-16)
≤1 year	124 (11.3) (0.6±0.26)
Preschool age (<5 years)	515 (47) (2.5±1)
>5 years	456 (41.7) (5.5±4.6)
Weight at time of surgery	17.1±11.5 (3-87)
<15 kg	593 (54.15) (9.72±2.661)
>15 kg	502 (45.84) (25.92±11.823)
Weight at time of surgery	17.1±11.5 (3-87)
<15 kg	593 (54.15) (9.72±2.661)
>15 kg	502 (45.84) (25.92±11.823)

Figure 1



Year-to-year changes in the mean of weight.

Surgical procedures

During the 10 years of the study period, a total of 1095 pediatric cardiac surgical procedures were performed. The majority of the procedures were open-heart surgery (77.5%; *n* = 849). The most frequent open-heart procedures were tetralogy of Fallout repair, ventricular septal defect closure, and atrial septal defect closure (19.54, 17.9, and 17.17%, respectively) (see Table 2).

Average cardiopulmonary bypass time and average aortic cross clamp time were 76.05 ± 40.45 and 49.3 ± 29.9 min, respectively.

Most of the procedures were stratified into the RACHS-1 levels [2] of 1 and 2 (38.9 and 51%, respectively), ABC levels [3] of 1 and 2 (39.3 and 36.3%, respectively), and STS-EACTS mortality categories [4] of 1 and 2 (66.2 and 24.2%, respectively) (see Table 3 and Figs. 2–4).

Mortality

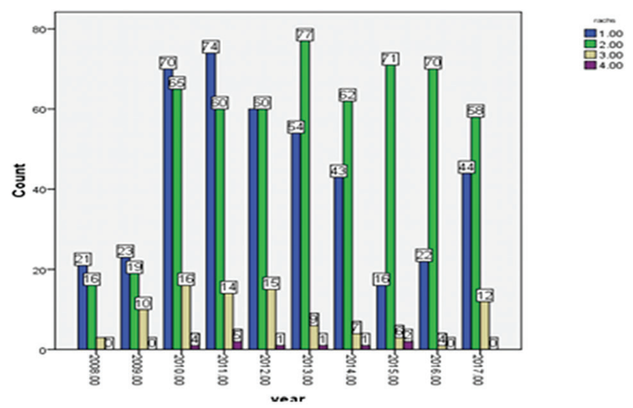
Overall in-hospital postoperative mortality in the present study was 5.83% (64 of 1095); see Fig. 5 and Table 4 for causes of mortality.

Using Pearson's correlation test, we found that younger age, smaller weight, higher RACHS-1 levels, higher ABC levels, higher STS-EACTS mortality categories, longer bypass time, and longer cross clamp time were significantly associated with increased mortality. The bypass times and aortic cross clamp time significantly affected the mortality, as they generally reflect the difficulty of procedures and the complexity of diseases as seen in Table 5.

The calculated surgical performance [3] of the department is as follows = hospital survival (1031/1095 = 94.15%)×the mean ABC score (5.55)/100 = 5.198. Fig. 6 shows changes in our performance year to year.

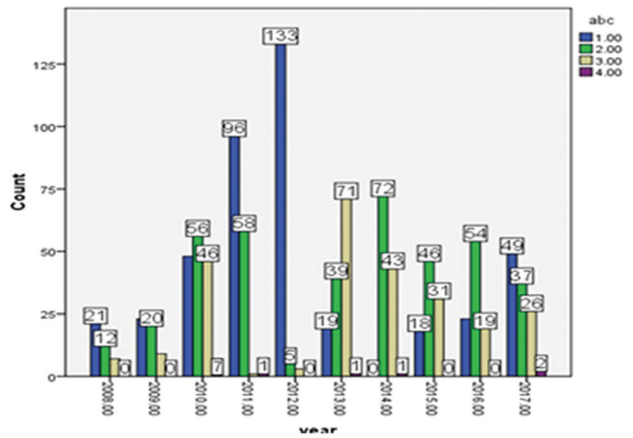
Using the ROC curve statistical method, we tested our mortality results against the 3 risk scoring systems to measure the sensitivity and specificity of these risk scores, and hence detect the method with the best predictability for the mortality in our cases. The area under the ROC curve was measured for each risk scoring system. Larger values of the test result

