THE POSTOPERATIVE COMPLICATED COURSE PROBABILITY PREDICTION IN CARDIAC SURGICAL PATIENTS

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Conflict of interest
The authors declare that they have no conflicts of interest

Abstract

Purpose of the study: to model the operative risk in patients with congenital heart defects, acquired valvular heart disease and ischemic heart disease using the stratification scales EuroSCORE and Aristotle Basic Complexity score. *Materials and methods.* 559 patients, who were in inpatient treatment in the period from 2011 to 2019 were examined and underwent surgical correction before the surgery. Among them, 327 (58,5%) patients with various forms of congenital heart defects (CHD), 120 (21,5%) patients with isolated and combined acquired valvular heart disease (VHD) and 112 (20,0%) - with chronic forms of ischemic heart disease (IHD). *Results.* According to the Aristotle Basic Complexity score, the operative risk in patients with CHD averaged 6.6±3.8 points, which corresponded to the 2nd level of complexity. The operative risk according to the Aristotle Basic Complexity score in patients with CHD and complicated postoperative course was 8,35±4,1 points (3,0-17,5), and in patients with a smooth course of the postoperative period – 6,34±3,5 points (3,0-2,5) with statistically significant (p=0,002). EuroSCORE scale logistic parameters's statistical analysis showed that in patients with acquired VHD and a smooth postoperative course, were significantly lower (approximately 3 times) and with a significant difference compared to patients with complicated course: 4,1±3,6% versus 12,9±14,0% (p=0,008). A similar state was observed while analyzing the logistic parameters of the EuroSCORE scale in patients with chronic forms of IHD: 3,6±3,4% and 8,8±10,2%, respectively (p=0,003). *Conclusion:* The operative risk according to the Aristotle Basic Complexity Score in patients with different types of CHD is statistically significantly different in patients with a complicated and smooth postoperative course (p=0,002). The EuroSCORE stratification risk assessment scale presents certain possibilities for predicting the complicated course of the early postoperative period in patients with acquired VHD (p=0,008).

Keywords
operative risk, EuroSCORE-II, Aristotle Basic Complexity score

Кардиохирургиялық науқастардың операциядан кейінгі асқынған ағымының ықтималдығын болжау

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Аңдатпа

Зерттеудің мақсаты - әр түрлі топтардағы жүректің туа біткен ақауы (ЖТБА), жүректің қақпақшалы ауруы (ЖҚА) және жүректің ишемиялық ауруы (ЖИА) бар науқастардың ең ықтимал операциялық қауіпін EuroSCORE және ABC score шкалаларын қолдана отырып модельдеу. *Материал және әдістер.* 2011 жылдан 2019 жылға дейінгі кезеңде А.Н. Сызғанов атындағы ҰҒХО-ң кардиохирургия бөлімшесіне жатқызылған барлығы 559 науқас операция алдында тексерілді және олар оталық ем қабылдады. Олардың ішінде ЖТБА-ң әр түрлі формалары бар 327 (58,5%) науқас, жекеленген және қосарланған ЖҚА-мен 120 (21,5%) науқас және ЖИА-ң созылмалы түрлерімен 112 (20,0%) науқас болды. *Нәтижелер.* ABC score бойынша ЖТБА-ы бар науқастардың операциялық қауіпі орта есеппен 6,6±3,8 баллды құрады, бұл екінші күрделілік деңгейіне сәйкес келді. Бұл жағдайда максималды мән 21,5-ке жетті, ал минималды мән 3,0 баллды құрады. ЖТБА-ы бар және операциядан кейінгі асқынған ағымы бар науқастарда ABC score ұпайына сәйкес операциялық қауіп 8,35±4,1 баллды (3,0-17,5) құраса, ал операциядан кейінгі кезеңнің асқынбаған ағымы бар науқастарда статистикалық маңызды айырмашылықпен (p=0,002) 6,34±3,5 баллды (3,0-2,5) құрады. EuroSCORE шкаласының логистикалық көрсеткіштерінің статистикалық талдауы көрсеткендей, ЖҚА-ы және операциядан кейінгі асқынбаған ағымы бар науқастарда олар едәуір төмен және ағымы асқынған науқастармен салыстырғанда айтарлықтай айырмашылық көрсетті: 4,1±3,6% қарсы 12,9±14,0% (p=0,008). Осыған ұқсас жағдай созылмалы ЖИА-ы бар науқастардың EuroSCORE шкаласының логистикалық көрсеткіштерін талдау барысында байқалды: сәйкесінше 8,8±10,2% қарсы 3,6±3,4% (p=0,003). *Қорытынды.* Әр түрлі ЖТБА-ы бар науқастарда ABC score көрсеткіші бойынша операциялық қауіп операциядан кейінгі асқынған және асқынбаған кезеңдері статистикалық тұрғыдан айтарлықтай ерекшеленді (p=0,002). Қауіпті бағалауға арналған EuroSCORE стратификациялық шкаласы ЖҚА-ы бар науқастардың операциядан кейінгі ерте кезеңнің асқынған ағымын болжаудың белгілі бір мүмкіндіктерін ұсынады (p=0,008).

