
The Aristotle Complexity Score: A Tool to Evaluate Performance in Congenital Heart Surgery

27

Francois Lacour-Gayet

Abstract

The Aristotle Score is a complexity stratification system that was based initially on expert opinion, in absence of sufficient objective data from databases. Because the scoring system was derived from opinions, we gave the name of Aristotle to this project.

The Aristotle Score follows several rules and principles:

- The Aristotle Score measures the complexity of surgical procedures. The Aristotle Score was designed to evaluate performance and not directly to predict mortality.
- The complexity of a surgical procedure is a constant and is calculated with the following equation:

$$\text{Complexity} = \text{Potential for Mortality} + \text{Potential for Morbidity} + \text{Technical Difficulty}$$

- The calculated complexity includes both the *Aristotle Basic Complexity Score* (ABC Score) and the *Aristotle Comprehensive Complexity Score* (ACC Score).
- Performance is calculated with the following equation:

$$\text{Performance} = \text{Outcome} \times \text{Complexity}$$

- Several performances can be calculated by combining complexity with various outcomes.

Two steps are defined:

1. The *Aristotle Basic Complexity Score* (ABC Score) is calculated on 15 points and is determined from the primary procedure of any operation

F. Lacour-Gayet, MD
Pediatric Cardiac Surgery, Royal Brompton Hospital,
Sydney Street, London SW3 6NP, UK
e-mail: f.lacour-gayet@rbht.nhs.uk

2. The *Aristotle Comprehensive Complexity Score (ACC Score)* is calculated on 25 points: The Aristotle Comprehensive Complexity Score equals the Aristotle Basic Complexity Score plus 5 points for *Procedure-dependent Factors* and 5 points for *Procedure-independent Factors*.

The *Aristotle Basic Complexity Score* was introduced in the Congenital Heart Surgery Database of The Society of Thoracic Surgeons (STS) and The European Association for Cardio-Thoracic Surgery (EACTS) in 2002 and has been instrumental for the success of these congenital databases. The *Aristotle Basic Complexity Score* was validated with a C-Index for mortality and morbidity of 0.70 and 0.67 respectively. The *Aristotle Comprehensive Complexity Score* (www.aristotleinstitute.org) is used by many individual institutions with a C-Index of 0.860 to predict mortality.

In the future, the next version of the Aristotle Score, named Aristotle 2, will be based on objective data provided by the new STAT Mortality Score and STAT Morbidity Score and will include an updated technical difficulty index re-calculated based on expert opinion. New basic performances for mortality, morbidity and technical difficulty will be proposed. The *Aristotle Comprehensive Complexity Score* will be updated and simplified and involve only around 70 procedures, including procedures performed on adults with congenital heart disease. New comprehensive performances will be proposed. The Aristotle 2 score will be ready in 2015. Once validated, it should provide a fair assessment for evaluation of performances in congenital heart surgery. Furthermore, the Aristotle Score is responsible for multiple important contributions leading to the development of newer tools to evaluate cardiac surgical performance.

Keywords

Complexity • Congenital Heart Surgery • Quality of care • Performance • Aristotle Score • Aristotle Basic Complexity Score (ABC Score) • Aristotle Comprehensive Complexity Score (ACC Score)

According to Aristotle's philosophy (Rhetoric, Book I, 350 BC):

When there is no scientific answer available, the opinion (Doxa) perceived and admitted by the majority has value of truth.

Introduction

Evaluation of quality of care in congenital cardiac surgery is challenging. Compared to adult cardiac surgery, congenital cardiac surgery covers a smaller pediatric population and deals with many times more different diagnoses and procedures.

This challenge explains the delay needed in our specialty to establish professional databases in the United States of America and in Europe.

The take-off of the Congenital Heart Surgery Database of The Society of Thoracic Surgeons (STS) and The European Association for Cardio-Thoracic Surgery (EACTS) occurred following the creation of the International Congenital Heart Surgery Nomenclature and Database Project led by Constantine Mavroudis, MD and Jeffrey P. Jacobs, MD and published on The Annals of Thoracic Surgery in 2000 [1]. The other obstacle was that outcome was only based on hospital

mortality without any risk stratification or adjustment for case-mix. As a consequence, the prominent centers dealing with the most complex cases and having a greater mortality were very reluctant to send their data. The creation of the Aristotle Score [2–6], based on the International Congenital Heart Surgery Nomenclature and Database Project, contributed to the full growth of the STS and EACTS Congenital Heart Surgery Databases [7].

The Aristotle Complexity Score project started in 2002, [2] and was published in 2004 [3, 6]. The objective of the Aristotle Score is to measure performance and to allow fair and meaningful comparison between centers and surgeons. The Aristotle Score is not specifically designed to predict mortality.

This chapter will focus on the role of the Aristotle Score in evaluating performance:

- First, this chapter will describe what was accomplished in the last decade with the Aristotle Score and the STS and EACTS Congenital Heart Surgery Databases.
- Second, this chapter will present the plans for the development of the next generation of the Aristotle Score.
- Third, this chapter will present the evolution of the Aristotle Score and its contributions towards the development of newer tools to evaluate cardiac surgical performance.

Current Aristotle Score

Definition of Performance

Performance in congenital cardiac surgery is a “proteiform” concept. The outcomes of surgery depends, in most cases, not solely on the surgeon but mainly on the performance of the entire team [8]:

- the pediatric cardiologist who insure an accurate diagnosis,
- the operative team including the surgeon and also the anesthetist and the perfusionist and
- the team in the intensive care unit.

We believe that several performances should be studied and analyzed separately, depending on the outcome considered. Since the inception of analysis of outcomes of pediatric and congen-

Table 27.1 Six performances can be defined according to outcomes

Outcome	Performance
Mortality	Safety
Morbidity	Efficiency
Technical difficulty	Proficiency
Long-term results	Quality
Patient satisfaction	Reputation
Cost	Economical performance

The Aristotle Score focuses only on the first three performances: safety, efficiency and proficiency. The other three are equally important

ital cardiac care, quality has been essentially measured based on operative mortality. Although assessment of mortality is essential, it is insufficient as it involves only around 4 % of the patients and therefore 96 % are excluded from the assessment. Instead of a assessing the unique and singular performance of mortality, the Aristotle Score is trying to evaluate all the aspect of congenital cardiac surgery, as shown in Table 27.1.

The Aristotle Score has focused on the first three performances documented in Table 27.1, based on mortality, morbidity and technical difficulty. Long term results, patient satisfaction and hospital cost are equally important but are not included in the Aristotle Score.

The Concept of Complexity

The Aristotle score propose a new and original approach to evaluate quality based on complexity. It is important to consider that complexity is different from risk [2–6]. The risk of mortality and morbidity of a Norwood operation is less in a large center with optimal experience and greater in a small center still confronted to a learning curve.

- *Risk is a variable factor and varies from center to center and even from surgeon to surgeon*
- *Complexity is designed to be a constant. Complexity is a calculated value based on the following algorithm that is evaluated for each procedure:*

$$\begin{aligned} \text{Complexity} = & \text{Potential for Mortality} \\ & + \text{Potential for Morbidity} \\ & + \text{Technical Difficulty} \end{aligned}$$

Initially [3], the potentials for mortality and morbidity were calculated by expert opinion and were subjective. Recently, the methodology for determining the first two factors, potential for mortality and potential for morbidity, has transitioned from subjective probability (expert opinion) to determination based on raw data from databases, and is therefore objective. The methodology to estimate the third factor, technical difficulty, remains subjective, but might approach more objectivity in the future in using the Technical Performance Score developed in Boston under the leadership of Emile Bacha [9–12].

The calculation of complexity using the Aristotle Score is done in *two steps*.

- The first step gives the **Aristotle Basic Complexity Score (ABC Score)** (Fig. 27.1). The **Aristotle Basic Complexity Score** is a simplified score that is calculated on 15 points and is determined from the primary procedure of any operation. The Aristotle Basic Complexity Score was ultimately also divided in four levels of complexity. The Aristotle Basic Complexity Score can be analyzed
- The second step is the **Aristotle Comprehensive Complexity Score (ACC Score)** (Fig. 27.1) that increases the potential for mortality, the potential for morbidity, and technical difficulty by adding procedure dependent factors and procedure independent factors. The Aristotle Comprehensive Complexity Score is calculated on 25 points: The Aristotle Comprehensive Complexity

using these four categories, which are known as the **Aristotle Basic Complexity Levels**. The **Aristotle Basic Complexity Score** and the **Aristotle Basic Complexity Levels** were introduced in the Congenital Heart Surgery Database of The Society of Thoracic Surgeons (STS) and The European Association for Cardio-Thoracic Surgery (EACTS) in 2002 and have been instrumental for the success of these congenital databases. The accuracy of the **Aristotle Basic Complexity Score** and the **Aristotle Basic Complexity Levels** are limited because of wide variations in complexity within a given procedure such as the Norwood (Stage 1) operation.

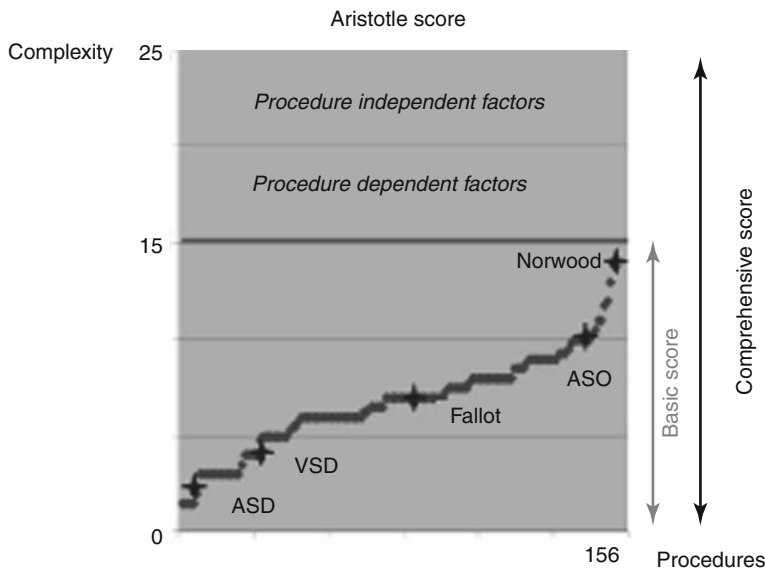


Fig. 27.1 Aristotle Score. The Aristotle Basic Complexity Score is calculated on 15 points and is determined from the primary procedure of any operation. The Aristotle Comprehensive Complexity Score equals the Aristotle Basic

Complexity Score plus 5 points for Procedure-dependent Factors and 5 points for Procedure-independent Factors. Therefore, the Aristotle Comprehensive Complexity Score is calculated on 25 points (www.thearistotleinstitute.org)

Score equals the Aristotle Basic Complexity Score plus 5 points for **Procedure-dependent Factors** and 5 points for **Procedure-independent Factors**. Procedure-dependent factors include anatomical factors, associated procedures, and age at procedure, and procedure independent factors include general factors, clinical factors, extracardiac factors, and surgical factors. Each factor is scored for contribution to mortality, morbidity, and technical difficulty. All complexity factors meet the following requirements: precisely quantifiable, easily available, admitted by a majority, and verifiable. These additional complexity factors (procedure dependent factors and procedure independent factors) are based on subjective opinions and will remain so for several years until the databases produce an accurate risk-stratification for each procedure. The *Aristotle Comprehensive Complexity Score* is available on the Aristotle website: [www.thearistotleinstitute.org]. The *Aristotle Comprehensive Complexity Score* has not been used so far in the STS Congenital Heart Surgery Database and the EACTS Congenital Heart Surgery Database. Multiple individual institutional studies have documented the utility of the *Aristotle Comprehensive Complexity Score* [13, 14] (see below in validation). Perhaps the most important multi-institutional contribution of the *Aristotle Comprehensive Complexity Score* to date has been that its components have been incorporated into the STS Congenital Heart Surgery Database and the EACTS Congenital Heart Surgery Database and have been used to inform the upgrade of these databases.