Figure 2



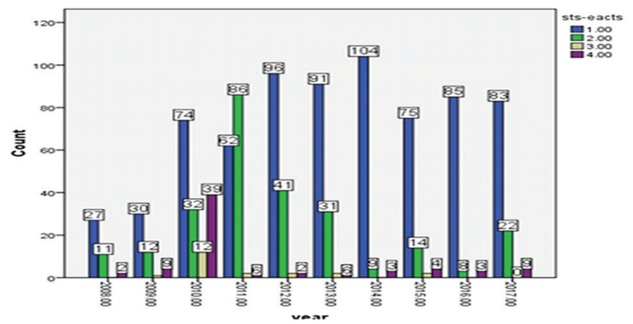
Year-to-year changes in the distribution of cases along the risk adjustment for congenital heart surgery-1 risk categories.

Figure 3



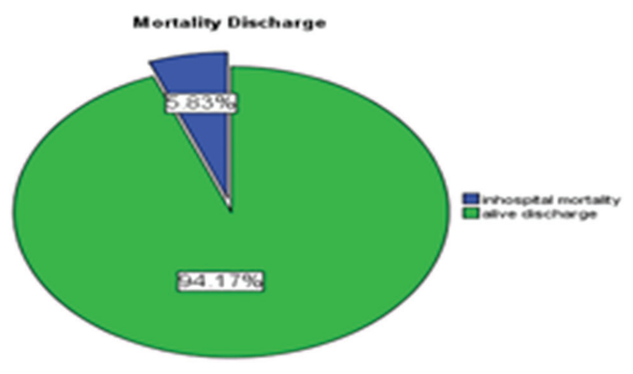
Year-to-year changes in the distribution of cases along the Aristotle basic complexity levels.

Figure 4



Year-to-year changes in the distribution of cases along the Society of Thoracic Surgeons-European Association for Cardiothoracic Surgery categories.

Figure 5



Pie chart of percentage of in-hospital mortality and a live discharge.

Table 2 Surgical procedures in this study (*n*=1095)

Procedure	*n*=1095 [*n* (%)]	Mortality [*n* (%)]
PDA closure	166 (15.15)	0
ASD closure	188 (17.17)	0
Direct closure	11	
With pericardial patch	177	
ASD + PS	11 (1)	1 (9.09)
Tetralogy of Fallot repair	214 (19.54)	28/214 (13.08)
With transannular patch	148	22/148 (14.86)
Without transannular patch	50	5/50 (10)
TOF absent PV repair	7	0
With shunt takedown	5	1/5 (20)
RV decompression without VSD closure	3	0
With pulmonary atresia	1	0
VSD closure	197 (17.9)	7/197 (3.55)
Direct closure	32	0
With patch	165	7/165 (4.24)
VSD + PS	7 (0.64)	1 (14.29)
ASD + VSD	11 (1)	0
Coarctation repair	43 (3.93)	3/43 (6.98)
Resection with end-to-end	16	1
Extended resection with end-to-end	14	0
Subclavian flab aortoplasty	10	1
Prosthetic patch aortoplasty	3	1
SAM resection+transaortic septal myectomy	41 (3.74)	1 (2.44)
Modified B-T shunt	14 (1.28)	6/14 (42.86)
AVSD repair	39 (3.56)	2/39 (5.13)
Partial	32	1
Transitional	4	1
Complete	3	1
Double chamber RV repair	17 (1.55)	0
Partial anomalous pulmonary venous return repair	21 (1.92)	0
Bidirectional Glenn (BCPC)	17 (1.55)	2/17 (11.76)
Mitral valve replacement	20 (1.83)	0
Double valve replacement	8 (0.7)	1/8 (12.5)
Aortic valve repair	3 (0.27)	0
Atrial septectomy	6 (0.55)	0
ASO	5 (0.46)	2/5 (40)
Simple	3	1/3
With VSD closure	1	0
With PS resection	1	1
PS: Pulmonary valvotomy + transannular patch	20 (1.8)	2/20 (10)
Pulmonary artery banding	3 (0.27)	0
Pulmonary conduit reoperation	2 (0.18)	0
Mitral valve repair	4 (0.37)	0
Completion Fontan (TCPC)	5 (0.46)	1/5 (20)
Pericardial patch augmentation of central and branch Pas+shunt or RVOT transannular patch	2 (0.18)	0
Truncus arteriosus repair	2 (0.18)	0
Septation of common atrium with bilateral SVC and unroofed CS+AML cleft closure	3 (0.27)	0
Central aortopulmonary shunt	2 (0.18)	2/2 (100)
Aortic valve replacement with root enlargement	3 (0.27)	0
Re-implantation of scimitar vein into LA	1 (0.09)	0
Aortic valve replacement	3 (0.27)	1 (33.33)
PV replacement with bioprosthesis	1 (0.09)	0
Ross procedure	1 (0.09)	1/1 (100)
Supravalvar AS: 2-sinus repair by pericardial pantaloon patch	2 (0.18)	0
Rastilli repair: D-TGA, VSD, PS	1 (0.09)	1/1 (100)
Ebstein's tricuspid valve repair	1 (0.09)	0
TAPVR repair	5 (0.46)	1/1 (100)