Түйін сөздер
операциялық қауіп, EuroSCORE-II, Aristotle Basic Complexity score

Прогнозирование вероятности осложненного послеоперационного течения у пациентов кардиохирургического профиля

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Аннотация

Цель исследования *- используя EuroSCORE и ABC score смоделировать наиболее вероятные операционные риски у пациентов в различных группах: с врожденными пороками сердца, приобретенными клапанными пороками сердца и ишемической болезнью сердца.* ***Материал и методы.*** *Перед хирургической операцией было обследовано и подвергнуто оперативной коррекции всего 559 пациентов, находившихся на стационарном лечении в отделении кардиохирургии ННЦХ им. А.Н. Сызганова в период с 2011 по 2019 год, из них 327 (58,5%) пациентов с различными формами ВПС, 120 (21,5%) пациентов с изолированными и комбинированными ППС и 112 (20,0%) – с хроническими формами ИБС.* ***Результаты.*** *По шкале ABC score операционный риск у пациентов с ВПС в среднем составил 6,6±3,8 балла, что соответствовало 2-му уровню сложности. При этом максимальное значение достигало 21,5, а минимальное значение составляло 3,0 балла. Операционный риск по шкале ABC score у пациентов с ВПС и осложненным послеоперационным течением составил 8,35±4,1 балла (3,0–17,5), а у пациентов с гладким течением послеоперационного периода – 6,34±3,5 балла (3,0–21,5) при статистически достоверном различии (р=0,002). Статистический анализ логистических показателей шкалы EuroSCORE показал, что у пациентов с ППС и гладким послеоперационным течением они были значительно ниже и с достоверным различием по сравнению с пациентами, имевшими осложненное течение: 4,1±3,6% против 12,9±14,0% (р=0,008). Похожее положение дел прослеживалось и при анализе логистических показателей шкалы EuroSCORE у пациентов с хроническими формами ИБС: 3,6±3,4% против 8,8±10,2% соответственно (р=0,003).* ***Заключение.*** *Операционный риск по шкале ABC score у пациентов с различными видами ВПС статистически достоверно отличается у пациентов с осложненным и гладким послеоперационными течениями (р=0,002). Стратификационная шкала оценки риска EuroSCORE представляет определенные возможности при прогнозировании осложненного течения раннего послеоперационного периода у пациентов с приобретенными клапанными пороками сердца (р=0,008).*

Introduction

As a general rule, assessing the risks associated with cardiac surgery, considers factors such as compensation, comorbidity, age, complexity of anatomy, time of artificial circulation, time of aortic clamping, depth of hypothermia, methods of protection of ischemic myocardium, experience of the surgeon, category of complexity of surgical interventions, equipment of the clinic and others [1-4]. In this regard, it is obvious that cardiac surgeons need to use one or more unified operative risk assessment scales in order to have more information about the frequency and nature of possible complications in the early postoperative period. However, as experience shows, in most cases there is an underestimation of the prognostic capabilities of stratification systems, which, among other things, can lead to an undesirable outcome of the disease with an adequate method of treatment [1-4].

The aim of the study is to stratify and model the most probable operative risks in patients in different groups: with congenital heart defects, acquired valvular heart disease and coronary heart disease using EuroSCORE and Aristotle Basic Complexity score.