It is obvious that a relationship exists between complexity, outcome, and performance. We have proposed a simple equation to measure performance:

$$\text{Performance} = \text{Complexity} \times \text{Survival}$$

To summarize, there are five principles behind the complexity concept:

1. *The Aristotle Score is a tool to evaluate performance and not directly to predict mortality*
2. *Complexity is a constant*
3. *Complexity = Sum of Potential for Mortality + Potential for Morbidity + Technical Difficulty*
4. *The true calculated complexity includes both the Aristotle Basic Complexity Score and the Aristotle Comprehensive Complexity Score*
5. *Performance = Complexity $\times$ Outcome*

Why Technical Difficulty?

In sports, the concept of complexity is widely used. The complexity of ski slopes is defined by colors. In gymnastics [15], diving, and figure skating, the activities attempted by the athletes are ranked according to a complexity score established by the judges. An athlete performing a low complex activity cannot obtain the maximum score.

Two main reasons support the inclusion of technical difficulty in the evaluation of performance:

First, it has been quite a surprise to observe on raw data from the STS Congenital Heart Surgery Database and the EACTS Congenital Heart Surgery Database that several complex procedures were performed with extremely low mortality, such as the arterial switch for transposition of the great arteries with intact ventricular septum and the Ross procedure [16]. Within a system of risk stratification that is exclusively based today on mortality, these procedures are considered as average difficulty. The reality however, is that most of those complex procedures are only performed by senior experienced surgeons. The addition of the component of technical difficulty allows one to evaluate the complexity fairly, and therefore evaluate the performance of the surgeon fairly.

Furthermore, the technical difficulty of a given procedure is not constant. An arterial switch

operation in a patient with an intramural coronary artery is more challenging than with in a patient with the usual pattern of coronary arteries. The technical difficulty in the *Aristotle Comprehensive Complexity Score* integrates these anatomical variations and provides more a fair assessment.

The second reason supporting the inclusion of technical difficulty in the evaluation of performance is that the current evaluation of quality is able to say “If we do things right” but is unable to say “If we do the right things”. For example, the ongoing controversy involving the management of patients with hypoplastic left heart syndrome involves uncertainty as to whether the Norwood (Stage 1) Operation is the best option for all patients or whether some patients will benefit from a less complex operation: the Hybrid Stage One. Many other examples exist where some surgeons prefer to choose a simple procedure, which may not be optimal for the long term results: Fontan versus repair of complex intracardiac repair for patients with complex double outlet right ventricle with remote ventricular septal defect, and even or mitral valve replacement versus mitral valve repair. We advocate that surgeons should perform the “right” operation, even if this operation is more demanding.

Methodology of the Aristotle Score

Methodology of the Aristotle Basic Complexity Score and Aristotle Basic Complexity Level

The Aristotle methodology to facilitate complexity adjustment is based upon the work of the Aristotle Committee. Starting in 2002, the STS Congenital Heart Surgery Database and the EACTS Congenital Heart Surgery Database incorporated the Aristotle Basic Complexity Score and Aristotle Basic Complexity Level in their analysis of discharge mortality analyses [17]. These complexity scores and levels can be reported by year, center, age group, and procedure. The complexity analysis

represents a basic complexity adjustment method to evaluate surgical results (Complexity is a constant precise value for a given patient at a given point in time; performance varies between centers and surgeons. In other words, in the same exact patient with the same exact pathology, complexity is a constant precise value for that given patient at a given point in time. The risk for that patient will vary between centers and surgeons because performance varies between centers and surgeons.).

The Aristotle complexity scoring was based on the primary procedure of a given operation as defined by the short list of procedures of the EACTS-STS International Nomenclature [1] and was evaluated in two steps. The first step was the Aristotle Basic Complexity Score, defining, basically, the complexity through three factors: the potential for mortality, the potential for morbidity, and the technical difficulty of the operation, using a questionnaire filled out by 50 surgeons representing international centers. Only the Aristotle Basic Complexity Score (1.5–15) and Aristotle Basic Complexity Level (four levels: 1–4) are used in the STS Congenital Heart Surgery Database and the EACTS Congenital Heart Surgery Database (Appendix 1).

The Aristotle Basic Complexity Score is created from a survey of all 50 of the Aristotle project congenital surgeon participants. Participants were asked to rank all procedures from the EACTS-STS Minimal Database Procedure Short List [1]. Each procedure was scored with a score of 0.5–5 in three areas: potential for mortality, potential for morbidity, and technical difficulty. Guidelines were provided to the Aristotle project participants. Five levels of suggested scoring were provided for each of these three areas, with each suggested level worth 1 point: potential for mortality (less than 1, 1–5 %, 5–10 %, 10–20 %, 20–50 %).

10–20 %, and greater than 20 %), potential for morbidity (based on estimated intensive care unit [ICU] stay: 0–24 h, 1–3 days, 4–7 days, 1–2 weeks, and greater than 2 weeks), and technical difficulty (elementary, simple, average, important, and major). The points (0.5–5) from each of these three areas were added together to give a total of 1.5–15. For each procedure, the median value of mortality, morbidity, and technical difficulty obtained from the 50 centers was calculated. The sum of these three median values gives the final Aristotle Basic Complexity Score for each procedure (Appendix 1). The distribution of the scoring among the centers was, in general, quite uniform, although some rare or new procedures had a large dispersion.

In addition to assigning each procedure an Aristotle Basic Complexity Score ranging from 1.5 to 15, each procedure was next assigned an Aristotle Basic Complexity Level ranging from 1 through 4 based on the Aristotle Basic Complexity Score (basic score of 1.5–5.9=basic level of 1, basic score of 6.0–7.9=basic level of 2, basic score of 8.0–9.9=basic level of 3, and basic score of 10.0–15.0=basic level of 4).

In the initial application of the Aristotle Basic Complexity Score in the STS Congenital Heart Surgery Database and the EACTS Congenital Heart Surgery Database [17], 145 procedures from the EACTS-STS procedure short list were scored and 29 procedures were in level 1, 46 procedures were in level 2, 45 procedures were in level 3, and 25 procedures were in level 4. Since this initial application, additional procedures have been added to the nomenclature and have been assigned Aristotle Basic Complexity Scores and Aristotle Basic Complexity Level. The Aristotle Basic Complexity Level provides a broad generalization of complexity by dividing surgical procedures into four complexity categories. Meanwhile, the Aristotle Basic

Complexity Score can provide more precise complexity stratification. Both the score and the level are useful tools; the appropriate tool can be chosen to match the required analysis.

Methodology of the Aristotle

Comprehensive Complexity Score

The Aristotle Comprehensive Complexity Scores add two sorts of complexity modifiers: procedure-dependent factors (including anatomical factors, associated procedures, and age at procedure) and procedure-independent factors (including general factors, clinical factors, extracardiac factors, and surgical factors). Each factor is scored for contribution to mortality, morbidity, and technical difficulty. All complexity factors meet the following requirements: precisely quantifiable, easily available, admitted by a majority, and verifiable. The Aristotle Committee is currently involved in ongoing research to validate this complexity adjustment scoring system on a multi-institutional basis.

Results of the Aristotle Score

The Aristotle Basic Complexity Score was first introduced in the STS Congenital Heart Surgery Database and the EACTS Congenital Heart Surgery Database in 2002 [17] and allowed original risk stratification with production of quite useful graphs to evaluate performance.

Figure 27.2 is a Bubble Chart that displays the outcomes of 42 institutions and 12,576 patients [reproduced with permission from Bohdan Maruszewski, MD, Chair of the EACTS Congenital Heart Surgery Database, EACTS 2004 database annual report]. The Aristotle Basic Complexity Score is plotted against Mortality combined. Each bubble represents a different center, and the size of the bubble correlates with programmatic volume. The graph allows one to define 4 quadrants, based on averages: *the best performing centers are in the lower right quad-*

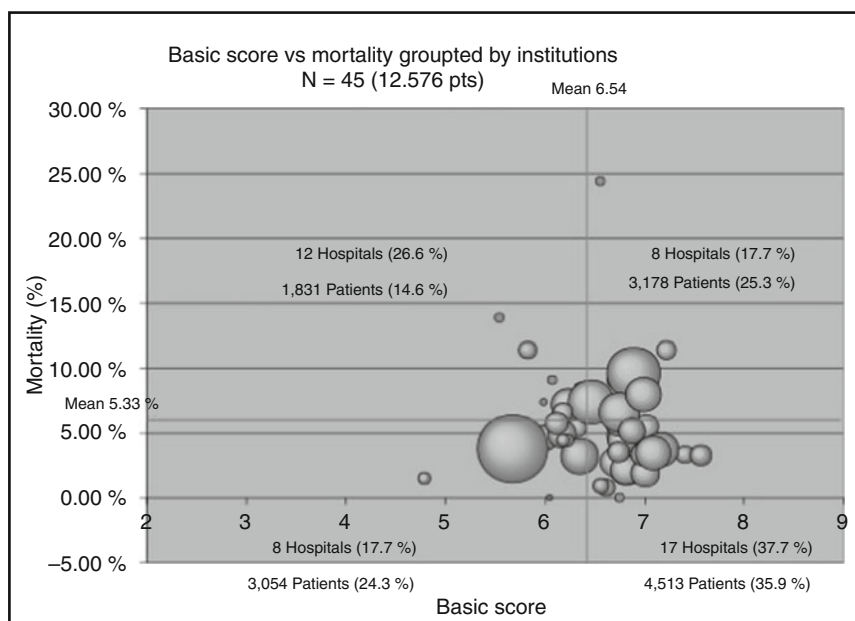


Fig. 27.2 This Bubble Chart displays the outcomes of 42 institutions and 12,576 patients. The Aristotle Basic Complexity Score is plotted against Mortality. Each bubble represents a different center, and the size of the bubble correlates with programmatic volume. Bubbles of different size represent the volume of centers. The graph allows one to define 4 quadrants, based on averages: the

best performing centers are in the lower right quadrant, with lower mortality and higher complexity. Notice that the best performing centers are not always the largest ones (Reproduced with permission from Bohdan Maruszewski, MD, Chair of the EACTS Congenital Heart Surgery Database, EACTS 2004 database annual report)

rant, with higher complexity and lower mortality. Notice that the best performing centers are not always the largest ones.

Figure 27.3 is a Bubble Chart that displays the outcomes of 226 surgeons [reproduced with permission from Bohdan Maruszewski, MD, Chair of the EACTS Congenital Heart Surgery Database, EACTS 2004 database annual report]. The Aristotle Basic Complexity Score is plotted against Mortality combined. Each bubble represents a different surgeon, and the size of the bubble correlates with the volume of cases performed by the individual surgeon. The graph also allows one to define 4 quadrants, based on averages: *the best performing surgeons are in the lower right quadrant*, with higher complexity and lower mortality.

