The Aristotle Score for Congenital Heart Surgery

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The aim of the Aristotle project was to develop a new method of evaluation of quality of care in congenital heart surgery based on the complexity of the surgical procedures. Involving a panel of expert surgeons, the project started in 1999 and included 50 pediatric surgeons from 23 countries representing International Scientific Societies. The complexity was based on the procedures as defined by the Society of Thoracic Surgeons (STS)/European Association for Cadiothoracic Surgery (EACTS) International Nomenclature and was undertaken in two steps: The first step was establishing the Basic Score, which adjusts only the complexity of the procedures and is based on three factors: the potential for mortality, the potential for morbidity, and the anticipated technical difficulty. The second step was the development of the Comprehensive Score, which further adjusts the complexity according to the specific patient characteristics .The Aristotle score allows precise scoring of the complexity for 145 congenital heart surgery procedures. One interesting concept coming out of this study is that complexity is a constant and precise value for a given patient regardless of the center where he is operated. The Aristotle method allows proposing the following equation of quality of care: Complexity FN Outcome = Performance. The Aristotle score, electronically available, was introduced in the EACTS and STS databases. A validation process, designed to evaluate its predictive value, is being developed.

Key words: Congential heart surgery, outcomes, complexity, performance.

THE EVALUATION of quality of care is becoming a duty of the surgical practice, particularly in pediatric cardiac surgery. Initially considered a research issue, this responsibility is rapidly increasing, driven by demand from hospital managers, referring physicians, families, insurance companies, government agencies, courts, and the media.

Evaluation of quality of care is a new chapter of modern medicine that follows a different rhetoric and the need to compare and measure. Many instruments used in the past to describe our results are obsolete. New methods, parameters, and vocabulary are needed.

Methods

The comparison and measurement of quality of care needs four tools:

1. A common language used in the population studied: nomenclature.[1,2]
2. A database with a simple data set: registry.[3,4]
3. A parameter to allow comparison: *complexity*.[5,6]
4. A data validation process.

Following several years of collaborative work among congenital heart surgeons,[6] representing International Scientific Societies (Society of Thoracic Surgeons [STS], European Association for Cardiothoracic Surgery [EACTS], European Congenital Heart Surgeon's Foundation [ECHSF], Congential Heart Surgeon's Society

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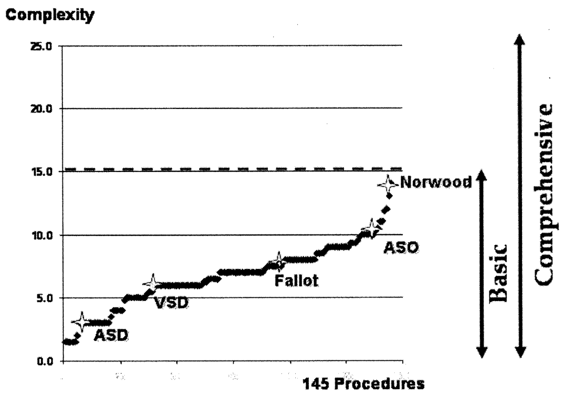

Figure 1. The Aristotle scale ranges from 1.5 to 25. The basic score (1.5 to 15) reflects only procedure complexity. The comprehensive score (1.5 to 25) includes complexity factors related to the specific patient. ASD, atrial septal defeat; VSD, ventricular septal defeat; ASO, aterial switch operation.

[CHSS]), a new parameter, "complexity," is proposed, with the following new equation for quality of care:

$$\underset{\text{(Constant)}}{\text{Complexity}}\ \text{FN}\ \underset{\text{(Variable)}}{\text{Outcome}} = \underset{\text{(Variable)}}{\text{Performance}}$$

Outcomes and performance can vary, according to surgeons or centers. On the contrary, the complexity of a procedure is a *constant* feature for a given patient and whatever his global location. Complexity was quantified (Fig 1), based on a consensus of international expert surgeons representing 50 centers and 23 countries. It is based on procedures and not on diagnoses because different procedures may be applied to the same diagnosis. Complexity of a procedure includes a basic value, modified by procedure-dependent and -independent factors. Each complexity factor was scored according to potential for operative mortality, morbidity, and surgical technique difficulty (Table 1). Mortality and morbidity were based on results published in the literature. Difficulty of surgical technique, however, is a new factor that was evaluated according to the perception of the group of experts. We have named this complexity stratification the "Aristotle score," following Aristotle's belief in the importance of current opinion: "When there is no scientific answer available, the opinion (Doxa) perceived and admitted by the majority has value of truth." (Aristotle, Rhetoric, Book I, 350 BC).