Material and methods

559 patients, who were in inpatient treatment at A.N. Syzganov NSCS's department of Cardiac Surgery in the period from 2011 to 2019 were examined and underwent surgical correction before the surgery, 327 (58.5%) patients with various forms of congenital heart disease (CHD), 120 (21.5%) patients with isolated and combined acquired valvular heart disease (VHD) and 112 (20.0%) – with ischemic heart disease (IHD). General characteristics of patients are demonstrated in Table 1.

The mean age of patients with CHD at the time of surgery was 19.6±14.8 years. The youngest of the patients was 3 months old and the oldest was 67. Females predominated among the patients (60.9%). These were mainly patients with various types of septal defects, less often - with tetralogy of Fallot, supra- and intracardiac forms of partial abnormal drainage of pulmonary veins, incomplete and complete balanced forms of atrioventricular septal defect, rupture of aneurysm of the Valsalva sinus and other obstructive defects and malformations at the level of valves parts of the ventricles.

The average age of patients with acquired VHD at the time of surgery was 48.8±14.3 years. The average age of patients under 40 was 27.3±9.5, over 40 years old - 55.4±7.4. The youngest patient was 10 years old and the oldest 72. Among the patients, males predominated slightly (52.5%). In most cases, plastic and/or prosthetics of the mitral and/or aortic valves were performed in combination with

Table 1.
General characteristics of
patients

Characteristic	CHD	VHD	IHD	p		
	1	2	3	1-2	2-3	1-3
Quantity, abs.,%	327 (58,5)	120 (21,5)	112 (20,0)	-	-	-
Mean age, years	19,6±14,8	48,8±14,3	60,8±8,5	<0,05	<0,05	<0,05
Male, abs.,%	128 (39,1)	63 (52,5)	100 (89,3)	-	-	-
Female, abs.,%	199 (60,9)	57 (47,5)	12 (10,7)	-	-	-
Asian race, abs.,%	295 (90,2)	103 (85,8)	74 (66,1)	-	-	-
European race, abs.,%	32 (9,8)	17 (14,2)	38 (33,9)	-	-	-
LV EF, %	68,8±7,2	61,0±11,8	52,7±14,2	<0,05	>0,05	<0,05
Average time of AC, min	123,4±79,2	154,2±59,5	138,3±63,3	>0,05	>0,05	>0,05
Average time of aortic compression, min	75,9±48,8	111,4±43,7	84,0±42,4	<0,05	<0,05	>0,05
PCCP, %	52,8	86,0	25,8	-	-	-
Blood cardioplegia, %	47,2	14,0	74,2	-	-	-
Resternotomy, %	2,4	9,2	5,4	-	-	-

Note: EF – ejection fraction; PCCP – pharmaco-cold cardioplegia

suture annuloplasty or tricuspid valve prosthetics or without them, including in a minimally invasive way. In several cases, Kawazoe atrioplasty, radio-frequency ablation (RFA), and thrombectomy from the left atrium and left atrial appendage with ligation of the appendage or suturing of the latter from the inside were performed additionally.

The mean age of patients with IHD at the time of surgery was 60.8±8.5. The youngest patient was 35 years old and the oldest 82. Among the patients, males predominated (89.3%). In most cases, the "gold standard" coronary artery bypass grafting in the form of mammary-coronary anastomosis in combination with autovenous bypass, autovenous coronary bypass, beating coronary artery bypass grafting and minimally invasive approach (MIDCAB) was used. Less commonly, coronary artery bypass grafting was combined with left ventricular remodeling according to Dore's or Cooley's techniques and thrombectomy, RFA, as well as with radical correction of concomitant CHD.

To stratify the operative risk, such scales as EuroSCORE - for patients with acquired valvular heart disease and coronary artery disease, and Aristotle Basic Complexity score - for patients with various types of CHD were used.

Data processing, including statistical data, was carried out using Windows applications (Access, Excel), as well as Statistica 5.5 and programs for calculating stratification scale indicators (euroscore.org; aristotleinstitute.org). Mean values are presented with standard deviation (M ± m). The differences between the mean values were considered significant at p<0.05. Normality criteria were determined by Kolmogorov-Smirnov and Shapiro-Wilk.