The **Aristotle Basic Complexity Score** is calculated on 15 points and is determined from the

primary procedure of any operation. The Aristotle Basic Complexity Score was ultimately divided in four levels of complexity. The Aristotle Basic Complexity Score can be analyzed using these four categories, which are known as the **Aristotle Basic Complexity Levels** (Fig. 27.4). Meanwhile, the **Risk Adjustment in Congenital Heart Surgery (RACHS-1)** has six categories (Fig. 27.4) [18]. Figure 27.4 displays the increment of mortality as the Aristotle Basic Complexity Levels and RACHS-1. The results are very similar, showing a good discrimination for the two systems. The **Aristotle Basic Complexity Score** includes 94 % of operations while the RACHS-1 includes 86 % [19].

RACHS-1 Category 5 is quite small, composed of patients who undergo combined repair of Truncus arteriosus and Interrupted aortic arch

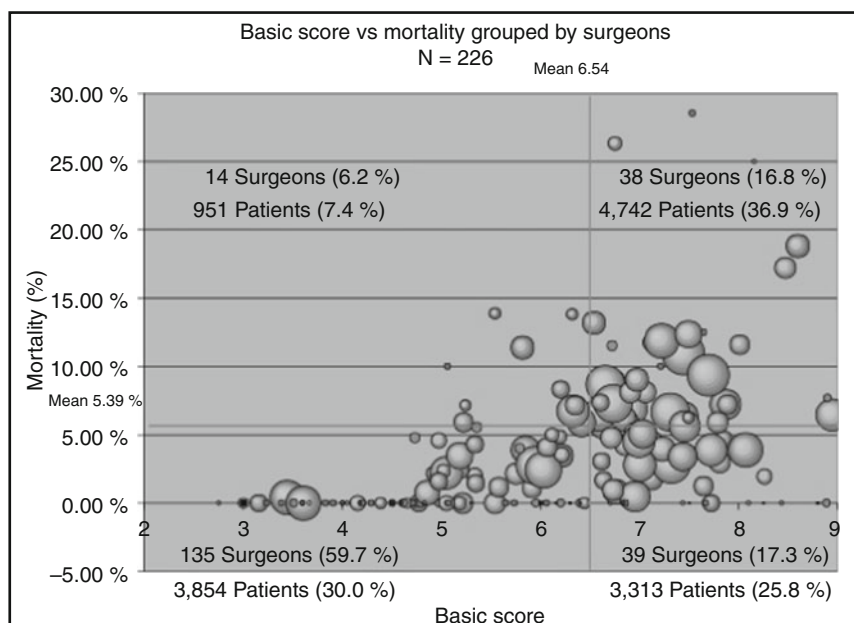


Fig. 27.3 This Bubble Chart displays the outcomes of 226 surgeons. The Aristotle Basic Complexity Score is plotted against Mortality. Each bubble represents a different surgeon, and the size of the bubble correlates with the volume of cases performed by the individual surgeon. The graph also allows one to define 4 quadrants, based on

averages: the best performing surgeons are in the lower right quadrant, with lower mortality and higher complexity (Reproduced with permission from Bohdan Maruszewski, MD, Chair of the EACTS Congenital Heart Surgery Database, EACTS 2004 database annual report)

repair. Therefore, at the analytic level, RACHS-1 Category 5 is usually combined with RACHS-1 Category 6, which includes:

- Damus-Kaye-Stansel procedure (DKS) (creation of AP anastomosis without arch reconstruction)
- Hybrid Approach “Stage 2”, Aortopulmonary amalgamation + Superior Cavopulmonary anastomosis(es) + PA Debanding + Aortic arch repair (Norwood [Stage 1] + SuperiorCavopulmonaryanastomosis(es) + PA Debanding)
- Norwood procedure

The exclusivity of the combined RACHS-1 Category 5 and RACHS-1 Category 6 allows for enhanced discrimination for prediction of mortality using RACHS-1. It is important to remember that the Aristotle Score was initially designed to measure performance and not to predict mortality; however,

Aristotle Basic Complexity Score actually does also quite well with prediction of mortality [20].

The results of the *Aristotle Comprehensive Complexity Score* are encouraging, but have been so far only been published by individual institutions and not by the STS Congenital Heart Surgery Database and the EACTS Congenital Heart Surgery Database (Perhaps the most important multi-institutional contribution of the *Aristotle Comprehensive Complexity Score* to date has been that its components have been incorporated into the STS Congenital Heart Surgery Database and the EACTS Congenital Heart Surgery Database and have been used to inform the upgrade of these databases.). As expected, these individual institutional analyses have documented that the discrimination of the *Aristotle Comprehensive Complexity Score* is superior. The reason for

Fig. 27.4 (a) Aristotle Basic Complexity Score and (b) RACHS-1 Categories versus mortality, by categories (four categories for Aristotle Basic Complexity Score and five categories for RACHS-1)

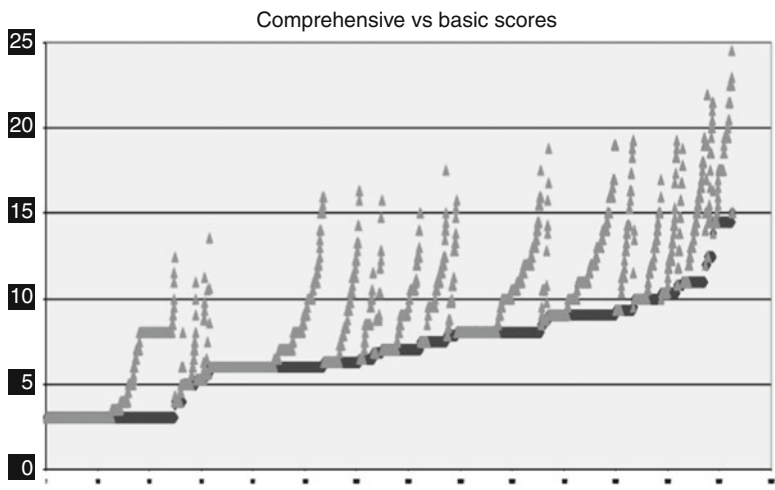
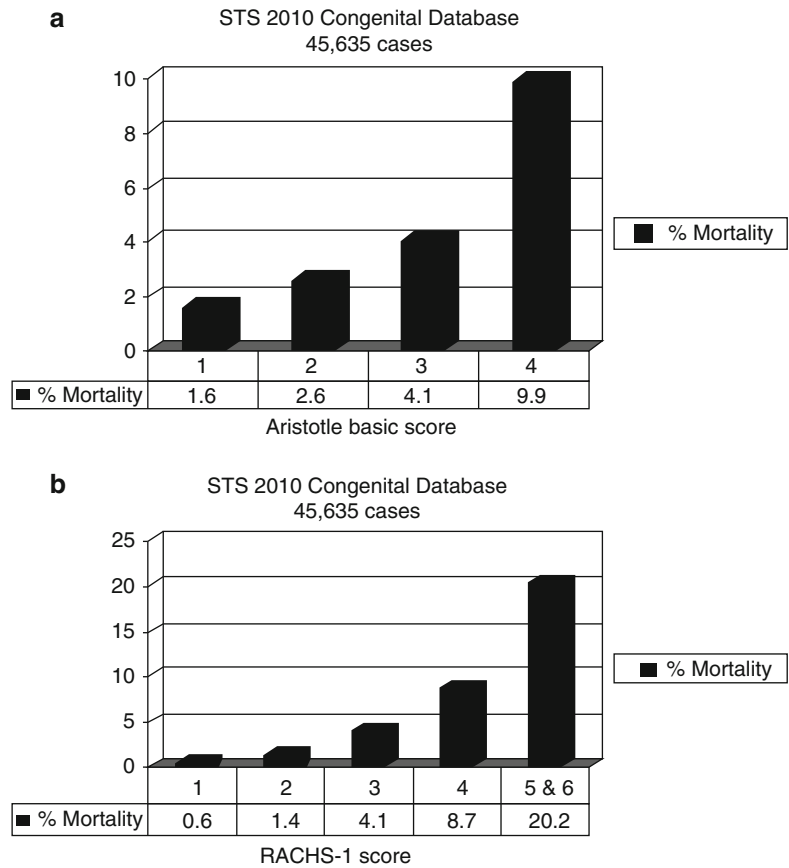


Fig. 27.5 Figure plots the Aristotle Basic Complexity Score (x-axis) versus the Aristotle Comprehensive Complexity Score (y-axis), in an analysis of 2,655 operations. Figure shows the incremental increased complexity documented in many operations due to the introduction

of Procedure Dependent Factors and Procedure Independent Factors. Notice the wide increase in complexity for many operations following the addition of procedure dependent factors and procedure independent factors

Fig. 27.6 Figure plots Aristotle Comprehensive Complexity Score (ACCS Level) versus Mortality. Notice the very severe observed mortality of 21.4 and 41.7 % when the Aristotle Comprehensive Complexity Score is beyond 15 and 20, respectively

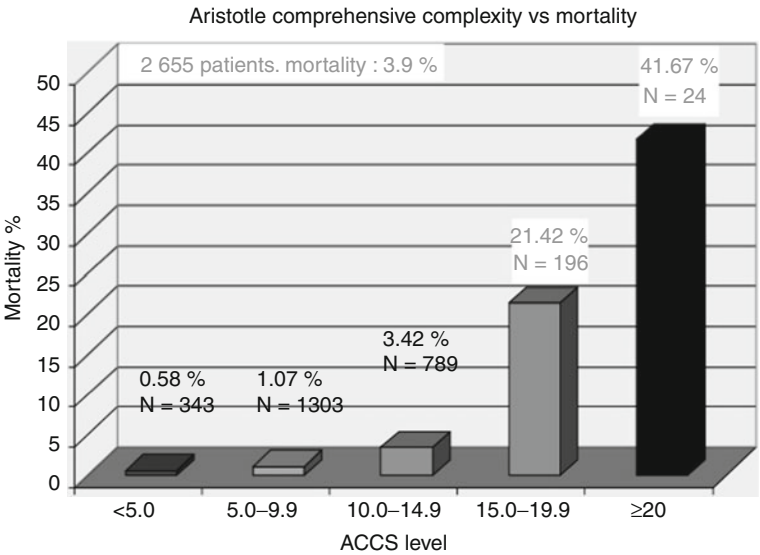


Table 27.2 Evolution of performance within the EACTS Congenital Heart Surgery Database

Year	Performance	Mean BS	Mean MS	No. of patients	30 days mortality (%)
2012	6.71	6.93	0.68	13,870 patients	3.17
2011	6.74	6.96	0.67	14,999 patients	3.22
2010	6.7	6.92	0.65	15,312 patients	3.21
2009	6.74	7.01	0.68	12,676 patients	3.76
2008	6.77	7.05	0.7	12,012 patients	4.00
2007	6.87	7.14	0.7	11,050 patients	3.71

Reproduced with permission from Bohdan Maruszewski, MD, Chair of the EACTS Congenital Heart Surgery Database (<http://www.eactskongenitaldb.org>)
BS basic score, MS mortality score

this superior performance is that the *Aristotle Comprehensive Complexity Score* is calculated based on 25 points, with the addition of many modifiers (Procedure Dependent Factors and Procedure Independent Factors) that improve its accuracy. Figures 27.5 and 27.6 are produced from the Aristotle Comprehensive Complexity Score Study Committee, [www.aristotleinstitute.org] and include 2,655 operations from 12 centers.