Several areas of surgical (or medical) performance can be studied, according to the outcome to be evaluated:

Operative performance: complexity FN hospital survival
Perioperative performance: complexity FN morbidity
Rehabilitation: complexity FN long-term survival
Satisfaction: complexity FN patient evaluation
Financial performance: complexity FN cost

Preliminary Results

The development of the Aristotle score took 4 years to complete, from 1999 through September 2003. It was finally achieved by the Aristotle Executive Committee, who met more than 20 times in conjunction with various international meetings. The *basic score* (Appendix 1) is a procedure-adjusted complexity and only applies to procedures. It can be used retrospectively to enter complexity into almost any database software. The *comprehensive score* (available on Internet in summer 2004) is much more precise and introduces patient-adjusted complexity, studying the combined procedures, the variation of the anatomy, and the clinical status of each patient. The respective scale of the basic and comprehensive

Table 1. Parameters Used for Complexity Scoring

Complexity Score	Mortality	Morbidity ICU Stay	Surgical Difficulty
1 pt	<1%	ICU 0-24 H	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

NOTE. Complexity is the sum of: potential for mortality (discharge or 30 days mortality), the potential for morbidity (ICU length of stay), and the anticipated surgical technique difficulty. Scoring was based on a grade from 1 to 5 in each category (see Appendix 1).

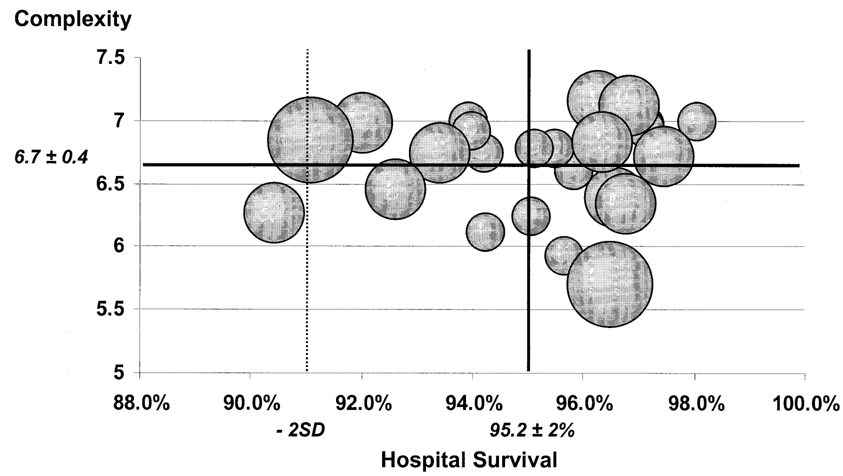

Figure 2. Hospital survival versus complexity. Data from 26 centers reporting to the EACTS congenital database. Three bubble sizes indicate the volume of procedures reported by centers (large, medium, small). Only centers having the same complexity level can be compared together.

score is shown in Fig 1. The scoring used for calculation of complexity is given in Table 1.

The first evaluation deals with a preliminary study of the variation in performance of European centers. Twenty-six EACTS Centers were studied during the period of 1999 to 2003, involving a total of 13,508 patients and 14,493 procedures. Centers with less than 200 procedures performed during the time period were excluded. The average number of procedures per center was 519 (range, 206 to 2,457). According to the volume harvested, there were: two large centers (>1,000 procedures), 10 medium centers (500 to 1,000 procedures), and 14 smaller centers (<500 procedures). The average hospital mortality within 30 days was 4.8% (range, 1.9 to 9.6), corresponding to a hospital survival of 95.2% ± 2.02% (range, 90.4% to 98.1%). The average complexity, according to the Basic Score was 6.7 ± 0.4 (range, 5.7 to 7.2).