Aristotle score

A group of 50 surgeons from 23 countries, representatives of the four largest international societies of pediatric cardiac surgery (STS, EACTS, Congenital Heart Surgeons Society - CHSS and ECHSA), concluded that the complexity of surgical intervention consists of three factors: the possibility of surgical mortality, the possibility of surgery interventions and surgery technical complexity [1-6].

Each surgery received a score for each of the three factors ranging from 0.5 to 5, forming a score ranging from 1.5 (0.5 + 0.5 + 0.5) to 15 (5 + 5 + 5). Surgical interventions were divided into categories (similar to RACHS-1) by points: 1stlevel (from 1.5 to 5.9), 2ndlevel (from 6.0 to 7.9), 3rdlevel (8.0 to 9.9) and 4thlevel (10.0 to 15.0).

EuroSCORE scale (EuroSCORE-II)

The European System for Cardiac Operative Risk Evaluation (EuroSCORE) is a cardiac risk model for predicting mortality after cardiac surgery. The scale was published in 1999 and is based on an international European database of patients undergoing cardiac surgery by the end of 1995 [24-29].

EuroSCORE-II, was first proposed at the annual conference of the European Association of Cardiothoracic Surgeons (EACTS) in Lisbon in 2011 [7]. Unlike the previous version, EuroSCORE-II allows stratification of operative risk, including by the following factors: insulin-dependent diabetes mellitus; 1-, 2-, 3-, 4th functional class (FC) according to NYHA; angina pectoris of the 4th FC according to CCS; left ventricular function, including left ventricular ejection fraction (EF) <20%; pulmonary hypertension, including the mean pressure in the pulmonary artery of 31–55 mm Hg; volume of surgery: isolated coronary artery bypass grafting, one procedure without coronary artery bypass grafting, two or three procedures [7].

Results

According to the Aristotle Basic Complexity score, the operative risk in patients with CHD av-

Group	Variables	Normality criterion					
		Kolmogorov-Smirnov			Shapiro-Wilk		
		Statistics	degree of freedom	P	Statistics	degree of freedom	P
CHD	smooth	.234	187	.000	.823	187	.000
	complicated	.162	45	.005	.936	45	.015
VHD	smooth	.247	32	.000	.699	32	.000
	complicated	.256	17	.004	.785	17	.001
IHD	smooth	.212	45	.000	.652	45	.000
	complicated	.314	14	.001	.662	14	.000

Table 2
Criteria for normality according to Kolmogorov-Smirnov and Shapiro-Wilk

Group	Variables	N	Average	Standard deviation	Median	Interquartile range	P
CHD	smooth	187	6.34	3.535	6.00	4	0,002
	complicated	45	8.35	4.079	8.00	6	
VHD	smooth	32	4.09	3.577	3.19	3	0,008
	complicated	17	12.85	13.928	7.71	15	
IHD	smooth	45	3.57	3.359	2.54	3	0,003
	complicated	14	8.82	10.172	5.56	6	

Table 3
Indicators of operational risk in patients with CHD, VHD and IHD, depending on the course of the early half-operational period

eraged 6.6±3.8 points, which corresponded to the 2nd level of complexity. In this case, the maximum value reached 21.5, and the minimum value was 3.0 points. The operative risk according to the Aristotle Basic Complexity score in patients with CHD and complicated postoperative course was 8.35±4.1 points (3.0-17.5), and in patients with a smooth course of the postoperative period - 6.34±3.5 points (3.0–21.5) with a statistically significant difference (p=0.002).

Since the distribution of all variables is not normal according to the Kolmogorov-Smirnov and Shapiro-Wilk criteria, the Median and interquartile range were also used for comparative assessment.

EuroSCORE scale logistic parameters's statistical analysis showed that in patients with VHD and smooth postoperative course, were significantly lower and with a significant difference compared with patients with complicated course: 4.1±3.6% versus 12.9±14.0 % (p=0.008) (Table 3).

A similar state was observed while analyzing the EuroSCORE scale logistic parameters in patients with chronic forms of IHD: 3.6±3.4% versus 8.8±10.2%, respectively (p=0.003) (Table 3).