The introduction of the performance equation has been a source of controversy:

Performance = Complexity × Outcome

The EACTS [<http://www.eactskongenitaldb.org>] have used this equation to measure performance.

Table 27.2 shows the stagnation of performance at the EACTS Congenital Heart Surgery Database, while the mortality decreases. We assume that this finding is a consequence of the decreased number of Norwood operations performed at centers participating in the EACTS Congenital Heart Surgery Database. This trend may be related to the development of the prenatal diagnosis.

Validation of the Aristotle Score

The validation of the *Aristotle Basic Complexity Score* was studied [20] using data from the EACTS Congenital Heart Surgery Database (17,838 operations, 56 centers) and the STS

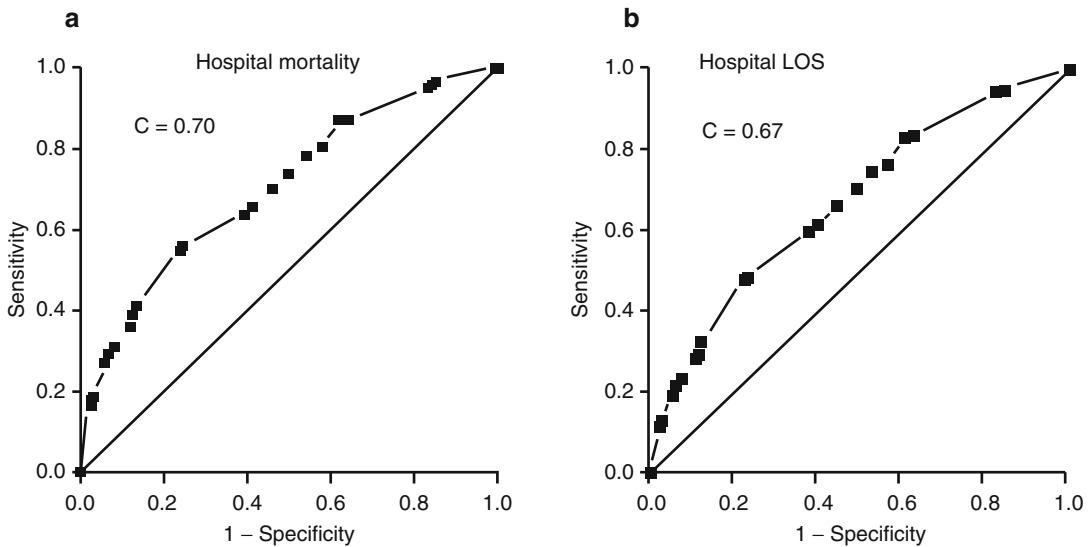


Fig. 27.7 Validation of the Aristotle Basic Complexity Score [20]. C-Index of 0.70 for prediction of mortality (a) and 0.67 for prediction of Hospital Length of Stay (LOS) (b)

Congenital Heart Surgery Database (18,024 operations, 32 centers). “Discrimination of the ABC score for predicting in-hospital mortality and postoperative length of stay (PLOS) of more than 21 days was quantified by the C statistic. Procedure-specific rates of mortality and prolonged PLOS were compared with predictions from a logistic regression model, and an exact binomial test was used to identify procedures that were mortality and morbidity outliers” [20]. This analysis revealed that a significant positive correlation exists between the Aristotle Basic Complexity Score of a procedure and its observed procedure-specific risk of mortality ($C=0.70$) and prolonged PLOS ($C=0.67$) (Fig. 27.7). It was concluded that the Aristotle Basic Complexity Score [20] “generally discriminates between low-risk and high-risk congenital procedures making it a potentially useful covariate for case-mix adjustment in congenital heart surgery outcomes analysis. Planned revisions of the ABC score will incorporate empirical data and will benefit from the large sample sizes of the STS and EACTS databases.”

The validation of the Aristotle Comprehensive Complexity Score was achieved by several individual institutions and the Aristotle

Comprehensive Complexity Score was used to study and compare outcomes of several complex procedures:

- The Aristotle Comprehensive Complexity Score was proposed in Germany as a reference for “pay for performance” and hospital reimbursement [21–28]
- For patients undergoing the Norwood (Stage 1) Operation, the Aristotle Comprehensive Complexity Score was found to be correlated with total cardiac output during the early post-operative period [29].
- In patients undergoing surgery for hypoplastic left heart syndrome, the Aristotle Comprehensive Complexity Score was correlated with survival [30, 31]
- In low weight patients placed on cardiopulmonary bypass, the Aristotle Comprehensive Complexity Score was correlated with survival [32].
- In post-operative extracorporeal membrane oxygenation (ECMO), the Aristotle Comprehensive Complexity Score was correlated with survival [33].
- In patients undergoing surgery for Truncus Arteriosus with Interrupted Aortic Arch, the Aristotle Comprehensive Complexity Score was correlated with survival [34].

- The Aristotle Comprehensive Complexity Score was used to evaluate the progress of an institution [35]. “A high correlation was found between the ACC scores and mortality, indices of morbidity and technique difficulty, Spearman’s correlation coefficient r being 0.9856, 1 and 0.9429, respectively. Mortality ($p=0.037$) and morbidity ($p=0.041$) were lower in year 2007 than in 2002, surgical performance being not significantly different.”
- In patients undergoing the arterial switch operation, the Aristotle Comprehensive Complexity Score was correlated with morbidity [36] and to mortality [37].
- The Aristotle Comprehensive Complexity Score was associated with the hospital length of stay in neonatal congenital cardiac surgery [38].
- In adults with congenital cardiac disease [39], the *Aristotle Comprehensive Complexity Score* was correlated with 30 day mortality with a C-Index of 0.755.
- The *Aristotle Score* was used to evaluate the impact of surgical volume on outcomes [40].
- The *Aristotle Comprehensive Complexity Score* was evaluated at the Necker Children’s Hospital in Paris on a cohort of 1,454 patients. The *Aristotle Comprehensive Complexity Score* was strongly related to mortality, with a C-Index of 0.86 [41].

The *Aristotle Comprehensive Complexity Score* compares favorably with all the existing models of complexity stratification, with a C-Index of 0.860, as shown in Table 27.3.

Table 27.3 Comparison of risk stratification models, for prediction of mortality. The Aristotle Comprehensive Complexity Score has the highest score C-Statistic [20]

Risk stratification modeling	C-Index
Aristotle Comprehensive Complexity Score^a	0860
STAT Mortality Score ^b	0816
STAT Mortality Categories ^b	0812
RACHS-1 Categories ^b	0802
Aristotle Basic Complexity Score ^b	0795

^aO’Brien et al. [20]

^bArtrip et al. [30]

Limitation of the Current Aristotle Scores

Complexity scores can incorporate only a finite number of known factors [17]. True complexity is related to both these known factors and other factors we may not know or measure. Although complexity itself is a constant precise value for a given patient at a given point in time, the Aristotle Basic Complexity Score, the Aristotle Basic Complexity Level, and the Aristotle Comprehensive Complexity Score all represent estimates to measure complexity.

Two Aristotle Scores exist: The *Aristotle Basic Complexity Score* and the *Aristotle Comprehensive Complexity Score*. Since its introduction [3], it was made clear that the *Aristotle Comprehensive Complexity Score* will be a more accurate score, not only to predict mortality but moreover to measure performance.

The expert opinion based system was initially judged inappropriate [42, 43]. In reality, the expert opinion is used in many disciplines and is objectively manageable using Bayesian statistics [16, 20, 44, 45]. When we started the new versions of the STS and EACTS Congenital Heart Surgery Databases in 2000 using the new international nomenclature based on the International Congenital Heart Surgery Nomenclature and Database Project, data about risk-stratification was not available. The only option was first to create a system of risk stratification based on expert opinion. The Aristotle Basic Complexity Score has been very instrumental to facilitate the growth of the STS Congenital Heart Surgery Database and the EACTS Congenital Heart Surgery Database: the most active centers are no longer reluctant to send their data, as a higher mortality was supported by a higher complexity. The transition and ultimate switch to a system of risk stratification based on raw, observed, objective data [16, 45] was ultimately made when enough data was accumulated in the STS Congenital Heart Surgery Database and the EACTS Congenital Heart Surgery Database (see below).

The combination of the three variables (potential for mortality, potential for morbidity, and

technical difficulty) in the Aristotle system has limited the power to predict mortality as it is also looking at two additional outcomes (potential for morbidity and technical difficulty). Nevertheless, it is noticeable that the Aristotle Comprehensive Complexity Score has today the best correlation to predict mortality (Table 27.3) [41].

To date, the Aristotle Comprehensive Complexity Score has not been introduced in the STS Congenital Heart Surgery Database and the EACTS Congenital Heart Surgery Database because it was felt that a scientific evaluation was required, which, we believe, it has since gained with many publications. However, the Aristotle Comprehensive Complexity Score is judged complicated and not user friendly. Meanwhile, the mortality in our specialty is today essentially limited to very complex patients who accumulate multiple risk factors that are not all included in any database. Using a more accurate system of system of risk stratification seems necessary to explain the cause of mortality and morbidity of the most complex patients, namely “those who die”. Perhaps the most important multi-institutional contribution of the Aristotle Comprehensive Complexity Score to date has been that its components have been incorporated into the STS Congenital Heart Surgery Database and the EACTS Congenital Heart Surgery Database and have been used to inform the upgrade of these databases, with the goal of increasing the accuracy of the methodology of risk stratification.

The treatment of adults with congenital cardiac disease has become a major component of our specialty. The Aristotle Comprehensive Complexity Score has been applied quite successfully to analyze the surgical outcomes of adults with congenital cardiac disease [39]. Nevertheless, it is insufficient. The *Aristotle Comprehensive Complexity Score* for surgery in adults with congenital cardiac disease will include in the future many risk factors specific to the adult patients.

Aware of the current limitations of the Aristotle Score [38], The Aristotle Committee is today developing an Aristotle 2 model that is summarized below. The first step is to incorpo-

rate the objectively derived STAT Mortality Score and the STAT Morbidity Score.

New Aristotle 2 Scores

From Subjective to Objective Evaluation: The STAT Mortality Score and the STAT Morbidity Score

The STAT Mortality Score was introduced in 2009 [16]. *The STAT Mortality Score* is a mortality score or mortality index. Mortality risk was estimated for 148 types of operative procedures using data from 77,294 operations entered into the EACTS Congenital Heart Surgery Database (33,360 operations) and the STS Congenital Heart Surgery Database (43,934 patients) between 2002 and 2007. Procedure-specific mortality rate estimates were calculated using a Bayesian model that adjusted for small denominators. Each procedure was assigned a numeric score (the STS–EACTS Congenital Heart Surgery Mortality Score [2009] or STAT Mortality Score) ranging from 0.1 to 5.0 based on the estimated mortality rate. Procedures were also sorted by increasing risk and grouped into five categories (the STS–EACTS Congenital Heart Surgery Mortality Categories [2009] or STAT Mortality Categories) that were chosen to be optimal with respect to minimizing within-category variation and maximizing between-category variation. The STAT Mortality Score and STAT Mortality Categories could predict mortality with a C-index for the score and the categories of 0.784 and 0.773, respectively. (It was noticed that the Aristotle Basic Complexity Score, based on expert opinion, had over-evaluated the risk of mortality for several procedures.)