The centers were compared plotting complexity against hospital survival, as shown in Fig 2. In addition, three different sized bubbles indicate the volume of procedures harvested by centers. The average values of complexity and survival allow defining four quadrants: (1) In the upper right quadrant are centers with high complexity and low mortality. (2) In the right lower quadrant are centers with low mortality but with less complex procedures; these centers might select their patients. (3) In the upper left quadrant are centers with high complexity but a higher mortality. These centers should be carefully evaluated; they can only be compared with centers of the same level of complexity. (4) The left lower quadrant contains centers with lower complexity and higher mortality. The survival level representing two standard deviation below the mean is indicated.

Discussion

The preliminary results shown on Fig 2 are based on data from the EACTS congenital database.[6] These data are not authenticated and do not represent the same time period of harvesting at each center. Therefore, this graph shows only preliminary results; final conclusions on the effect of a center's size on outcomes will be drawn later with verified and validated data.

The validation process of the scientific society databases remains a controversial issue. Nevertheless, it is needed and is anticipated by the health care payers. The mechanism of such a process is not established yet and is still under investigation at the STS and EACTS.

The original contribution of the Aristotle project is to define *complexity* as a constant and global value for a given patient and to define *performance* as a combination of *complexity* and *outcome*. Based on this concept, we have proposed that *performance* equals *complexity* times *outcome*.[6] At this stage of development, we believe that the hypothesized equation provides a fair definition of performance.

This new method of evaluation of quality of care requires further validation. The next task of the Aristotle Committee will be to evaluate the predictive value of the Aristotle Score for mortality and morbidity and compare the respective value of the basic score and the comprehensive score. The validation process is under way and should be completed in 2004 for the basic score and in 2005 for the comprehensive score, respectively.

Conclusion

The Aristotle project is now complete. Two scores are available: the basic score, a procedure-adjusted complexity score, and the comprehensive score, a patient-adjusted complexity score. Preliminary results comparing complexity with survival allow establishing a new mode of categorization of the CHS centers that we believe is more precise and fair. Allowing accurate evaluation of surgical performance in CHS, the Aristotle score is also a powerful vector of communication with patients, surgeons, cardiologists, and health care payers. Evaluating the predictive value of the Aristotle method is in progress to confirm the validity of the method.

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Appendix 1. Aristotle Basic Complexity Score

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

N	Procedures	Basic Score	Levels	Mortality	Morbidity	Difficulty
135	Pleural drainage procedure	1.5	1	0.5	0.5	0.5
141	Bronchoscopy	1.5	1	0.5	0.5	0.5
143	Delayed sternal closure	1.5	1	0.5	0.5	0.5
144	Mediastinal exploration	1.5	1	0.5	0.5	0.5
145	Sternotomy wound drainage	1.5	1	0.5	0.5	0.5
138	Intra-aortic balloon pump (IABP) insertion	2.0	1	0.5	1.0	0.5
1	PFO, primary closure	3.0	1	1.0	1.0	1.0
2	ASD repair, primary closure	3.0	1	1.0	1.0	1.0
3	ASD repair, patch	3.0	1	1.0	1.0	1.0
6	ASD partial closure	3.0	1	1.0	1.0	1.0
76	Pericardial drainage procedure	3.0	1	1.0	1.0	1.0
106	PDA closure, surgical	3.0	1	1.0	1.0	1.0
114	Pacemaker implantation, permanent	3.0	1	1.0	1.0	1.0
115	Pacemaker procedure	3.0	1	1.0	1.0	1.0
121	Shunt, ligation, and takedown	3.5	1	1.5	1.0	1.0
4	ASD, common atrium (single atrium), septation	3.8	1	1.0	1.0	1.8
5	ASD creation/enlargement	4.0	1	1.0	2.0	1.0
97	Coronary artery fistula ligation	4.0	1	1.0	2.0	1.0
116	ICD (AICD) implantation	4.0	1	1.5	1.0	1.5
117	ICD (AICD) (automatic implantable cardioverter defibrillator) procedure	4.0	1	1.5	1.0	1.5
136	Ligation, thoracic duct	4.0	1	1.0	2.0	1.0
142	Diaphragm plication	4.0	1	1.0	2.0	1.0
7	Atrial septal fenestration	5.0	1	2.0	2.0	1.0