According to the obtained results, a rather significant difference in the EuroSCORE scale logistic parameters can be noted in patients with VHD with complicated and smooth postoperative course. And in patients with coronary artery disease with complicated and smooth postoperative course, the difference in indicators was not so significant, although it was more than 2 times higher. As a result of the statistical analysis of the EuroSCORE logistic

indicators in patients with acquired valvular pathology, the following data were obtained: in patients under the age of 40, regardless of the course of the early postoperative period, the indicators were 3.5±2.2%, and in patients over the age of 40 - 8.4±5.1% (p=0.397).

Statistically significant differences were found for all indicators, the Mann-Whitney test. The above data are presented more clearly in the diagrams (Fig. 1, 2, 3).

Discussion

There are numerous works devoted to risk stratification in cardiac surgery using various scalesas Aristotle Basic Complexity score, Aristotle Comprehensive Complexity score, EuroSCORE, EuroSCORE-II, GRACE, Mass-DAC Mortality Risk, PCI Risk score, Risk Adjustment for Congenital Heart Surgery - 1, STS score, STS-EACTS Mortality
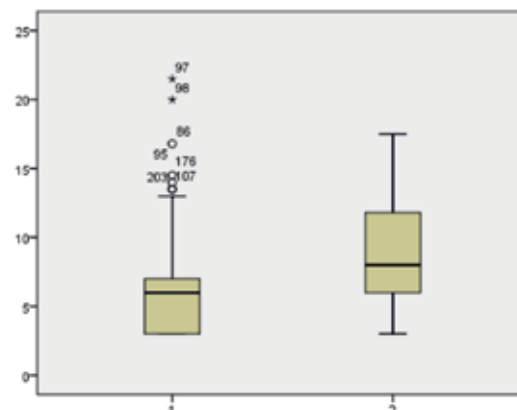

Figure 1
Risk stratification in patients with CHD: 1 - smooth, 2 - complicated course (p = 0.002)

Figure 2
Risk stratification in patients with VHD:
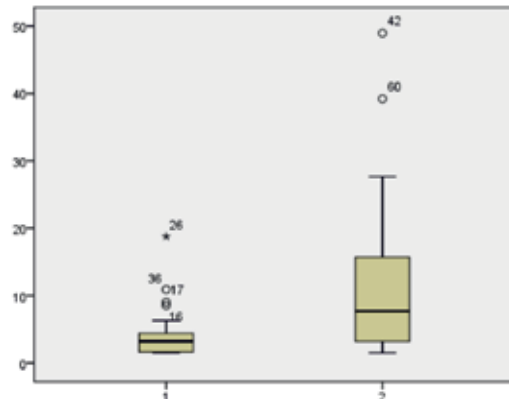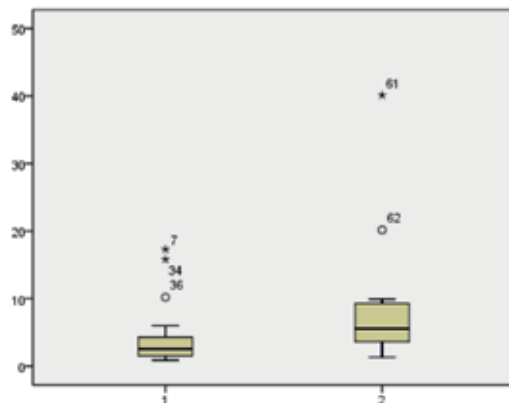1 - smooth, 2 - complicated course (p = 0.008)

Figure 3
Risk stratification in patients with IHD:
1 - smooth, 2 - complicated course (p = 0.003)

score, CRUSADE, SYNTAX score and many others. The predictive value of these scales is known and proven in patients with a large number of cases. The most popular in clinical practice among these stratification scales are EuroSCORE, EuroSCORE-II and SYNTAX score in patients with CAD and VHD, as well as Aristotle Basic Complexity score, RACHS-1, STS-EACTS Mortality score in patients with CHD [1-6, 8-29].