The STAT Morbidity Score followed in 2013 [45], after a very long debate around its definition. The STAT Morbidity Score was created because it was felt very necessary to evaluate the morbidity of the 96 % of patients surviving the operation; whose quality assessment was ignored in a system based only on mortality. The STAT Morbidity Score was developed using data from 62,851 operations in the STS Congenital Heart

Surgery Database (2002–2008). Model-based estimates with 95 %Bayesian credible intervals were calculated for each procedure’s average risk of major complications and average postoperative length of stay. These 2 measures were combined into a composite morbidity score. A total of 140 procedures were assigned scores ranging from 0.1 to 5.0 and sorted into five relatively homogeneous categories. It is expected that the impact of the STAT Morbidity Score will be very important to compare hospital cost between centers in the future.

The STAT Mortality Score and the STAT Morbidity Score are objectively derived and may replace the subjectively derived “potential for mortality” and “potential for morbidity” in the Aristotle Score. *The technical difficulty component of the Aristotle Score* remains today based on expert opinion. In 2009, the Congenital Data Base Committee produced a new ranking of

technical difficulty based on 148 procedures. Procedures with highest technical difficulty are listed on Table 27.4.

Timing

The development of the Aristotle 2 score will start when the STS and EACTS have accumulated sufficient data on the Morbidity Score. It is expected that the new score will be *available in 2015*.

Adults with Congenital Cardiac Disease

A score for adults with congenital cardiac disease will be developed using new adult specific procedure independent factors required for the adult population [39]

Table 27.4 Technical difficulty ranking of the 15 most technically demanding procedures

Technical difficulty ranking	Procedures
1	Congenitally corrected TGA repair, Atrial switch and ASO (Double switch)
2	Norwood procedure
3	Ross-Konno procedure
4	HLHS biventricular repair
5	Arterial switch procedure and VSD repair + Aortic arch repair
6	Fontan revision or conversion (Re-do Fontan)
7	Aortic root replacement, Valve sparing
8	Transplant, Heart and lung
9	Truncus + IAA Repair
10	Congenitally corrected TGA repair, Atrial switch and Rastelli
11	Arterial switch operation (ASO) and VSD repair
12	Pulmonary atresia – VSD – MAPCA (pseudotruncus) repair
13	Arterial switch procedure + Aortic arch repair
14	Congenitally corrected TGA repair, VSD closure and LV to PA conduit
15	Truncus arteriosus repair

Simplification of the Aristotle Scores

The Aristotle Basic Complexity Score 2 (ABS2) will be calculated, using the objective STAT Mortality Score and STAT Morbidity Score are. The technical Difficulty will remain based on expert opinion. A new Technical Difficulty may eventually be produced, incorporating the Surgical Performance data available from the Technical Performance Score developed in Boston under the leadership of Emile Bacha [9–12].

The Aristotle Basic Complexity Score 2 will be calculated with the following equation:

$$\text{Complexity} = \text{STATMortality Score} + \text{STATMorbidity Score} + \text{Technical Difficulty}$$

The Aristotle Comprehensive Complexity Score 2 (ACS2) will remain based again on expert opinion. An international committee of expert centers, surgeons, and intensivists will insure the definition of the procedure-dependent factors and procedure-independent factors [46, 47].

The Aristotle Comprehensive Complexity Score 2 will be *reduced to 70 procedures* out of

180, by selecting the 20 most frequent procedures (with the exception of “PDA closure”) and the procedures for most complex pathologies. The nine pathologies studied in the Lesion Specific Section of the STS Congenital Heart Surgery Database Feedback Report will be included:

1. **Atrial Septal Defect (ASD)**
2. **Ventricular Septal Defect (VSD)**
3. **Coarctation of the Aorta (COA)**
4. **Tetralogy of Fallot (TOF) Palliation**
5. **Tetralogy of Fallot (TOF) Repair**
6. **AV Canal (AVC) Defect**
7. **Aortic Stenosis and Insufficiency (ASAI)**
8. **Transposition of the Great Arteries (TGA)**
9. **Hypoplastic Left Heart Syndrome (HLHS) (Norwood procedure, Damus–Kaye–Stansel procedure [DKS] and Hybrid procedures)**

The Aristotle Comprehensive Complexity Score 2 will also include 11 other pathologies and cardiac transplantation:

1. **Adults with Congenital Cardiac Disease,**
2. **Truncus Arteriosus,**
3. **Corrected Transposition,**
4. **Double Outlet Right Ventricle (DORV),**
5. **Interrupted Aortic Arch (IAA),**
6. **Abnormal origins of coronary arteries,**
7. **Total anomalous pulmonary venous return (TAPVR),**
8. **Mitral Valve Stenosis and Regurgitation,**
9. **Ebstein’s repair,**
10. **Functionally univentricular heart (Cavopulmonary anastomoses and Fontan procedures), and**
11. **Cardiac Transplantation.**

Performance Measurements

A new methodology of Performance Measurement will be proposed. This new methodology of Performance Measurement will be discussed and evaluated by the Aristotle Committee.

In the Aristotle system, the Performance is defined by the axiom (axiom definition: “a basic proposition assumed to be true”):

$$\text{Performance} = \text{Outcome} \times \text{Complexity.}$$

The new system of Basic and Comprehensive Performance Measurement in Aristotle 2 will use the STAT Mortality Score and the STAT Morbidity Score based on raw data; meanwhile, technical difficulty will remain based on expert opinion.

We, along with David Clarke, coined the term Optivital [48, 49], to measure the antonym of morbidity:

$$\text{Optivital} = 100\% - \text{Morbidity } \%$$

(Survival is the antonym of mortality and Optivital is the antonym of morbidity).

Contributions of the Aristotle Score Towards the Development of Newer Tools to Evaluate Cardiac Surgical Performance

Perhaps the most important contribution of the Aristotle Comprehensive Complexity Score to date has been that its components have been incorporated into the STS Congenital Heart Surgery Database and the EACTS Congenital Heart Surgery Database and have been used to inform the upgrade of these databases, with the goal of increasing the accuracy of the methodology of risk stratification.

The motivation to develop the STAT Mortality Score and the STAT Morbidity Score was at least in a large part related to the Aristotle Score. The desire to transition from subjective probability to objective data within the Aristotle Score is the rational for the eventual incorporation of the STAT Mortality Score and the STAT Morbidity Score into the Aristotle Score.

Although the Aristotle Comprehensive Complexity Score has not been incorporated into the STS Congenital Heart Surgery Database and the EACTS Congenital Heart Surgery Database, many of its components have been added individually to these databases.

The listings of the procedure independent factors have been used to inform the STS Congenital Heart Surgery Database and the EACTS Congenital Heart Surgery Database. Procedure independent factors in the Aristotle Comprehensive Complexity Score include gen-

eral factors, clinical factors, extracardiac factors, and surgical factors. These procedure independent factors have been incorporated into these databases in comprehensive listings of chromosomal abnormalities, syndromes, noncardiac abnormalities, and preoperative factors (Of note, the term “preoperative factors” is used rather than “preoperative risk factors” because the data will help determine whether or not these preoperative factors are actually associated with risk.).

The listings of the procedure dependent factors have also been used to inform the STS Congenital Heart Surgery Database and the EACTS Congenital Heart Surgery Database. Procedure dependent factors in the Aristotle Comprehensive Complexity Score include anatomical factors, associated procedures, and age at procedure. Incorporation of a list of procedure dependent factors for all of the procedures in the STS Congenital Heart Surgery Database and the EACTS Congenital Heart Surgery Database would have been extremely challenging as in initial step because of the huge number of elements of data. Consequently, list of procedure dependent factors named: “Procedure Specific Factors” were incorporated into the STS Congenital Heart Surgery Database and the EACTS Congenital Heart Surgery Database for the following ten benchmark operations:

1. Ventricular Septal Defect (VSD) repair
2. Tetralogy of Fallot (TOF) repair
3. Complete atrioventricular canal repair
4. Arterial switch
5. Arterial switch+VSD repair
6. Glenn/HemiFontan
7. Fontan operation
8. Truncus arteriosus repair
9. Norwood procedure
10. Off Bypass Coarctation repair - only include cases with Operation Type=No CPB Cardiovascular

Thus, although the Aristotle Comprehensive Complexity Score has not been incorporated into the STS Congenital Heart Surgery Database and the EACTS Congenital Heart Surgery Database, many of its procedure dependent factors and procedure independent factors have been added individually to these databases.

Conclusion

In conclusion, the Aristotle Score is an original method to evaluate quality in congenital cardiac surgery. The Aristotle Basic Complexity Score has been instrumental to help the growth of the STS Congenital Heart Surgery Database and the EACTS Congenital Heart Surgery Database. The Aristotle Comprehensive Complexity Score has proven to be today the best predictor of hospital mortality with a C-Index of 0.86, and is successfully used by many institutions. The Aristotle Score system is designed to evaluate performance of centers and surgeons, not to predict individual patient mortality.

The next steps will be to incorporate the STAT Mortality Score and STAT Morbidity Score into the Aristotle Score. New measurements of Performance are proposed. The new Aristotle 2 will need more objective data on Morbidity to ultimately be constructed. The new Aristotle 2 should be available in 2015.

Finally, it is certain that the Aristotle Score is responsible for multiple important contributions leading to the development of newer tools to evaluate cardiac surgical performance. The name of the philosopher Aristotle is derived from the term “aristos”, which means “the best” in Greek. Performance is therefore within the idiom “Aristotle Score”.

Appendix 1: The Aristotle Basic Complexity Score (ABC Score) and the Aristotle Basic Complexity Levels (ABC Levels) (January 1, 2010)

Appendix 1 documents how the Aristotle Basic Complexity Score is applied in the STS Congenital Heart Surgery Database and the EACTS Congenital Heart Surgery Database. (Appendix 1 is reproduced with permission from Jacobs et al. [50])

Score	Mortality	Morbidity	Difficulty
1 pt	<1%	ICU 0-24H	elementary
2 pt	1-5%	ICU 1D-3D	simple
3 pt	5-10%	ICU 4D-7D	average
4 pt	10-20%	ICU 1W-2W	important
5 pt	> 20%	ICU > 2W	major

Complexity

1.5 to 5.9	1
6.0 to 7.9	2
8.0 to 9.9	3
10.0 to 15.0	4

Procedures	Total (Basic Score)	Complexity (Basic Level)	Mortality	Morbidity	Difficulty
Pleural drainage procedure	1.5	1	0.5	0.5	0.5
Bronchoscopy	1.5	1	0.5	0.5	0.5
Delayed sternal closure	1.5	1	0.5	0.5	0.5
Mediastinal exploration	1.5	1	0.5	0.5	0.5
Sternotomy wound drainage	1.5	1	0.5	0.5	0.5
Intra-aortic balloon pump (IABP) insertion	2.0	1	0.5	1.0	0.5
Explantation of pacing system	2.5	1	1.0	1.0	0.5
PFO, Primary closure	3.0	1	1.0	1.0	1.0
ASD repair, Primary closure	3.0	1	1.0	1.0	1.0
ASD repair, Patch	3.0	1	1.0	1.0	1.0
ASD partial closure	3.0	1	1.0	1.0	1.0
Atrial fenestration closure	3.0	1	1.0	1.0	1.0
Pericardial drainage procedure	3.0	1	1.0	1.0	1.0
PDA closure, Surgical	3.0	1	1.0	1.0	1.0
Pacemaker implantation, Permanent	3.0	1	1.0	1.0	1.0
Pacemaker procedure	3.0	1	1.0	1.0	1.0
Shunt, Ligation and takedown	3.5	1	1.5	1.0	1.0
ASD, Common atrium (Single atrium), Septation	3.8	1	1.0	1.0	1.8
AVC (AVSD) repair, Partial (incomplete) (PAVSD)	4.0	1	1.0	1.0	2.0
Coronary artery fistula ligation	4.0	1	1.0	2.0	1.0
Aortopexy	4.0	1	1.5	1.5	1.0
ICD (AICD) implantation	4.0	1	1.5	1.0	1.5
ICD (AICD) (automatic implantable cardioverter defibrillator) procedure	4.0	1	1.5	1.0	1.5
Ligation, Thoracic duct	4.0	1	1.0	2.0	1.0
Diaphragm plication	4.0	1	1.0	2.0	1.0
ECMO decannulation	4.0	1	2.0	1.0	1.0
ASD creation/enlargement	5.0	1	2.0	2.0	1.0