Appendix 1. Aristotle Basic Complexity Score *(Cont'd)*

N	Procedures	Basic Score	Levels	Mortality	Morbidity	Difficulty
21	PAPVC repair	5.0	1	2.0	1.0	2.0
111	Lung biopsy	5.0	1	1.5	2.0	1.5
133	Ligation, pulmonary artery	5.0	1	1.5	2.0	1.5
137	Decortication	5.0	1	1.0	1.0	3.0
113	Pectus repair	5.3	1	2.0	1.0	2.3
50	Valvuloplasty, pulmonic	5.6	1	1.8	1.8	2.0
8	VSD repair, primary closure	6.0	2	2.0	2.0	2.0
9	VSD repair, patch	6.0	2	2.0	2.0	2.0
15	AVC (AVSD) repair, partial (incomplete) (PAVSD)	6.0	2	2.0	2.0	2.0
16	AP window repair	6.0	2	2.0	2.0	2.0
20	Valve replacement, truncal valve	6.0	2	2.0	2.0	2.0
45	PA, reconstruction (plasty), main (trunk)	6.0	2	2.0	2.0	2.0
77	Pericardiectomy	6.0	2	2.0	2.0	2.0
99	Coarctation repair, end to end	6.0	2	2.0	2.0	2.0
101	Coarctation repair, subclavian flap	6.0	2	2.0	2.0	2.0
102	Coarctation repair, patch aortoplasty	6.0	2	2.0	2.0	2.0
107	Vascular ring repair	6.0	2	2.0	2.0	2.0
122	PA banding (PAB)	6.0	2	2.0	2.0	2.0
123	PA debanding	6.0	2	2.0	2.0	2.0
139	ECMO procedure	6.0	2	2.0	3.0	1.0
64	Aortic stenosis, subvalvar, repair	6.3	2	2.0	1.8	2.5
119	Shunt, systemic to pulmonary, modified Blalock-Taussig shunt (MBTS)	6.3	2	2.0	2.0	2.3
14	AVC (AVSD) repair, Intermediate (transitional)	6.5	2	2.0	2.0	2.5
43	RVOT procedure	6.5	2	2.0	2.0	2.5
51	Valve replacement, pulmonic (PVR)	6.5	2	2.0	2.0	2.5
24	Cor triatriatum repair	6.8	2	2.0	2.0	2.8
120	Shunt, systemic to pulmonary, central (from aorta or to main pulmonary artery)	6.8	2	2.0	2.0	2.8
125	Bidirectional cavopulmonary anastomosis (BDCPA) (bidirectional Glenn)	6.8	2	2.3	2.0	2.5
19	Valvuloplasty, truncal valve	7.0	2	2.0	2.0	3.0
27	Anomalous systemic venous connection repair	7.0	2	2.0	2.0	3.0
38	Occlusion MAPCA(s)	7.0	2	2.0	2.0	3.0
39	Valvuloplasty, tricuspid	7.0	2	2.0	2.0	3.0
42	Valve excision, tricuspid (without replacement)	7.0	2	3.0	3.0	1.0
48	DCRV repair	7.0	2	2.0	2.0	3.0
55	Valve replacement, aortic (AVR), mechanical	7.0	2	2.0	2.0	3.0
56	Valve replacement, aortic (AVR), bioprosthetic	7.0	2	2.0	2.0	3.0
104	Aortic arch repair	7.0	2	2.0	2.0	3.0
126	Glenn (unidirectional cavopulmonary anastomosis) (unidirectional Glenn)	7.0	2	2.5	2.0	2.5
140	Right/left heart assist device procedure	7.0	2	2.0	3.0	2.0
12	Ventricular septal fenestration	7.5	2	3.0	2.0	2.5
30	TOF repair, ventriculotomy, non-transanular patch	7.5	2	2.5	2.0	3.0
40	Valve replacement, tricuspid (TVR)	7.5	2	2.5	2.0	3.0
52	Conduit placement, RV to PA	7.5	2	2.5	2.0	3.0
65	Aortic stenosis, supravalvar, repair	7.5	2	2.5	2.0	3.0
66	Sinus of Valsalva, aneurysm repair	7.5	2	2.5	2.0	3.0
70	Valve replacement, mitral (MVR)	7.5	2	2.5	2.0	3.0
98	Coronary artery bypass	7.5	2	2.5	2.0	3.0
127	Bilateral bidirectional cavopulmonary anastomosis (BBDCPA) (bilateral bidirectional Glenn)	7.5	2	2.5	2.0	3.0
26	Atrial baffle procedure (non-Mustard, non-Senning)	7.8	2	2.8	2.0	3.0
46	PA, reconstruction (plasty), branch, central (within the hilar bifurcation)	7.8	2	2.8	2.0	3.0
47	PA, reconstruction (plasty), branch, peripheral (at or beyond the hilar bifurcation)	7.8	2	2.8	2.0	3.0