Taking into account obtained data, in order to ensure the most favorable conditions for surgery and the course of the hospital period in patients with high and significantly high operative risks, it is necessary: to attract additional safety technologies and other auxiliary methods of blood circulation; if necessary, divide operations into stages; if possible, use hybrid operations using modern endovascular technologies; refuse any surgical intervention due to an unreasonably high risk of mortality.

Conclusion

Operative risk according to the Aristotle Basic Complexity Score in patients with different types of CHD is statistically significantly different in patients with complicated and smooth postoperative course (p = 0.002).

The EuroSCORE stratification scale for risk assessment presents certain possibilities for predicting the complicated course of the early postoperative period in patients with acquired VHD (p = 0.008).

With high and significantly high operative risks according to the EuroSCORE (p = 0.008, p = 0.003) and Aristotle Basic Complexity Score (p = 0.002) scales, it is necessary to take into account the possible correction of the type, combination, sequence and volume of surgical correction.

References

1. Sagatov I.Y. Modeling of the operational risk in patients with congenital heart diseases. Cardiology. 2015. Vol. 131 (suppl. 1). P. 29-30.
2. Cavalcanti P.E., Santos C.A., Esmeraldo I.M., Chaves M.L., Lins R.F., Lima Rde C. Stratification of complexity in congenital heart surgery: comparative study of the Risk Adjustment for Congenital Heart Surgery (RACHS-1) method, Aristotle basic score and Society of Thoracic Surgeons-European Association for Cardio-Thoracic Surgery (STS-EACTS) mortality score. Rev Bras Cir Cardiovasc. 2015. Mar-Apr. Vol. 30 (2). P. 148-158.
3. Lacour-Gayet F., Clarke D., Jacobs J. et al. The Aristotle score for congenital heart surgery. SeminThorac Cardiovasc Surg Pediatr Card Surg Annu. 2004. № 7. P. 185-191.
4. Poullis M., Pullan M., Chalmers J., Mediratta N. The validity of the original EuroSCORE and EuroSCORE II in patients over the age of seventy. Interact Cardiovasc Thorac Surg. 2015. Feb. Vol. 20 (2). P. 172-177.
5. Sabuncu T., Demircin M., Dogan R., Y. Imaz M., Aypar U., Pa aoglu I. Comparison of risk scoring systems in congenital heart surgery. Turk J Pediatr. 2016. Vol. 58 (5). P. 512-517.
6. Wang T.K., Harmos S., Gamble G.D., Ramanathan T., Ruygrok P.N. Performance of contemporary surgical risk scores for mitral valve surgery. J Card Surg. 2017. Mar. Vol. 32 (3). P. 172-176.
7. The manuscript which supports the new model is being submitted for publication. The new model has been validated by the EuroSCORE Project Group and awaits validation by users worldwide. It was presented at EACTS in Lisbon on 3rd. 2011. Oct.
8. Khairy P, Ionescu-Ittu R, Mackie AS, Abrahamowicz M, Pilote L, Marelli AJ. Changing mortality in congenital heart disease. J Am Coll Cardiol. 2010;56(14):1149–1157.
9. Lacour-Gayet F, Clarke D, Jacobs J, Comas J, Daebritz S, Daenen W, Aristotle Committee et al. The Aristotle score: a complexity-adjusted method to evaluate surgical results. Eur J Cardiothorac Surg. 2004;25(6):911–924. 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(5):1139–1153.
10. Jacobs JP, Edwards FH. Quality improvement and risk stratification for congenital cardiac surgery. In:

Sellke FW, Del Nido PJ, Swanson SJ, editors. Sabiston and Spencer Surgery of the chest. 8th ed. Philadelphia: Elsevier Publishing; 2010. pp. 2105–2123.

11. Jacobs JP, Jacobs ML, Lacour-Gayet FG, Jenkins KJ, Gauvreau K, Bacha E, et al. Stratification of complexity improves the utility and accuracy of outcomes analysis in a Multi-Institutional Congenital Heart Surgery Database: Application of the Risk Adjustment in Congenital Heart Surgery (RACHS-1) and Aristotle Systems in the Society of Thoracic Surgeons (STS) Congenital Heart Surgery Database. Pediatr Cardiol. 2009;30(8):1117–1130.