Atrial septal fenestration	5.0	1	2.0	2.0	1.0
AVC (AVSD) repair, Intermediate (transitional)	5.0	1	1.5	1.5	2.0
PAPVC repair	5.0	1	2.0	1.0	2.0
Lung biopsy	5.0	1	1.5	2.0	1.5
Ligation, Pulmonary artery	5.0	1	1.5	2.0	1.5
Decortication	5.0	1	1.0	1.0	3.0
ASD repair, Patch + PAPVC repair	5.0	1	2.0	1.0	2.0
PAPVC Repair, Baffle redirection to left atrium with systemic vein translocation (Warden) (SVC sewn to right atrial appendage)	5.0	1	1.0	2.0	2.0
ECMO cannulation	5.0	1	2.0	1.0	2.0
Pectus repair	5.3	1	2.0	1.0	2.3
Aortic stenosis, Supravalvar, Repair	5.5	1	1.5	2.0	2.0
Valvuloplasty, Pulmonic	5.6	1	1.8	1.8	2.0
VSD repair, Primary closure	6.0	2	2.0	2.0	2.0
VSD repair, Patch	6.0	2	2.0	2.0	2.0
AP window repair	6.0	2	2.0	2.0	2.0
Valve replacement, Truncal valve	6.0	2	2.0	2.0	2.0
Cor triatriatum repair	6.0	2	2.0	2.0	2.0
Valve excision, Tricuspid (without replacement)	6.0	2	2.0	2.0	2.0
PA, reconstruction (plasty), Main (trunk)	6.0	2	2.0	2.0	2.0
Pericardiectomy	6.0	2	2.0	2.0	2.0
Coarctation repair, End to end	6.0	2	2.0	2.0	2.0
Coarctation repair, Subclavian flap	6.0	2	2.0	2.0	2.0
Coarctation repair, Patch aortoplasty	6.0	2	2.0	2.0	2.0
Vascular ring repair	6.0	2	2.0	2.0	2.0
PA banding (PAB)	6.0	2	2.0	2.0	2.0
PA debanding	6.0	2	2.0	2.0	2.0
ECMO procedure	6.0	2	2.0	3.0	1.0
Aortic stenosis, Subvalvar, Repair	6.3	2	2.0	1.8	2.5
Shunt, Systemic to pulmonary, Modified Blalock–Taussig shunt (MBTS)	6.3	2	2.0	2.0	2.3
RVOT procedure	6.5	2	2.0	2.0	2.5
Valve replacement, Pulmonic (PVR)	6.5	2	2.0	2.0	2.5
Shunt, Systemic to pulmonary, Central (From aorta or to main pulmonary artery)	6.8	2	2.0	2.0	2.8
Valvuloplasty, Truncal valve	7.0	2	2.0	2.0	3.0
Anomalous systemic venous connection repair	7.0	2	2.0	2.0	3.0
Occlusion MAPCA(s)	7.0	2	2.0	2.0	3.0
Valvuloplasty, Tricuspid	7.0	2	2.0	2.0	3.0
DCRV repair	7.0	2	2.0	2.0	3.0
Valve replacement, Aortic (AVR), Mechanical	7.0	2	2.0	2.0	3.0
Valve replacement, Aortic (AVR), Bioprosthetic	7.0	2	2.0	2.0	3.0
Atrial baffle procedure, Mustard or Senning revision	7.0	2	2.0	2.0	3.0
Aortic arch repair	7.0	2	2.0	2.0	3.0
Bidirectional cavopulmonary anastomosis (BDCPA) (bidirectional Glenn)	7.0	2	2.5	2.0	2.5
Glenn (unidirectional cavopulmonary anastomosis) (unidirectional Glenn)	7.0	2	2.5	2.0	2.5
Right/left heart assist device procedure	7.0	2	2.0	3.0	2.0
Hybrid Approach "Stage 1", Stent placement in arterial duct (PDA)	7.0	2	1.5	1.5	4.0
VAD implantation	7.0	2	2.0	3.0	2.0
VAD explantation	7.0	2	2.0	3.0	2.0
Ventricular septal fenestration	7.5	2	3.0	2.0	2.5
TOF repair, Ventriculotomy, Non-transanular patch	7.5	2	2.5	2.0	3.0
Valve replacement, Tricuspid (TVR)	7.5	2	2.5	2.0	3.0
Conduit placement, RV to PA	7.5	2	2.5	2.0	3.0
Sinus of Valsalva, Aneurysm repair	7.5	2	2.5	2.0	3.0
Valve replacement, Mitral (MVR)	7.5	2	2.5	2.0	3.0
Coronary artery bypass	7.5	2	2.5	2.0	3.0
Bilateral bidirectional cavopulmonary anastomosis (BBDCPA) (bilateral bidirectional Glenn)	7.5	2	2.5	2.0	3.0
Conduit placement, Other	7.5	2	2.5	2.0	3.0
Hybrid Approach "Stage 1", Application of RPA and LPA bands	7.5	2	2.5	2.5	2.5
Atrial baffle procedure (non-Mustard, non-Senning)	7.8	2	2.8	2.0	3.0
PA, reconstruction (plasty), Branch, Central (within the hilar bifurcation)	7.8	2	2.8	2.0	3.0
Coarctation repair, Interposition graft	7.8	2	2.8	2.0	3.0
PAPVC, Scimitar, Repair	8.0	3	3.0	2.0	3.0
Systemic venous stenosis repair	8.0	3	3.0	2.0	3.0
TOF repair, No ventriculotomy	8.0	3	3.0	2.0	3.0
TOF repair, Ventriculotomy, Transanular patch	8.0	3	3.0	2.0	3.0
TOF repair, RV-PA conduit	8.0	3	3.0	2.0	3.0
Conduit reoperation	8.0	3	3.0	2.0	3.0

Conduit placement, LV to PA	8.0	3	3.0	2.0	3.0
Valvuloplasty, Aortic	8.0	3	3.0	2.0	3.0
Aortic root replacement	8.0	3	2.5	2.0	3.5
Valvuloplasty, Mitral	8.0	3	3.0	2.0	3.0
Mitral stenosis, Supravalvar mitral ring repair	8.0	3	3.0	2.0	3.0
Coarctation repair, End to end, Extended	8.0	3	3.0	2.0	3.0
Arrhythmia surgery - atrial, Surgical ablation	8.0	3	3.0	2.0	3.0
Arrhythmia surgery - ventricular, Surgical ablation	8.0	3	3.0	2.0	3.0
Hemifontan	8.0	3	3.0	2.0	3.0
Aneurysm, Ventricular, Right, Repair	8.0	3	3.0	2.0	3.0
Aneurysm, Pulmonary artery, Repair	8.0	3	3.0	2.0	3.0
Cardiac tumor resection	8.0	3	3.0	2.0	3.0
Pulmonary embolectomy	8.0	3	3.0	3.0	2.0
Pulmonary embolectomy, Acute pulmonary embolus	8.0	3	3.0	3.0	2.0
Aortic stenosis, Subvalvar, Repair, With myectomy for IHSS	8.0	3	2.0	2.0	4.0
Valvuloplasty converted to valve replacement in the same operation, Pulmonic	8.0	3	2.5	2.5	3.0
LV to aorta tunnel repair	8.3	3	3.0	2.3	3.0
Valve replacement, Aortic (AVR), Homograft	8.5	3	3.0	2.0	3.5
Aortic root replacement, Valve sparing	8.5	3	2.0	2.0	4.5
Senning	8.5	3	3.0	2.5	3.0
PA, reconstruction (plasty), Branch, Peripheral (at or beyond the hilar bifurcation)	8.8	3	2.8	2.5	3.5
Aortic root replacement, Mechanical	8.8	3	3.3	2.0	3.5
Aortic aneurysm repair	8.8	3	3.0	2.8	3.0
VSD, Multiple, Repair	9.0	3	3.0	2.5	3.5
VSD creation/enlargement	9.0	3	3.0	3.0	3.0
AVC (AVSD) repair, Complete (CAVSD)	9.0	3	3.0	3.0	3.0
Pulmonary artery origin from ascending aorta (hemitruncus) repair	9.0	3	3.0	3.0	3.0
TAPVC repair	9.0	3	3.0	3.0	3.0
Pulmonary atresia - VSD (including TOF, PA) repair	9.0	3	3.0	3.0	3.0
Valve closure, Tricuspid (exclusion, univentricular approach)	9.0	3	4.0	3.0	2.0
1 1/2 ventricular repair	9.0	3	3.0	3.0	3.0
Fontan, Atrio-pulmonary connection	9.0	3	3.0	3.0	3.0
Fontan, Atrio-ventricular connection	9.0	3	3.0	3.0	3.0
Fontan, TCPC, Lateral tunnel, Fenestrated	9.0	3	3.0	3.0	3.0
Fontan, TCPC, Lateral tunnel, Non-fenestrated	9.0	3	3.0	3.0	3.0
Fontan, TCPC, External conduit, Fenestrated	9.0	3	3.0	3.0	3.0
Fontan, TCPC, External conduit, Non-fenestrated	9.0	3	3.0	3.0	3.0
Congenitally corrected TGA repair, VSD closure	9.0	3	3.0	3.0	3.0
Mustard	9.0	3	3.0	3.0	3.0
Pulmonary artery sling repair	9.0	3	3.0	3.0	3.0
Aneurysm, Ventricular, Left, Repair	9.0	3	3.0	2.5	3.5
Conduit placement, Ventricle to aorta	9.0	3	3.0	3.0	3.0
Pulmonary embolectomy, Chronic pulmonary embolus	9.0	3	3.0	3.0	3.0
Valvuloplasty converted to valve replacement in the same operation, Truncal valve	9.0	3	2.5	3.0	3.5
Valvuloplasty, Common atrioventricular valve	9.0	3	3.5	2.5	3.0
TOF - Absent pulmonary valve repair	9.3	3	3.0	3.0	3.3
Transplant, Heart	9.3	3	3.0	3.3	3.0
Aortic root replacement, Bioprosthetic	9.5	3	3.5	2.0	4.0
Aortic root replacement, Homograft	9.5	3	3.5	2.0	4.0
Damus-Kaye-Stansel procedure (DKS) (creation of AP anastomosis without arch reconstruction)	9.5	3	3.0	3.0	3.5
Valvuloplasty converted to valve replacement in same operation, Tricuspid	9.5	3	3.0	2.5	4.0
Superior cavopulmonary anastomosis(es) + PA reconstruction	9.5	3	3.0	3.0	3.5
Atrioventricular valvuloplasty	9.5	3	3.0	3.0	3.5
Ebstein's repair	10.0	4	3.0	3.0	4.0
Arterial switch operation (ASO)	10.0	4	3.5	3.0	3.5
Rastelli	10.0	4	3.0	3.0	4.0
Coarctation repair + VSD repair	10.0	4	2.5	3.5	4.0
Aortic arch repair + VSD repair	10.0	4	3.0	3.0	4.0
Anomalous origin of coronary artery from pulmonary artery repair	10.0	4	3.0	3.0	4.0
Superior cavopulmonary anastomosis(es) + PA reconstruction	10.0	4	3.5	3.0	3.5
Hybrid Approach "Stage 2", Aortopulmonary amalgamation + Superior Cavopulmonary anastomosis(es) + PA Debanding + Without aortic arch repair	10.0	4	2.5	3.5	4.0
Hybrid Approach "Stage 1", Stent placement in arterial duct (PDA) + application of RPA and LPA bands	10.0	4	3.0	3.0	4.0
Valve replacement, Common atrioventricular valve	10.0	4	3.5	3.5	3.0
Ross procedure	10.3	4	4.0	2.3	4.0