Appendix 1. Aristotle Basic Complexity Score *(Cont'd)*

N	Procedures	Basic Score	Levels	Mortality	Morbidity	Difficulty
103	Coarctation repair, Interposition graft	7.8	2	2.8	2.0	3.0
22	PAPVC, scimitar, repair	8.0	3	3.0	2.0	3.0
28	Systemic venous stenosis repair	8.0	3	3.0	2.0	3.0
29	TOF repair, no ventriculotomy	8.0	3	3.0	2.0	3.0
31	TOF repair, ventriculotomy, transanular patch	8.0	3	3.0	2.0	3.0
32	TOF repair, RV-PA conduit	8.0	3	3.0	2.0	3.0
49	Conduit reoperation	8.0	3	3.0	2.0	3.0
53	Conduit placement, LV to PA	8.0	3	3.0	2.0	3.0
54	Valvuloplasty, aortic	8.0	3	3.0	2.0	3.0
58	Aortic root replacement	8.0	3	2.5	2.0	3.5
68	Valvuloplasty, mitral	8.0	3	3.0	2.0	3.0
69	Mitral stenosis, supravalvar mitral ring repair	8.0	3	3.0	2.0	3.0
100	Coarctation repair, end to end, extended	8.0	3	3.0	2.0	3.0
118	Arrhythmia surgery-atrial, surgical ablation	8.0	3	3.0	2.0	3.0
128	Hemifontan	8.0	3	3.0	2.0	3.0
129	Aneurysm, ventricular, right, repair	8.0	3	3.0	2.0	3.0
131	Aneurysm, pulmonary artery, repair	8.0	3	3.0	2.0	3.0
132	Cardiac tumor resection	8.0	3	3.0	2.0	3.0
134	Pulmonary embolectomy	8.0	3	3.0	3.0	2.0
67	LV to aorta tunnel repair	8.3	3	3.0	2.3	3.0
57	Valve replacement, aortic (AVR), homograft	8.5	3	3.0	2.0	3.5
90	Senning	8.5	3	3.0	2.5	3.0
59	Aortic root replacement, mechanical	8.8	3	3.3	2.0	3.5
109	Aortic aneurysm repair	8.8	3	3.0	2.8	3.0
10	VSD, multiple, repair	9.0	3	3.0	2.5	3.5
11	VSD creation/enlargement	9.0	3	3.0	3.0	3.0
13	AVC (AVSD) repair, complete (CAVSD)	9.0	3	3.0	3.0	3.0
17	Pulmonary artery origin from ascending aorta (hemitruncus) repair	9.0	3	3.0	3.0	3.0
23	TAPVC repair	9.0	3	3.0	3.0	3.0
35	Pulmonary atresia-VSD (including TOF, PA) repair	9.0	3	3.0	3.0	3.0
41	Valve closure, tricuspid (exclusion, univentricular approach)	9.0	3	4.0	3.0	2.0
44	1 1/2 ventricular repair	9.0	3	3.0	3.0	3.0
78	Fontan, atrio-pulmonary connection	9.0	3	3.0	3.0	3.0
79	Fontan, atrio-ventricular connection	9.0	3	3.0	3.0	3.0
80	Fontan, TCPC, lateral tunnel, fenestrated	9.0	3	3.0	3.0	3.0
81	Fontan, TCPC, lateral tunnel, non-fenestrated	9.0	3	3.0	3.0	3.0
82	Fontan, TCPC, external conduit, Fenestrated	9.0	3	3.0	3.0	3.0
83	Fontan, TCPC, external conduit, non-fenestrated	9.0	3	3.0	3.0	3.0
86	Congenitally corrected TGA repair, VSD closure	9.0	3	3.0	3.0	3.0
91	Mustard	9.0	3	3.0	3.0	3.0
108	Pulmonary artery sling repair	9.0	3	3.0	3.0	3.0
130	Aneurysm, ventricular, left, repair	9.0	3	3.0	2.5	3.5
34	TOF - absent pulmonary valve repair	9.3	3	3.0	3.0	3.3
73	Transplant, heart	9.3	3	3.0	3.3	3.0
60	Aortic root replacement, homograft	9.5	3	3.5	2.0	4.0
124	Damus-Kaye-Stansel procedure (DKS) (creation of AP anastomosis without arch reconstruction)	9.5	3	3.0	3.0	3.5
88	Arterial switch operation (ASO)	10.0	4	3.5	3.0	3.5
92	Rastelli	10.0	4	3.0	3.0	4.0
96	Anomalous origin of coronary artery from pulmonary artery repair	10.0	4	3.0	3.0	4.0
61	Ross procedure	10.3	4	4.0	2.3	4.0
94	DORV, Intraventricular tunnel repair	10.3	4	3.3	3.0	4.0
105	Interrupted aortic arch repair	10.8	4	3.8	3.0	4.0
18	Truncus arteriosus repair	11.0	4	4.0	3.0	4.0
33	TOF - AVC (AVSD) repair	11.0	4	4.0	3.0	4.0