Contd...

Table 2 Contd...

Procedure	*n*=1095 [*n* (%)]	Mortality [*n* (%)]
Resection of intracardiac tumor	2 (0.18)	0
Resection of subaortic muscular ridge in L-TGA	1 (0.09)	0
Repair of cor triatriatum+severe PH	1 (0.09)	1
double aortic arch (complete vascular ring)	2 (0.18%	0
Total	1095	64 (5.8)

AML, Anterior mitral leaflet; ASD, Atrial septal defect; AVSD, Atrio-ventricular septal defect; D-TGA, Dextro-transposition of great arteries; L-TGA, Levo-transposition of great arteries; PDA, Patent ductus arteriosus; PS, Pulmonary stenosis; PV, Pulmonary valve; RV, Right ventricle; SAM, Sub-aortic membrane; TOF, Tetralogy of fallout; VSD, Ventricular septal defect; JET, Junctional ectopic tachycardia.

Table 3 Distribution of cases along the different risk adjustment for congenital heart-1 risk categories, Aristotle basic complexity complexity levels, and Society of Thoracic Surgeons-European Association for Cardiothoracic Surgery mortality categories

Date	RACHS-1 category	ABC score	ABC level	STS-EACTS mortality score	STS-EACTS categories	STS-EACTS technical difficulty
2008	1.55	5.035	1.65	0.312	1.425	30.63
2009	1.75	5.36	1.73	0.471	1.788	35.19
2010	1.74	5.63	1.90	0.471	1.72	38.75
2011	1.63	5.16	1.74	0.476	1.84	32.00
2012	1.69	5.55	1.83	0.387	1.61	37.59
2013	1.69	5.59	1.92	0.334	1.42	39.14
2014	1.7	5.62	1.84	0.361	1.47	36.62
2015	1.94	6.26	2.14	0.327	1.32	45.46
2016	1.81	5.89	1.96	0.260	1.18	39.49
2017	1.72	5.5	1.83	0.343	1.43	38.97
Total	1.72	5.57	1.86	0.375	1.5	37.64

ABC, Aristotle basic complexity; RACHS-1, risk adjustment for congenital heart surgery; STS-EACTS, Society of Thoracic Surgeons-European Association for Cardiothoracic Surgery.