DORV, Intraventricular tunnel repair	10.3	4	3.3	3.0	4.0
Valvuloplasty converted to valve replacement in the same operation, Aortic	10.3	4	3.5	2.5	4.3
Ventricular septation	10.5	4	3.5	3.5	3.5
Valvuloplasty converted to valve replacement in the same operation, Mitral	10.5	4	4.0	2.5	4.0
Interrupted aortic arch repair	10.8	4	3.8	3.0	4.0
Truncus arteriosus repair	11.0	4	4.0	3.0	4.0
TOF - AVC (AVSD) repair	11.0	4	4.0	3.0	4.0
Pulmonary atresia - VSD - MAPCA (pseudotruncus) repair	11.0	4	4.0	3.0	4.0
Unifocalization MAPCA(s)	11.0	4	4.0	3.0	4.0
Konno procedure	11.0	4	4.0	3.0	4.0
Congenitally corrected TGA repair, Atrial switch and Rastelli	11.0	4	4.0	3.0	4.0
Congenitally corrected TGA repair, VSD closure and LV to PA conduit	11.0	4	4.0	3.0	4.0
Arterial switch operation (ASO) and VSD repair	11.0	4	4.0	3.0	4.0
REV	11.0	4	4.0	3.0	4.0
DOLV repair	11.0	4	4.0	3.0	4.0
Aortic dissection repair	11.0	4	4.0	3.0	4.0
TAPVC repair + Shunt - Systemic to pulmonary	11.0	4	4.0	3.5	3.5
Arterial switch procedure + Aortic arch repair	11.5	4	4.0	3.5	4.0
Valvuloplasty converted to valve replacement in the same operation, Common atrioventricular valve	11.5	4	4.5	3.0	4.0
Fontan + Atrioventricular valvuloplasty	11.5	4	4.0	3.5	4.0
Pulmonary venous stenosis repair	12.0	4	4.0	4.0	4.0
Partial left ventriculectomy (LV volume reduction surgery) (Batista)	12.0	4	4.0	4.0	4.0
Transplant, Lung(s)	12.0	4	4.0	4.0	4.0
Aortic root translocation over left ventricle (Including Nikaidoh procedure)	12.0	4	3.0	4.0	5.0
Valvuloplasty converted to valve replacement in the same operation, Aortic - with Ross procedure	12.0	4	4.0	3.5	4.5
Ross-Konno procedure	12.5	4	4.5	3.0	5.0
Fontan revision or conversion (Re-do Fontan)	12.5	4	4.0	4.0	4.5
Arterial switch procedure and VSD repair + Aortic arch repair	13.0	4	4.5	4.0	4.5
Hybrid Approach "Stage 2", Aortopulmonary amalgamation + Superior Cavopulmonary anastomosis(es) + PA Debanding + Aortic arch repair (Norwood [Stage 1] + Superior Cavopulmonary anastomosis(es) + PA Debanding)	13.0	4	4.0	4.5	4.5
Transplant, Heart and lung(s)	13.3	4	4.0	5.0	4.3
Congenitally corrected TGA repair, Atrial Switch and ASO (Double switch)	13.8	4	5.0	3.8	5.0
Valvuloplasty converted to valve replacement in the same operation, Aortic - with Ross-Konno procedure	14.0	4	4.5	4.5	5.0
Norwood procedure	14.5	4	5.0	4.5	5.0
HLHS biventricular repair	15.0	4	5.0	5.0	5.0
Truncus + Interrupted aortic arch repair (IAA) repair	15.0	4	5.0	5.0	5.0

Interventional cardiology or not eligible (intentionally excluded from Aristotle) procedures:

ASD repair, Device
 VSD repair, Device
 PDA closure, Device
 ASD creation, Balloon septostomy (BAS) (Rashkind)
 ASD creation, Blade septostomy
 Balloon dilation
 Stent placement
 Device closure
 RF ablation
 Coil embolization
 Pulmonary AV fistula repair/occlusion
 TGA, Other procedures (Kawashima, LV-PA conduit, other)
 Cardiovascular catheterization procedure, Therapeutic
 Echocardiography procedure, Sedated transesophageal echocardiogram
 Echocardiography procedure, Sedated transthoracic echocardiogram
 Non-cardiovascular, non-thoracic procedure on cardiac patient with cardiac anesthesia
 Radiology procedure on cardiac patient, Cardiac Computerized Axial Tomography (CT Scan)
 Radiology procedure on cardiac patient, Cardiac Magnetic Resonance Imaging (MRI)
 Radiology procedure on cardiac patient, Diagnostic radiology
 Radiology procedure on cardiac patient, Non-Cardiac Computerized Tomography (CT) on cardiac patient
 Radiology procedure on cardiac patient, Non-Cardiac Magnetic Resonance Imaging (MRI) on cardiac patient
 Radiology procedure on cardiac patient, Therapeutic radiology
 Cardiovascular catheterization procedure, Diagnostic
 Cardiovascular catheterization procedure, Diagnostic, Hemodynamic data obtained
 Cardiovascular catheterization procedure, Diagnostic, Angiographic data obtained
 Cardiovascular catheterization procedure, Diagnostic, Transluminal test occlusion
 Cardiovascular catheterization procedure, Diagnostic, Hemodynamic alteration

Cardiovascular catheterization procedure, Diagnostic, Electrophysiology alteration
 Cardiovascular catheterization procedure, Therapeutic, Septostomy
 Cardiovascular catheterization procedure, Therapeutic, Balloon valvotomy
 Cardiovascular catheterization procedure, Therapeutic, Stent re-dilation
 Cardiovascular catheterization procedure, Therapeutic, Perforation (establishing interchamber and/or intervessel communication)
 Cardiovascular catheterization procedure, Therapeutic, Transcatheter Fontan completion
 Cardiovascular catheterization procedure, Therapeutic, Transcatheter implantation of valve
 Cardiovascular catheterization procedure, Therapeutic Adjunctive therapy
 Cardiovascular electrophysiological catheterization procedure
 Cardiovascular electrophysiological catheterization procedure, Therapeutic ablation

Other miscellaneous, not scored:

(Either too vague or not a primary procedure)

Atrial baffle procedure, NOS
VSD repair, NOS
Valve surgery, Other, Tricuspid
Valve surgery, Other, Pulmonic
Valve surgery, Other, Mitral
Valve surgery, Other, Aortic
Tracheal procedure
TOF repair, NOS
Thoracotomy, Other
Thoracic and/or mediastinal procedure, Other
TGA, Other procedures (Nikaidoh, Kawashima, LV-PA conduit, other)
Shunt, Systemic to pulmonary, Other
Shunt, Systemic to pulmonary, NOS
Pleural procedure, Other
Peripheral vascular procedure, Other
Pericardial procedure, Other
PDA closure, NOS
Palliation, Other
PA, reconstruction (plasty), NOS
Other
Organ procurement
Miscellaneous procedure, Other
Mediastinal procedure
Fontan, TCPC, Lateral tunnel, NOS
Fontan, Other
Fontan, NOS
Esophageal procedure
DORV repair, NOS
Diaphragm procedure, Other
Coronary artery procedure, Other
Congenitally corrected TGA repair, Other
Congenitally corrected TGA repair, NOS
Conduit placement, NOS
Coarctation repair, Other
Coarctation repair, NOS
Cardiotomy, Other
Cardiac procedure, Other
AVC (AVSD) repair, NOS
ASD repair, NOS
Arrhythmia surgery, NOS
Other annular enlargement procedure
Fontan, TCPC, External conduit, NOS
VATS (video assisted thoracoscopic surgery)
Minimally invasive procedure
Bypass for non-cardiac lesion
Valve replacement, Aortic