Appendix 1. Aristotle Basic Complexity Score *(Cont'd)*

N	Procedures	Basic Score	Levels	Mortality	Morbidity	Difficulty
36	Pulmonary atresia - VSD - MAPCA (pseudotruncus) repair	11.0	4	4.0	3.0	4.0
37	Unifocalization MAPCA(s)	11.0	4	4.0	3.0	4.0
62	Konno procedure	11.0	4	4.0	3.0	4.0
85	Congenitally corrected TGA repair, atrial switch and Rastelli	11.0	4	4.0	3.0	4.0
87	Congenitally corrected TGA repair, VSD closure and LV to PA conduit	11.0	4	4.0	3.0	4.0
89	Arterial switch operation (ASO) and VSD repair	11.0	4	4.0	3.0	4.0
93	REV	11.0	4	4.0	3.0	4.0
95	DOLV repair	11.0	4	4.0	3.0	4.0
110	Aortic dissection repair	11.0	4	4.0	3.0	4.0
25	Pulmonary venous stenosis repair	12.0	4	4.0	4.0	4.0
75	Partial left ventriculectomy (LV volume reduction surgery) (Batista)	12.0	4	4.0	4.0	4.0
112	Transplant, lung(s)	12.0	4	4.0	4.0	4.0
63	Ross-Konno procedure	12.5	4	4.5	3.0	5.0
74	Transplant, heart and lung(s)	13.3	4	4.0	5.0	4.3
84	Congenitally corrected TGA repair, atrial switch and ASO (double switch)	13.8	4	5.0	3.8	5.0
71	Norwood procedure	14.5	4	5.0	4.5	5.0
72	HLHS biventricular repair	15.0	4	5.0	5.0	5.0