Table 4 Causes of mortality

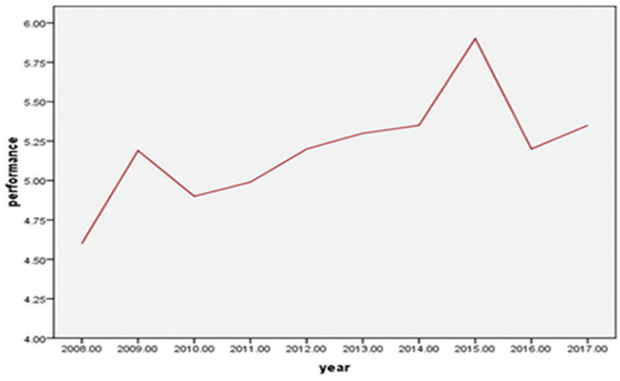
	Causes of mortality	Number of cases	Diagnoses
1	Uncontrolled Pulmonary arterial hypertensive crisis	5	3 hypertensive VSDs AVSDs DORV, PS, remote VSD
2	Uncontrolled arrhythmias	8	5 Tetralogy of Fallot VSD, severe PS 2 VSD, PH
3	Uncontrolled Coagulopathy bleeding	5	Ross for AS, Redo sternotomy for total correction of TOF, BT shunt and atrial septectomy and PAB for TGA Patch aortoplasty for coarctation of aorta Double valve replacement
4	Uncontrolled chest infection	5	Cor triatriatum repair Bilateral BDG+repair of TAPVC Completion Fontan TCPC Subclavian flab aortoplasty for coarctation Single ventricle, PS-bilateral BDG
5	Low cardiac output	29	14 Tetralogy of Fallot total correction (ICU) 2 ASO for simple TGA, TGA+VSD+PS 7 Modified B-T shunt (ICU) Rastilli repair for D-TGA, VSD, PS (ICU) Pulmonary patch angioplasty for severe PS Subclavian flab aortoplasty for Coarctation VSD+severe MS (parachute)+severe PHTN+PDA AVR for AS Partial A-V canal
6	Diffuse cerebral infarction	3	Bidirectional Glenn without CPB VSD+Straddling of Tricuspid valve Subaortic membrane+severe AS
7	Refractory hypoxemia	2	FALLOUT, Mc index=2 FALLOUT, Mc index=2.3
8	Malignant hyperthermia	1	FALLOUT, Mc index=1.5
9	Infective endocarditis	1	FALLOUT McGoon's 2 : 1
10	Hyperkalemic Arrest	5	Coarctation of aorta VSD + PS FALLOUT McGOON=2 Complete AVSD VSD + severe PHTN

Table 5 Correlation between different variables in this study and the mortality

	Age (years)	Weight (kg)	POLS	RACHS-1 category	ABC level	STS-EACTS categories	Bypass time	Cross clamp time
Mortality discharge								
Pearson correlation	−0.119**	−0.112**	0.118**	0.195**	0.216**	0.097**	0.309**	0.225*
Significance (two-tailed)	0.000	0.001	0.000	0.000	0.000	0.001	0.000	0.000
n	1095	1095	1095	1095	1095	1095	1095	1095

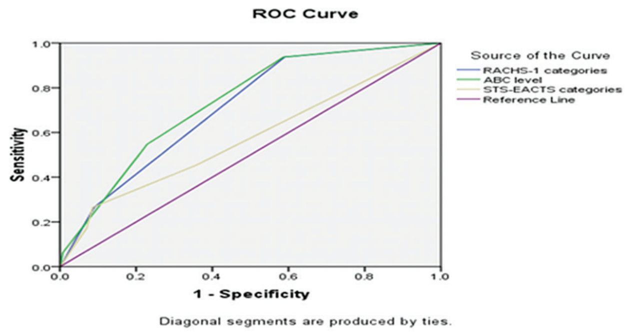
ABC, Aristotle basic complexity; RACHS-1, risk adjustment for congenital heart surgery; STS-EACTS, Society of Thoracic Surgeons-European Association for Cardiothoracic Surgery. *Correlation is significant at the 0.05 level (two-tailed). **Correlation is significant at the 0.01 level (two-tailed).

Figure 6



Changes in performance year-to-year.

Figure 7



Receiver operating characteristic curves for the different risk stratification systems.

Table 6 Area under the curve

Test result variable (s)	Area	SE[a]	Asymptotic significance[b]	Asymptotic 95% confidence interval	
				Lower bound	Upper bound
RACHS-1 categories	0.710	0.029	0.000	0.653	0.767
ABC level	0.734	0.028	0.000	0.678	0.789
STS-EACTS categories	0.574	0.040	0.046	0.495	0.653

ABC, Aristotle basic complexity; RACHS-1, risk adjustment for congenital heart surgery; STS-EACTS, Society of Thoracic Surgeons-European Association for Cardiothoracic Surgery.

variable(s) indicate stronger evidence for a positive actual state (better matching). ABC complexity levels system provided the best results with area under the curve of 0.734, followed by the RACHS-1 risk categories system with area under the curve of 0.710, and the least predictability was by STS-EACTS mortality categories system with an area under the curve of 0.574 (Fig. 7 and Table 6).

Morbidity

Multivariate analysis identified cardiopulmonary bypass time, cross clamp time, RACHS-1 category, ABC levels, and STS-EACTS mortality categories as risk factors for prolonged postoperative hospital stay ($P < 0.05$), as shown in Table 7. The most common events were cardiac arrhythmia events, which required medical intervention; temporary pacing or electrical cardioversion (29.4%); and postoperative pyrexia and chest infections (9.1%), as seen in Table 8.