References

1. Mavroudis C, Jacobs JP. The international congenital heart surgery nomenclature and database project. *Ann Thorac Surg*. 2000;(Suppl):S1–372.
2. Lacour-Gayet F. Risk stratification theme for congenital heart surgery. *Semin Thorac Cardiovasc Surg Pediatr Card Surg Annu*. 2002;5:148–52.
3. Lacour-Gayet F, Clarke D, Jacobs J, Comas J, Daebritz S, Daenen W, Gaynor W, Hamilton L, Jacobs M, Maruszewski B, Pozzi M, Spray T, Stellin G, Tchervenkov C, Mavroudis and the Aristotle Committee. The Aristotle score: a complexity-adjusted method to evaluate surgical results. *Eur J Cardiothorac Surg*. 2004;25(6):911–24.
4. Lacour-Gayet F, Jacobs JP, Clarke DR, Maruszewski B, Jacobs ML, O'Brien SM, Mavroudis C. Evaluation of the quality of care in congenital heart surgery: contribution of the Aristotle complexity score. *Adv Pediatr*. 2007;54:67–83.
5. Lacour-Gayet F, Clarke DR, Aristotle Committee. The Aristotle method: a new concept to evaluate quality of care based on complexity. *Curr Opin Pediatr*. 2005;17(3):412–7.
6. Lacour-Gayet F, Clarke D, Jacobs J, Gaynor W, Hamilton L, Jacobs M, Maruszewski B, Pozzi M, Spray T, Tchervenkov C, Mavroudis C, Aristotle Committee. The Aristotle score for congenital heart surgery. *Semin Thorac Cardiovasc Surg Pediatr Card Surg Annu*. 2004;7:185–91.
7. Jacobs JP, Jacobs ML, Maruszewski B, Lacour-Gayet FG, Clarke DR, Tchervenkov CI, Gaynor JW, Spray TL, Stellin G, Elliott MJ, Ebels T, Mavroudis C. Current status of the European Association for Cardio-Thoracic Surgery and the Society of Thoracic Surgeons Congenital Heart Surgery Database. *Ann Thorac Surg*. 2005;80(6):2278–83; discussion 2283–4.
8. Jacobs JP, Wernovsky G, Elliott MJ. Analysis of outcomes for congenital cardiac disease: can we do better? *Cardiol Young*. 2007;17 Suppl 2:145–58.
9. Nathan M, Karamichalis JM, Liu H, del Nido P, Pigula F, Thiagarajan R, Bacha EA. Intraoperative adverse events can be compensated by technical performance in neonates and infants after cardiac surgery: a prospective study. *J Thorac Cardiovasc Surg*. 2011;142(5):1098–107, 1107.
10. Nathan M, Karamichalis JM, Liu H, Emani S, Baird C, Pigula F, Colan S, Thiagarajan RR, Bacha EA, Del Nido P. Surgical technical performance scores are predictors of late mortality and unplanned reinterventions in infants after cardiac surgery. *J Thorac Cardiovasc Surg*. 2012;144(5):1095–101.
11. Shuhaiber J, Gauvreau K, Thiagarajan R, Bacha E, Mayer J, Del Nido P, Pigula F. Congenital heart surgeon's technical proficiency affects neonatal hospital survival. *J Thorac Cardiovasc Surg*. 2012;144(5):1119–24.
12. Nathan M, Pigula FA, Liu H, Gauvreau K, Colan SD, Fynn-Thompson F, Emani S, Baird CA, Mayer JE, Del Nido PJ. Inadequate technical performance scores are associated with late mortality and late reintervention. *Ann Thorac Surg*. 2013;96(2):664–9.
13. Bojan M, Gerelli S, Gioanni S, Pouard P, Vouhé P. Evaluation of a new tool for morbidity assessment in congenital cardiac surgery. *Ann Thorac Surg*. 2011;92(6):2200–4.
14. 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(3):949–56.
15. Code of points in artistic gymnastics. [http://en.wikipedia.org/wiki/Code_of_Points_\(artistic_gymnastics\)](http://en.wikipedia.org/wiki/Code_of_Points_(artistic_gymnastics)).
16. O'Brien SM, Clarke DR, Jacobs JP, Jacobs ML, Lacour-Gayet FG, Pizarro C, Welke KF, Maruszewski B, Tobota Z, Miller WJ, Hamilton L, Peterson ED, Mavroudis C, Edwards FH. An empirically based tool for analyzing mortality associated with congenital heart surgery. *J Thorac Cardiovasc Surg*. 2009;138(5):1139–53.
17. Jacobs JP, Lacour-Gayet FG, Jacobs ML, Clarke DR, Tchervenkov CI, Gaynor JW, Spray TL, Maruszewski B, Stellin G, Gould J, Dokholyan RS, Peterson ED, Elliott MJ, Mavroudis C. Initial application in the STS congenital database of complexity adjustment to evaluate surgical case mix and results. *Ann Thorac Surg*. 2005;79(5):1635–49; discussion 1635–49.
18. 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.
19. Jacobs JP, Jacobs ML, Lacour-Gayet FG, Jenkins KJ, Gauvreau K, Bacha E, Maruszewski B, Clarke DR, Tchervenkov CI, Gaynor JW, Spray TL, Stellin G, O'Brien SM, Elliott MJ, Mavroudis C. 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):1117–30.
20. O'Brien SM, Jacobs JP, Clarke DR, Maruszewski B, Jacobs ML, Walters 3rd HL, Tchervenkov CI, Welke KF, Tobota Z, Stellin G, Mavroudis C, Hamilton JR,

- Gaynor JW, Pozzi M, Lacour-Gayet FG. Accuracy of the Aristotle basic complexity score for classifying the mortality and morbidity potential of congenital heart surgery operations. *Ann Thorac Surg.* 2007; 84(6):2027–37; discussion 2027–37.
21. Arenz C, Asfour B, Hraska V, Photiadis J, Haun C, Schindler E, Sinzobahamvya N. Congenital heart surgery: surgical performance according to the Aristotle complexity score. *Eur J Cardiothorac Surg.* 2011; 39(4):e33–7.
22. Sinzobahamvya N, Photiadis J, Arenz C, Kopp T, Blaschczok HC, Hraska V, Asfour B. Congenital heart surgery: applicability of hospital reimbursement according to German diagnosis-related groups system in conformity with the Aristotle complexity score. *Thorac Cardiovasc Surg.* 2010;58(6):328–32.
23. Schreiber C, Hörer J. Congenital heart surgery and Aristotle complexity score. *Thorac Cardiovasc Surg.* 2010;58(6):333.
24. Sinzobahamvya N, Kopp T, Photiadis J, Arenz C, Schindler E, Haun C, Hraska V, Asfour B. Surgical management of congenital heart disease: correlation between hospital costs and the Aristotle complexity score. *Thorac Cardiovasc Surg.* 2010;58(6):322–7.
25. Williams WG. Congenital heart disease: interrelation between German diagnoses-related groups system and Aristotle complexity score. *Eur J Cardiothorac Surg.* 2010;37(6):1276–7.
26. Photiadis J, Sinzobahamvya N, Arenz C, Sata S, Haun C, Schindler E, Asfour B, Hraska V. Congenital heart surgery: expected versus observed surgical performance according to the Aristotle complexity score. *Thorac Cardiovasc Surg.* 2011;59(5):268–73.
27. Sinzobahamvya N, Photiadis J, Kopp T, Arenz C, Haun C, Schindler E, Hraska V, Asfour B. Surgical management of congenital heart disease: contribution of the Aristotle complexity score to planning and budgeting in the German diagnosis-related groups system. *Pediatr Cardiol.* 2012;33(1):36–41.
28. Sinzobahamvya N, Kopp T, Arenz C, Blaschczok HC, Hraska V, Asfour B. Reimbursement by current German Diagnosis-Related Groups system penalises complex congenital heart surgery. *Cardiol Young.* 2013;13:1–7.
29. Li J, Zhang G, Holtby H, Cai S, Walsh M, Caldarone CA, Van Arsdell GS. Significant correlation of comprehensive Aristotle score with total cardiac output during the early postoperative period after the Norwood procedure. *J Thorac Cardiovasc Surg.* 2008;136(1):123–8.
30. Artrip JH, Campbell DN, Ivy DD, Almodovar MC, Chan KC, Mitchell MB, Clarke DR, Lacour-Gayet F. Birth weight and complexity are significant factors for the management of hypoplastic left heart syndrome. *Ann Thorac Surg.* 2006;82(4):1252–7; discussion 1258–9.
31. Sinzobahamvya N, Photiadis J, Kumpikaite D, Fink C, Blaschczok HC, Brecher AM, Asfour B. Comprehensive Aristotle score: implications for the Norwood procedure. *Ann Thorac Surg.* 2006;81(5):1794–800.
32. Miyamoto T, Sinzobahamvya N, Photiadis J, Brecher AM, Asfour B. Survival after surgery with cardiopulmonary bypass in low weight patients. *Asian Cardiovasc Thorac Ann.* 2008;16(2):115–9.
33. Derby CD, Kolcz J, Kerins PJ, Duncan DR, Quezada E, Pizarro C. Aristotle score predicts outcome in patients requiring extracorporeal circulatory support following repair of congenital heart disease. *ASAIO J.* 2007;53(1):82–6.
34. Miyamoto T, Sinzobahamvya N, Kumpikaite D, Asfour B, Photiadis J, Brecher AM, Urban AE. Repair of truncus arteriosus and aortic arch interruption: outcome analysis. *Ann Thorac Surg.* 2005;79(6):2077–82.
35. Heinrichs J, Sinzobahamvya N, Arenz C, Kallikourdis A, Photiadis J, Schindler E, Hraska V, Asfour B. Surgical management of congenital heart disease: evaluation according to the Aristotle score. *Eur J Cardiothorac Surg.* 2010;37(1):210–7.
36. Stoica S, Carpenter E, Campbell D, Mitchell M, da Cruz E, Ivy D, Lacour-Gayet F. Morbidity of the arterial switch operation. *Ann Thorac Surg.* 2012; 93(6):1977–83.
37. Lacour-Gayet F. Complexity stratification of the arterial switch operation: a second learning curve. *Cardiol Young.* 2012;22(6):739–44.
38. Gillespie M, Kuijpers M, Van Rossem M, Ravishankar C, Gaynor JW, Spray T, Clark 3rd B. Determinants of intensive care unit length of stay for infants undergoing cardiac surgery. *Congenit Heart Dis.* 2006;1(4):152–60.
39. Hörer J, Vogt M, Wottke M, Cleuziou J, Kasnar-Samprec J, Lange R, Schreiber C. Evaluation of the Aristotle complexity models in adult patients with congenital heart disease. *Eur J Cardiothorac Surg.* 2013;43(1):128–34; discussion 134–5.
40. 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):1133–40.
41. 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(4):1214–21.
42. Blackstone EH. Let the data speak for themselves. *Semin Thorac Cardiovasc Surg Pediatr Card Surg Annu.* 2004;7:192–8.
43. Blackstone EH. Statistics for the Rest of Us: monitoring surgical performance. *J Thorac Cardiovasc Surg.* 2004;128:807–10.
44. Lacour-Gayet F, Jacobs JP, Clarke DR, Gaynor JW, Jacobs ML, Anderson RH, Elliott MJ, Maruszewski B, Vouhé P, Mavroudis C. Performance of surgery for congenital heart disease: shall we wait a generation or look for different statistics? *J Thorac Cardiovasc Surg.* 2005;130(1):234–5.
45. Jacobs ML, O'Brien SM, Jacobs JP, Mavroudis C, Lacour-Gayet F, Pasquali SK, Welke K, Pizarro C, Tsai F, Clarke DR. An empirically based tool for analyzing morbidity associated with operations for congenital heart disease. *J Thorac Cardiovasc Surg.* 2013;145(4):1046–57.

46. Jacobs JP, Jacobs ML, Mavroudis C, Backer CL, Lacour-Gayet FG, Tchervenkov CI, Franklin RC, Béland MJ, Jenkins KJ, Walters H, Bacha EA, Maruszewski B, Kurosawa H, Clarke DR, Gaynor JW, Spray TL, Stellin G, Ebels T, Krogmann ON, Aiello VD, Colan SD, Weinberg P, Giroud JM, Everett A, Wernovsky G, Elliott MJ, Edwards FH. Nomenclature and databases for the surgical treatment of congenital cardiac disease—an updated primer and an analysis of opportunities for improvement. *Cardiol Young*. 2008;18 Suppl 2:38–62.
47. Jacobs ML, Jacobs JP, Jenkins KJ, Gauvreau K, Clarke DR, Lacour-Gayet F. Stratification of complexity: the risk adjustment for congenital heart surgery-1 method and the Aristotle complexity score—past, present, and future. *Cardiol Young*. 2008;18 Suppl 2:163–8.
48. Kang N, Tsang VT, Elliott MJ, de Leval MR, Cole TJ. Does the Aristotle Score predict outcome in congenital heart surgery? *Eur J Cardiothorac Surg*. 2006;29(6):986–8.
49. Clarke DR, Lacour-Gayet F, Jacobs JP, Jacobs ML, Maruszewski B, Pizarro C, Edwards FH, Mavroudis C. The assessment of complexity in congenital cardiac surgery based on objective data. *Cardiol Young*. 2008;18 Suppl 2:169–76.
50. Jacobs JP, Jacobs ML, Mavroudis C, Lacour-Gayet FG, Tchervenkov CI, Pasquali SK. Executive Summary: The Society of Thoracic Surgeons Congenital Heart Surgery Database – Nineteenth Harvest – (July 1, 2009 – June 30, 2013). The Society of Thoracic Surgeons (STS) and Duke Clinical Research Institute (DCRI), Duke University Medical Center, Durham; 2013 Harvest.