12. Jacobs JP, Jacobs ML, Austin EH, 3rd, Mavroudis C, Pasquali SK, Lacour-Gayet FG, et al. Quality measures for congenital and pediatric cardiac surgery. World J Pediatr Congenit Heart Surg. 2012;3(1):32–47.

13. Kogon B, Oster M. Assessing surgical risk for adults with congenital heart disease: are pediatric scoring systems appropriate? J Thorac Cardiovasc Surg. 2014;147(2):666–671.

14. Bojan M, Gerelli S, Gioanni S, Pouard P, Vouhй P. Comparative study of the Aristotle Comprehensive Complexity and the Risk Adjustment in Congenital Heart Surgery scores. Ann Thorac Surg. 2011;92(3):949–956.

15. 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(1):210–217.

16. Vijarnsorn C, Laohaprasitiporn D, Durongpisitkul K, Chantong P, Soongswang J, Cheungsomprasong P, et al. Surveillance of pediatric cardiac surgical outcome using risk stratifications at a tertiary care center in Thailand. Cardiol Res Pract. 2011

17. Jacobs JP, Jacobs ML, Austin EH, 3rd, Mavroudis C, Pasquali SK, Lacour-Gayet FG, et al. Quality measures for congenital and pediatric cardiac surgery. World J Pediatr Congenit Heart Surg. 2012;3(1):32–47.

18. Mattos SS, Neves JR, Costa MC, Hatem TP, Luna CF. An index for evaluating results in paediatric cardiac intensive care. Cardiol Young. 2006;16(4):369–377.

19. 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 multi-institutional registry. Pediatr Cardiol. 2013;34(5):1226–1236.

20. Pasquali SK, Li JS, Burstein DS, Sheng S, O'Brien SM, Jacobs ML, et al. Association of center volume with mortality and complications in pediatric heart surgery. Pediatrics. 2012;129(2):e370–e376.

21. 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(5):1133–1140.

22. Welke KF, Karamlou T, Ungerleider RM, Diggs BS. Mortality rate is not a valid indicator of quality differences between pediatric cardiac surgical programs. Ann Thorac Surg. 2010;89(1):139–144.

23. Pasquali SK, He X, Jacobs JP, Jacobs ML, O'Brien SM, Gaynor JW. Evaluation of failure to rescue as a quality metric in pediatric heart surgery: an analysis of the STS Congenital Heart Surgery Database. Ann Thorac Surg. 2012;94(2):573–579.

24. Nashef SA, Roques F, Michel P, Gauducheau E, Lemeshow S, Salamon R. European system for cardiac operative risk evaluation (EuroSCORE). Eur J Cardiothorac Surg. 1999 Jul;16(1):9-13.

25. Roques F, Michel P, Goldstone AR, Nashef SA. The logistic EuroSCORE. Eur Heart J. 2003 May;24(9):882-3

26. Nashef SA, Roques F, Hammill BG, Peterson ED, Michel P, Grover FL, Wyse RK, Ferguson TB. Validation of European System for Cardiac Operative Risk Evaluation (EuroSCORE) in North American cardiac surgery. Eur J Cardiothorac Surg. 2002 Jul;22(1):101-5.

27. Roques F, Nashef SA, Michel P, Gauducheau E, de Vincentiis C, Baudet E, Cortina J, David M, Faichney A, Gabrielle F, Gams E, Harjula A, Jones MT, Pintor PP, Salamon R, Thulin L. Risk factors and outcome in European cardiac surgery: analysis of the EuroSCORE multinational database of 19030 patients. Eur J Cardiothorac Surg. 1999 Jun;15(6):816-22; discussion 822-3.

28. Sergeant P, de Worm E, Meyns B. Single centre, single domain validation of the EuroSCORE on a consecutive sample of primary and repeat CABG. Eur J Cardiothorac Surg 2001 Dec;20(6):1176-82

29. Sagatov I.Y., Medeubekov U.S. Dynamics of urine neutrophil gelatinase-associated lipocalin in cardiac surgery patients in the near term after surgery. Chirurgia 2019 April;32(2):59-61. DOI: 10.23736/S0394-9508.18.04797-6