Discussion

In the present study, 1095 operations have been done in our department from January 2008 to December 2017, with changes in the number of procedures from year to year. The mean age of our cases is 5.05 years and the mean weight is 17.1 kg, and approximately 54.15% of the cases have a weight less than 15 kg.

Most procedures were open-heart surgery (77.5%; n = 849). The most frequent open-heart procedures were tetralogy of Fallout repair, ventricular septal defect closure, and atrial septal defect closure (19.54, 17.9, and 17.17%, respectively).

Most of the procedures were stratified into the RACHS-1 levels of 1 and 2 (38.9 and 51%, respectively), ABC levels of 1 and 2 (39.3 and 36.3%, respectively), and STS-EACTS mortality categories of 1 and 2 (66.2 and 24.2%, respectively).

Before studying our results regarding mortality, we have to highlight two important points whose influence on our hospital mortality is not negligible:

(1) First point – center in establishment phase: considering the initial establishment of a center, even with experience in the surgical treatment of congenital heart disease, the patient outcomes are extremely dependent of the infrastructure at preoperative, transoperative and postoperative times, with special emphasis on the many difficulties faced in the establishment process of a surgical center of high complexity in our country. We found that mortality rates also reflect the many difficulties encountered, even in cases of low complexity, with 5.09 and 4.1% in STS-EACTS category 1 and 2, respectively, which is considered high in comparison with a study on STS and EACTS database that was found to be 0.55% for category 1 and 1.7% for category 2 [4].
(2) Second point – low total volume: despite having a cardiovascular surgery center and a medical residency program, the annual average of surgery cases in congenital heart disease in patients younger than 16 years is fewer than 110 surgeries/year. The surgical volume is a factor whose association with hospital mortality is well established in the literature [5].

Table 7 Correlations of prolonged postoperative hospital stay

	Age (years)	Weight (kg)	RACHS-1 category	ABC level	STS-EACTS categories	Bypass time	Cross clamp time
POLS							
Pearson correlation	0.075	0.066	0.370**	0.407**	0.105**	0.174**	0.179**
Significance (two-tailed)	0.013	0.029	0.000	0.000	0.001	0.000	0.000
N	1095	1095	1095	1095	1095	1095	1095

ABC, Aristotle basic complexity; RACHS-1, risk adjustment for congenital heart surgery; STS-EACTS, Society of Thoracic Surgeons-European Association for Cardiothoracic Surgery. *Correlation is significant at the 0.05 level (two-tailed). **Correlation is significant at the 0.01 level (two-tailed).

Table 8 Postoperative morbidities

Postoperative morbidities	*n* (%)
Serious cardiac arrhythmia (total events)	322 (29.4)
Junctional ectopic tachycardia JET	107 (9.77)
Supraventricular tachycardia	100 (9.1)
Autonomic ectopic tachycardia	52 (4.7)
Ventricular tachycardia	29 (2.65)
Sinus bradycardia	22 (2)
Ventricular fibrillation	10 (0.9)
Complete heart block requiring permanent pacemaker	2 (0.18)
Postoperative pyrexia, chest infections	100 (9.1)
Bleeding or cardiac tamponade requiring reoperation	71 (6.5)
Required reintubation	68 (6.21)
Pleural effusion and chylothorax	43 (3.9)
Pneumothorax (needed more ICT)	11 (1.02)
Neurological deficit	7 (0.68)
Wound infection and mediastinitis	10 (0.91)
Renal failure required peritoneal dialysis	4 (0.37)
Total	636 (58.1)

ICT, Inter-costal tube.

We bring to attention the recent retrospective study of Vinocur *et al.* [5] enrolling 49 American centers, which was included in the Pediatric Cardiac Care Consortium database. After analysis of 85 023 surgeries (45.5% of which were categories 1 and 2 by RACHS-1 method), the mortality rate was 6.2% [5].

In our center in Assiut University Hospital, most of the procedures were stratified into the RACHS-1 levels of 1 and 2 (38.9 and 51%, respectively), and the mortality rate is 5.8%.

It is important to underline the findings of the study of Welke *et al.* [6], and the fact that the inverse correlation between volume and mortality has been demonstrated for the group with more complex procedures (Aristotle score >3). Centers with a volume less than 150 surgeries/year had higher mortality rates in comparison with centers with volume greater than or equal to 350 surgeries [6].

Our view agrees with what was described in the study by Welke *et al.* [6], in which there might be intrinsic factors associated with the centers, other than surgical volume itself, influencing the outcomes. It is necessary to identify these factors with appropriate studies in parallel to the employment of measures aiming to augment the surgical volume. It is precisely this increase of the volume that theoretically reduces the influence of these factors, promoting the interaction of staff and the establishment of a necessary routine in all steps involved (preoperative, transoperative, and postoperative).

Postoperative in-hospital all-over mortality discharge was 5.8%, with increasing mortality rates at the higher levels of the RACHS-1 and the ABC. Nevertheless, no patients were at RACHS-1 levels 5 and 6. The mean ABC score was 5.55 ± 2.01, which represents a complexity between ABC levels 1 and 2. Likewise, the mean STS-EACTS mortality score was 0.374 ± 0.376, which again placed our complexity of procedures into categories 1–2. These scores imply a procedural-based level of complexity in the institute, which would be useful information for a longitudinal study.

Regarding the variability of in-hospital mortality discharge from year to year with the highest rate in 2010 (16/155 = 10.3%) and in 2016 (11/96 = 11.45) the reason for that was transition of our pediatric cardiac surgery unit from place to place, lack of resources and equipment, and our trial to operate on cases with higher complexity, which has also affected on our performance in these years (2010 = 4.9 and 2016 = 5.2), otherwise our performance was steady in the other years.

Overall, the present study besides a previous study applied on Assiut University Hospital conducted by Ghoneim *et al.* [7] shows that the three scoring systems can be applied to a medium volume hospital. The areas under the ROC curves for the ABC and RACHS-1, for predicting in-hospital mortality, are impressive, with 0.734 and 0.710, respectively.

The mortality rate distributed by the ABC risk categories looks a bit different from those of the RACHS-1 or STS-EACTS systems. In the ABC complexity categories, the highest mortality percentage was found at level 3 (50%), followed by level 2 (37.5%), then level 1 (6.25%) and level 4 (6.25%), whereas in the RACHS-1, the highest mortality percentage was found at category 2 (68.75%), followed by category 3 (23.4%).

Using Pearson's correlation test, we found that younger age, smaller weight, higher RACHS-1 levels, higher ABC levels, higher STS-EACTS mortality categories, longer bypass time, and longer cross clamp time were significantly associated with increased mortality. The bypass times and aortic cross clamp time significantly affect the mortality as they generally reflect the difficulty of procedures and the complexity of diseases.

Regarding the causes of mortality postoperatively, it was found that the most common cause was low cardiac output (45.3%) followed by uncontrolled arrhythmia (12.5%), both of which failed to be managed properly in ICU. That reveals the importance of increasing our experience in the management of such cases in the postoperative ICU. Moreover, limited availability of some drugs such as milrinone (phosphodiesterase inhibitor, a potent ino-dilator) and dual chamber pacing devices pay important role in those deaths.

Using the ROC curve statistical method, we tested our mortality results against the 3 risk scoring systems to measure the sensitivity and specificity of these risk scores, and hence detect the method with the best predictability for the mortality in our cases. The area under the ROC curve was measured for each risk scoring system. Larger values of the test result variable (s) indicate stronger evidence for a positive actual state (better matching). ABC complexity levels system provided the best results with area under the curve of 0.734, followed by the RACHS-1 risk categories system with area under the curve of 0.710, and the least predictability was by STS-EACTS mortality categories system with an area under the curve of 0.574.

The most common complications were postoperative serious arrhythmias (22.4%), followed by postoperative fever and chest infections (9.1%). In comparison with others, Chodchanok *et al.* [8] in their series from Thailand, reported postoperative fever (43%), and bleeding tamponade, causing unstable hemodynamics requiring reoperation (9.6%) to be their most common postoperative complications. Other morbidities appeared to be similar to those reported by other authors [8–10].

Comparison of our results with the results of other centers in developing countries was found satisfactory regarding the overall mortality discharge (5.8%), which was found to be less than leading centers in other developing countries, for example, Messejana Hospital, Fortaleza, Brazil 2003–2014 (11.5%) [11] and Sri Jayadeva Institute, India 2007–2013 (7.91%) [12].

Regarding the mortality in relation to risk scores especially of low complexity (RACHS catagory 1 = 0.7% and RACHS catagory 2 = 7.78%), it was in the same range.

By comparing our results to those of the largest database from the STS and EACTS congenital registry [4], the performance at our center has a higher mortality, especially for higher STS-EACTS categories. Jacobs and colleagues in his 2009 study of 58 506 operations at 73 centers revealed an overall discharge mortality as follows: in category 1 = 0.55% (0–1.0%), category 2 = 1.7% (1.0–2.2%), category 3 = 2.6% (1.1–4.4%), category 4 = 8.0% (6.3–11.1%), and category 5 = 18.4% (13.9–27.9%) [4]. Our series revealed mortality rates of 5.09, 4.1, 23.8,

Table 9 Discharge mortality in our results relative to other centers using risk adjustment for congenital heart surgery-1

RACHS-1 groups	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)	6 (%)
11 533 patients, Hospital for Sick Children, Toronto, Canada, 1982-2004 [13]	0.01-0	0.06-0.01	0.09-0.04	0.27-0.07	0.78-0.17	
2368 patients of Bad Oeynhausen Hospital, Germany; 1996-2002 [14]	0.3	4.0	5.7	9.9	50.0	40.1
Messejana Hospital, Fortaleza, Brazil. 2003-2014 [11]	1.8	5.5	14.9	32.5	-	68.6
1150 patients Sri Jayadeva Institute, India 2007-2013 [12]	2.2	8.5	14.3	20	-	-
360 patients, University of Pernambuco, Brazil 2016 [11]	1.3	11.4	27.3	50	-	-
1384 patients, France [15]	0	1.7	3	7.1	10	57.9
Assiut University Hospital 2008-2017	0.7 (3/428)	7.87 (44/559)	15.6 (15/96)	14.28 (2/14)	No patients	

RACHS-1, risk adjustment for congenital heart surgery.

Table 10 Our results relative to other centers using the Aristotle basic complexity risk stratification system

	Average hospital mortality	Average survival	Average complexity score	Average performance
Twenty-six EACTS Centers; Lacour-Gayet *et al.* [4]	4.8% (1.9-9.6)	95.2±2.02% (90.4-98.1%)	6.7±0.4 (5.7-7.2)	6.3±0.4 (5.5-6.9)
Training and Research Hospital, İstanbul, Turkey 2012 [16]	12.5%	87.5%	7.5±2.7	6.56
Congenital Cardiac Center Sankt Augustin, Germany 2002-2007 [17]	3.1%	96.9%	7.61±2.46	7.37
230 patients, Siriraj Hospital, Thailand 2011 [9]	6.1%	93.9%	7.1±1.9	6.66
Assiut University Hospital 2008-2017	5.8%	94.155%	5.55%	5.198

Table 11 Discharge mortality in our results relative to other centers using Society of Thoracic Surgeons-European Association for Cardiothoracic Surgery

	STS-EACTS category 1 (%)	STS-EACTS category 2 (%)	STS-EACTS category 3 (%)	STS-EACTS category 4 (%)	STS-EACTS category 5 (%)
Database from the STS and EACTS congenital registry of 58 506 operations at 73 centers. [4]	0.55 (0-1.0)	1.7 (1.0-2.2)	2.6 (1.1-4.4)	8.0 (6.3-11.1)	18.4 (13.9-27.9)
360 patients, University of Pernambuco, Brazil 2015[11]	5.5	13.6	18.7	35.8	No patients
Assiut University Hospital 2008-2017	5.09	4.1	23.8	13.09	No patients

STS-EACTS, Society of Thoracic Surgeons-European Association for Cardiothoracic Surgery.

and 13.09% for categories 1–4, respectively, with no operations in category 5. Accordingly, the performance of congenital heart surgery at our center needs to be improved to achieve a standard of quality matching the STS-EACTS results.

Tables 9–11 show the comparison of our results with the results of other centers of the world from both developed and developing countries.

Acknowledgements
First and foremost, thanks are due to ALLAH the most Gracious and Merciful, to whom the author attribute the success in achieving any work in his life.

Financial support and sponsorship
Nil.

Conflicts of interest
There are no conflicts of interest.

References

1 Meisner H. Victory by stages: The 'Tour De Force' to early correction in congenital heart surgery. Thorac Cardiovasc Surg 2005; 53:198–204.

2 Jenkins KJ, Gavreau K, Newburger JW, Spray TL, Moller JH, Iezzoni L. Consensus-based method for risk adjustment for surgery for congenital heart disease. J Thorac Cardiovasc Surg 2002; 123:110–118.

3 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; 25:911–924.

4 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 Surgqcvxf 2009; 138:1139–1153.

5 Vinocur JM, Menk JS, Connett J, Moller JH, Kochilas LK. Surgical volume and center effects on early mortality after pediatric cardiac surgery: 25-year North American experience from a multiinstitutional registry. Pediatr Cardiol 2013; 34:1226–1236.

6 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; 137:1133–1140.

7 Ghoneim AMF, Elshafy SKA, El-Hafez AFA, Allah EA, El-minshawy A. Risk stratified outcome of congenital heart surgery in Assiut University Pediatric cardiothoracic surgery unit. Journal of the Egyptian Society of Cardio-Thoracic Surgery 2013; 21:79-90.

8 Chodchanok V, Duangmanee L, Kritvikrom D, Prakul CH, Jarupim S, Paweena CH, *et al.* Surveillance of pediatric cardiac surgical outcome using risk stratifications at a Tertiary Care Center in Thailand. Cardiol Res Pract 2011; 2011:254321.

9 Vlez J, Sandoval N, Cadavid E, Zapata J. Cooperative study of operatory mortality in the correction of congenital cardiopathies in Colombia. Revista Colombiana de Cardiologia 2005; 11:397–400. Cited from: Chodchanok V, Duangmanee L, Kritvikrom D, Prakul Ch, Jarupim S, Paweena Ch, Apichart N, Somchai S, Thawon S, Punnarerk Th, Ungkab P, Jiraporn K, and Julaporn P. Surveillance of Pediatric Cardiac Surgical Outcome Using Risk Stratifications at a Tertiary Care Center in Thailand. Cardiology Research and Practice, Vol. 2011, 9.

10 Larrazabal LA, Jenkins KJ, Gauvreau K, Vida VL, Benavidez O, Gaitán GA, *et al.* Improvement in congenital heart surgery in a developing country: the Guatemalan experience. Circulation 2007; 116:1882–1887.

11 Cavalcante CT, de Souza NMG, Pinto VC Júnior, Branco KM, Pompeu RG, Teles AC, *et al.* Analysis of surgical mortality for congenital heart defects using RACHS-1 risk score in a Brazilian single center. Braz J Cardiovasc Surg 2016; 31:219–225.

12 Joshi S, Anthony G, Manasa D, Ashwini T, Jagadeesh AM, Deepak P. Predicting mortality after congenital heart surgeries: evaluation of the Aristotle and Risk Adjustement in Congenital Heart surgery-1 risk prediction scoring systems: a retrospective single center analysis of 1150 patients. Ann Card Anaesth 2014; 17:266–270.

13 Al-Radi OO, Harrell JrFE, Caldarone CA, McCrindle BW, Jacobs JB, Williams MG, *et al.* Case complexity scores in congenital heart surgery: a comparative study of the Aristotle Basic Complexity score and the Risk Adjustment in Congenital Heart Surgery (RACHS-1) system. J Thorac Cardiovasc Surg 2007; 133:865–875.

14 Boethig D, Jenkins KJ, Hecker H, Thies WR, Breymann T. The RACHS-1 risk categories reflect mortality and length of hospital stay in a large German pediatric cardiac surgery population. Eur J Cardiothorac Surg 2004; 26:12–17.

15 Bojan M, Gerelli S, Gioanni S, Pouard P, Vouhé P. Comparative Study of the Aristotle Comprehensive Complexity and the Risk Adjustment in Congenital Heart Surgery Scores. Ann Thorac Surg 2011; 92:949–956.

16 Erek E. Analysis of results according to the Aristotle scoring system in congenital heart surgery. Turk J Thorac Cardiovasc Surg 2014; 22:509–516.

17 Heinrichs J, Sinzobahamvya N, Arenz C, Kallikourdis A, Photiadis J, Schindler E, *et al.* Surgical management of congenital heart disease: evaluation according to the Aristotle score. Eur J Cardiothorac Surg 2010; 37:210–217.